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TEN MILE RIVER BASIN
1984 WATER QUALITY PROGRAM AND NPDES PERMIT DEVELOPMENT
FINAL REPORT

Prepared By

United States Environmental Protection Agency - Region 1
Boston, Massachusetts

and

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December, 1985

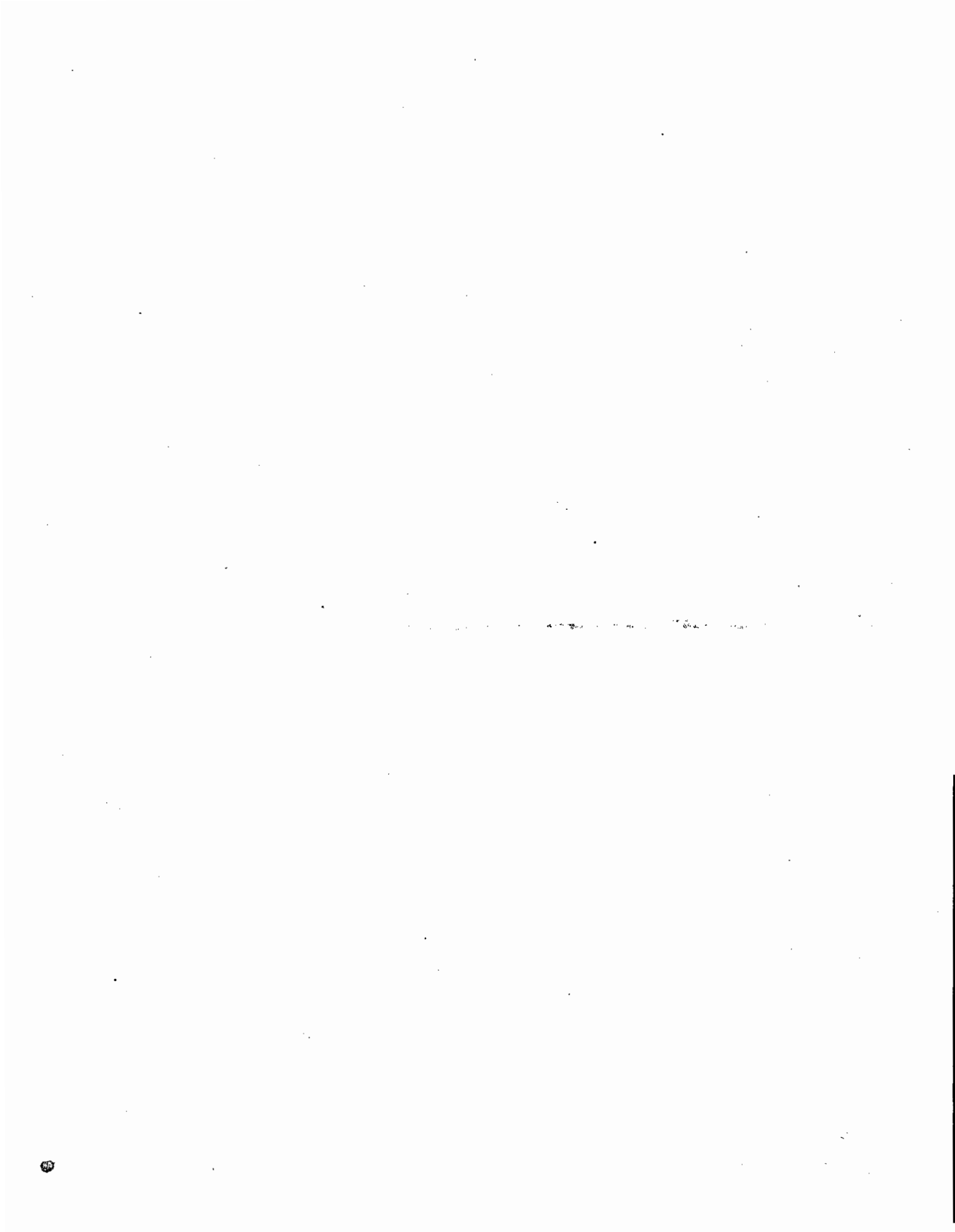


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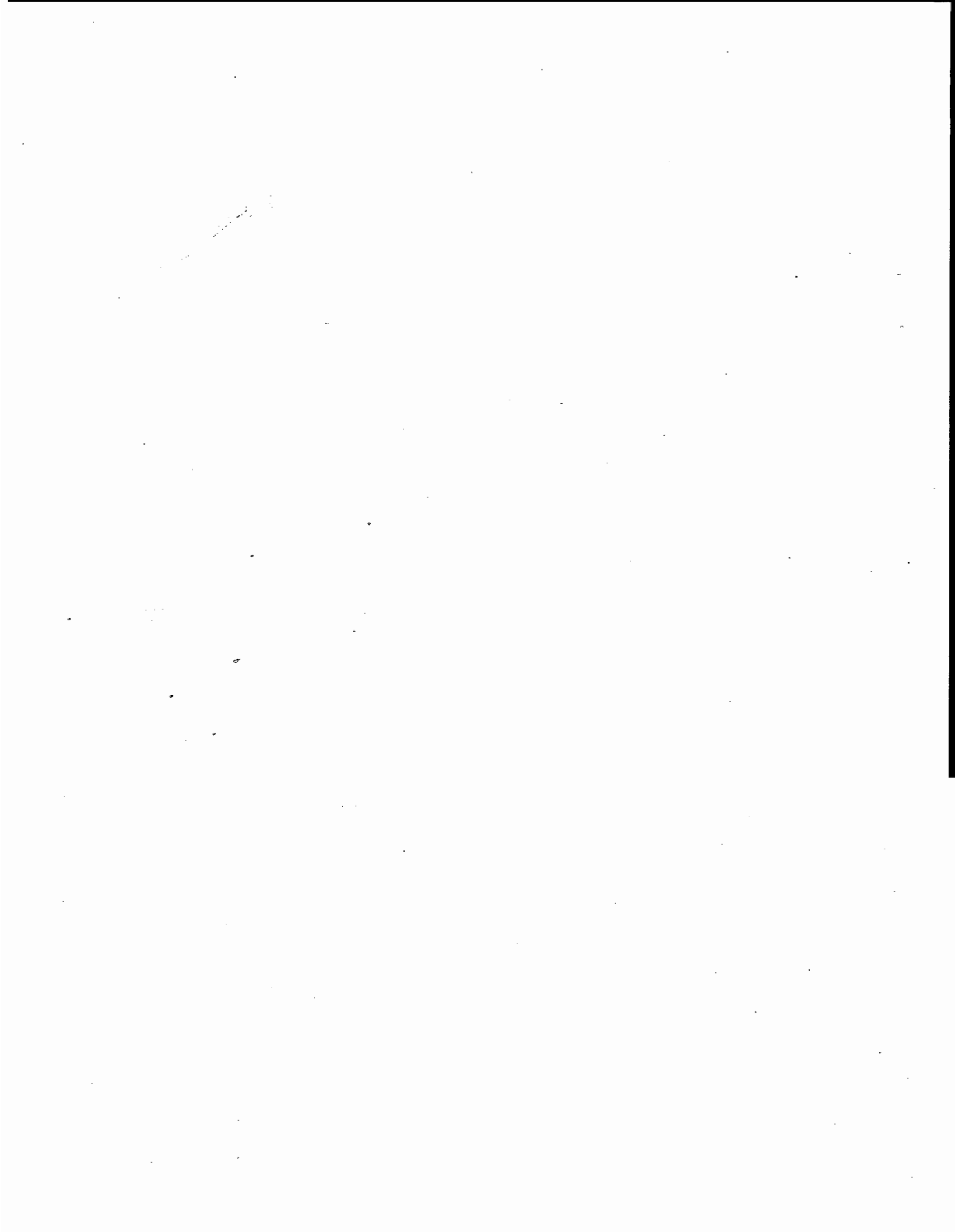
(Following Reports Are Published Under Separate Cover)

- Ten Mile River Water Quality Data - 1984. A. River Data
- Ten Mile River Water Quality Data - 1984. A. Impoundment Data
- Ten Mile River Water Quality Data - 1984. B. Wastewater Discharge Data
- Ten Mile River Hydraulic Profile - 1984.
- Biological Assessment of Water Pollution in the Ten Mile River- 1985
- Ten Mile River Chronic Toxicity Testing - 1984
- Ten Mile River Acute Toxicity Testing - 1984
- Ten Mile River Modeling Report - 1985
- Ten Mile River Sediment Microtox™ Study - 1986



ABSTRACT

The United States Environmental Protection Agency Region I and the Massachusetts Division of Water Pollution Control, undertook an intensive monitoring program of the waters of the Ten Mile River Basin in 1984. The purpose of the program was to evaluate all environmental components of the Basin related to water quality and biological integrity. Those results were used to determine effluent limitations for all significant dischargers in the Basin. The findings of the program indicated that the Ten Mile River was biologically stressed and was toxic, to varying degrees, to aquatic organisms. Many wastewater discharges were extremely toxic and significantly impacted the receiving stream and its biota. Heavy metals were prevalent throughout the system, particularly in the numerous impoundments on the Ten Mile River. The limitations for discharge to the river are very restrictive for heavy metals in order to eliminate toxicity and prevent further accumulation of metals in the sediment of the river.



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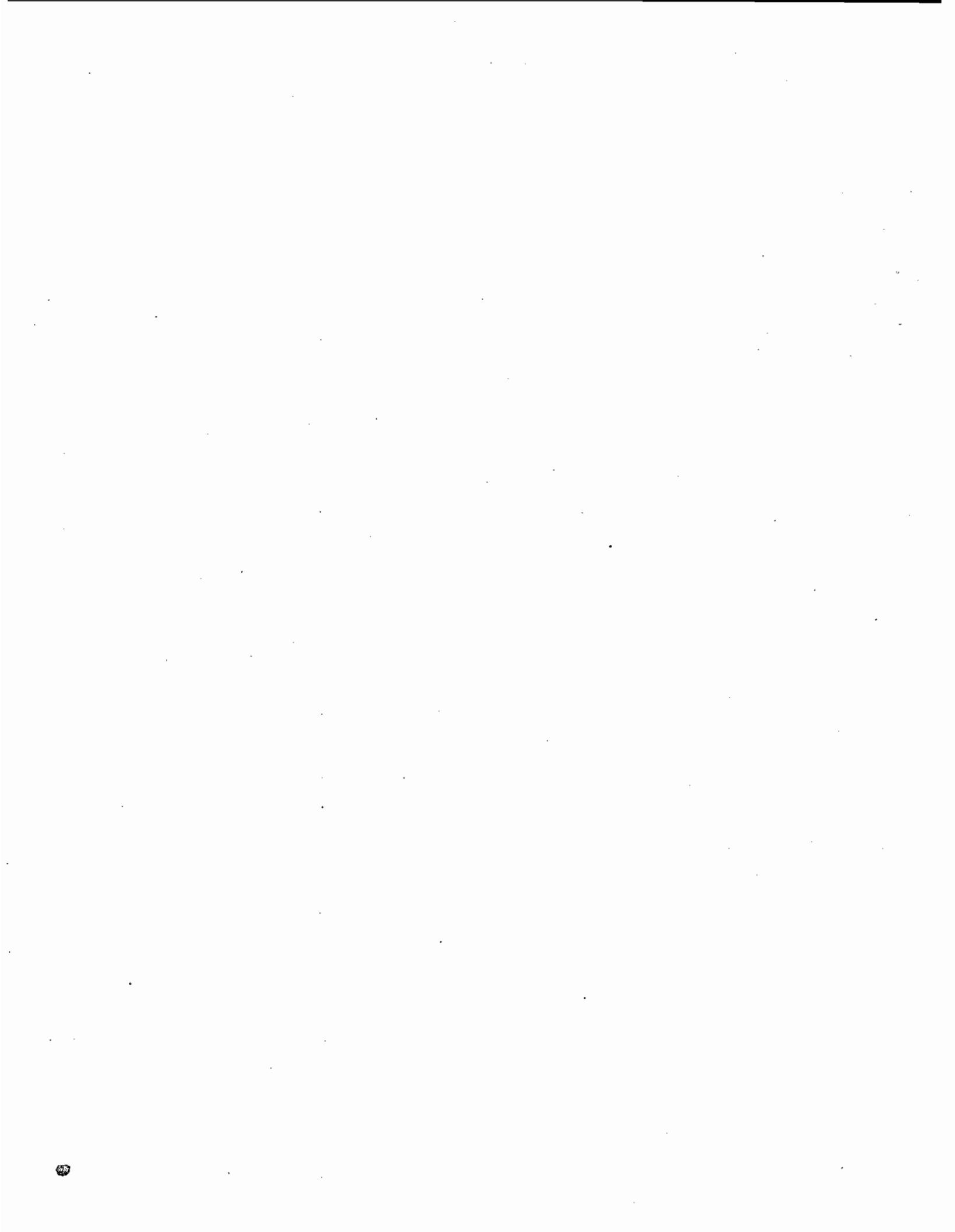
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I. INTRODUCTION

A. Description of the Ten Mile River Basin

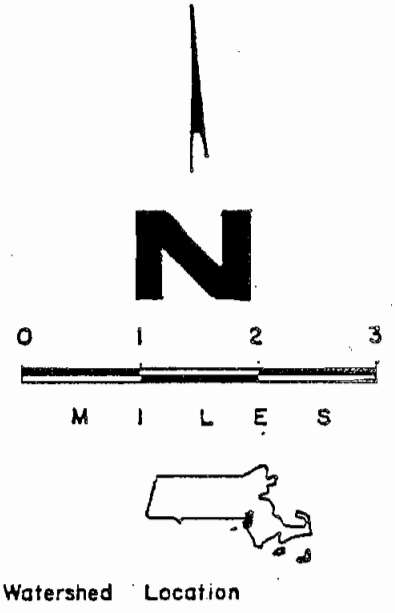
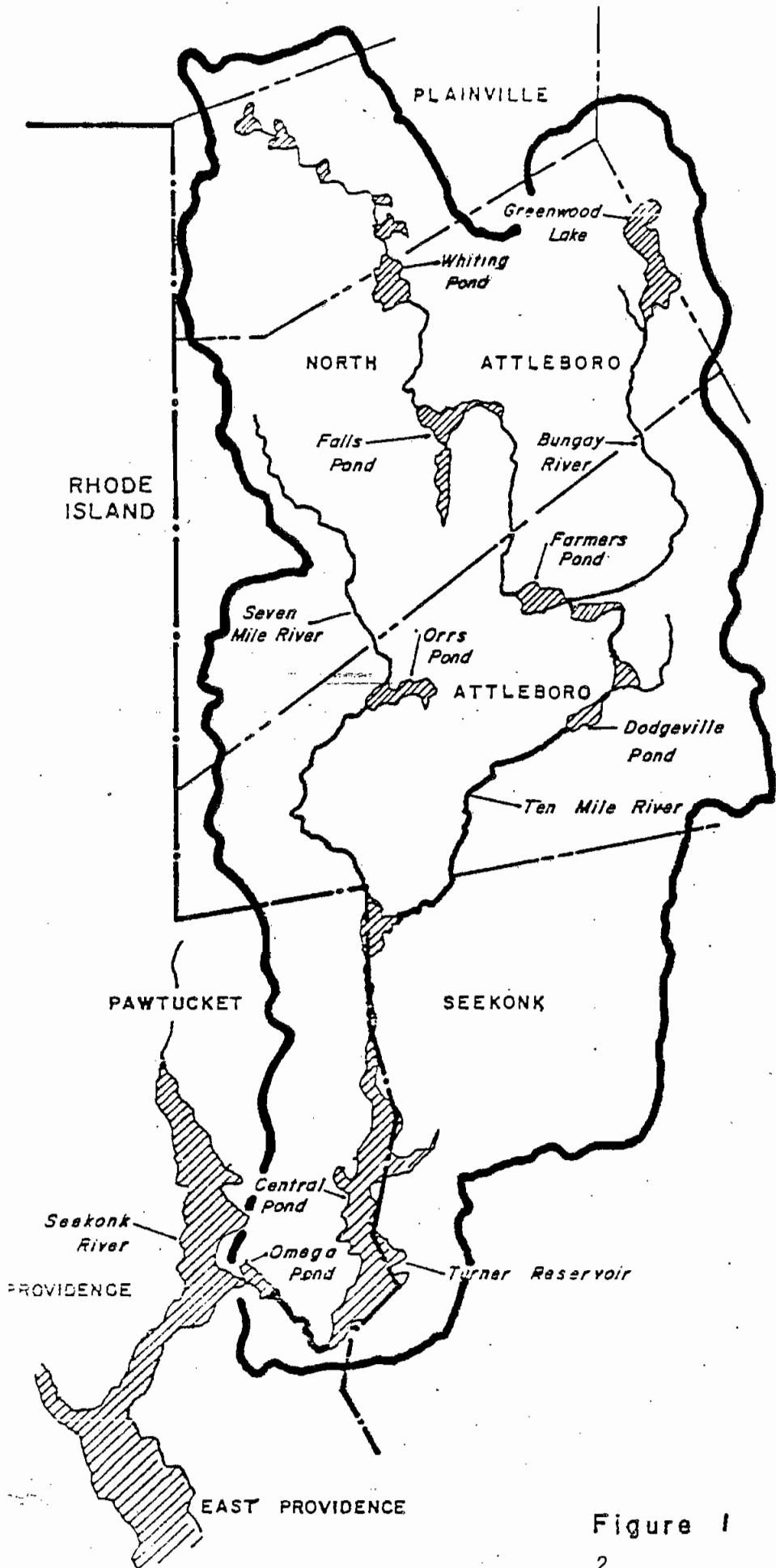
The Ten Mile River drains an area of 54 square miles in southeastern Massachusetts and eastern Rhode Island. The river basin is shown in Figure 1. Originating in Savage's Pond in Plainville, Massachusetts, the river flows generally south to southwest through the Massachusetts communities of Plainville, North Attleborough, Attleboro, and Seekonk to Pawtucket and East Providence, Rhode Island, where the Ten Mile River empties into the Seekonk River and ultimately into the Narragansett Bay estuary. The total length of the Ten Mile River is 22 miles, of which 15 miles are in Massachusetts. The elevation of the river drops from 230 feet above mean sea level at its source to ten feet at its confluence with the Seekonk River. River flow is characterized, and controlled, by 15 dams along the river which create eutrophic impoundments.

The two major tributaries to the Ten Mile River are the Bungay and Seven Mile rivers, as shown in Figure 1. The former originates in a wetland in the town of North Attleborough and flows southerly through an extensive wetland system for approximately five miles, joining the Ten Mile River just upstream of Mechanics Pond in the city of Attleboro. The drainage area for the Bungay River system is less than eight square miles. The Seven Mile River system begins in the town of North Attleborough and flows in a southerly direction through a series of ponds and reservoirs which are controlled for the city of Attleboro's water supply system. The drainage area for this system is 12.7 square miles. These tributaries are considered as the natural, "clean-water" background conditions which are compared with the Ten Mile River. These systems are not truly pristine as they are affected by non-point sources typically found in Massachusetts rivers, but they are not impacted by point source discharges of pollutant. Their quality is used as a benchmark for the evaluation of the Ten Mile River.

The physical characteristics of the basin are dominated by low, gently rolling hills with elevations ranging from near sea level at the mouth to over 400 feet above sea level in the northern portion of the basin. Urban development in the basin is centered in the communities of Plainville, North Attleborough, Attleboro, Pawtucket, and East Providence with the development along most of the areas adjacent to the Ten Mile River. Recent development in the basin has reflected the growth patterns in eastern Massachusetts and has brought increased pressure upon the natural resources of the basin.

The Ten Mile River basin has a temperate climate typical of coastal New England. Average annual temperature is 50°F, with February being the coldest month with a mean temperature of 29°F and July being the warmest with a mean temperature of 72°F. Precipitation is generally well distributed throughout the year, averaging 44 inches annually.

TEN MILE RIVER BASIN



Watershed Location

Figure 1

B. Need for a Comprehensive Program

The Ten Mile River is a wastewater discharge dominated river system. There are over 30 point source discharges to the main stem and its tributaries. Federal and state regulations require that any wastewater discharger to a surface water have a legal permit to discharge under the National Pollutant Discharge Elimination System (NPDES). The permits are issued jointly by the United States Environmental Protection Agency (U.S. EPA) Region I and the Massachusetts Division of Water Pollution Control. After careful documentation and review of all dischargers in the Ten Mile River Basin, 22 dischargers were subjected to an intensive monitoring and evaluation program in 1984. All NPDES permits for the discharges, with the exception of the two municipal wastewater treatment plants, were expired for an extensive period, in some cases up to four years.

The determination of the necessary limitations to be included in the reissued NPDES permits was based upon a water quality management approach, which would fulfill the requirements of the Massachusetts Surface Water Quality Standards (Appendix A). Particular attention needed to be paid toward: the protection of public health; the protection, propagation, and revitalization of a balanced, indigenous population of aquatic organisms; and the elimination of toxic discharges to and toxic conditions in the Ten Mile River.

The Massachusetts Water Quality Standards (most recently amended as of December 20, 1984) designate the Ten Mile River as a Class B water body which provides that "Waters assigned to this class are designated for the uses of protection and propagation of fish, other aquatic life and wildlife, and for primary and secondary contact recreation." Each water quality class is defined by the most sensitive, and therefore, governing use which it is intended to protect. In regulating discharges of pollutants to surface waters, the Division will limit or prohibit such discharges to insure that the water quality standards of the receiving water(s) will be maintained or achieved. In establishing water quality based effluent limitations, as is the case in the Ten Mile River Basin, the Division must consider natural background conditions, existing discharges, must protect existing downstream uses, and not interfere with the maintenance and attainment of beneficial uses in downstream waters. The Division may provide a reasonable margin of safety to account for any lack of knowledge concerning the relationship between the pollutants being discharged and their impact upon water quality.

The water quality standards must be met at the low flow hydraulic condition defined by the Standards as the average minimum consecutive seven-day flow to be expected once in ten years. Also, the Division will use U.S. EPA criteria as guidance in establishing case-by-case discharge limits or in a basin-wide approach as is applied to the Ten Mile River Basin. The Massachusetts Water Quality Standards established as a minimum criteria, that waters shall be free from pollutants in concentrations or combinations that:

- a) Exceed the recommended limits on the most sensitive receiving water use;
- b) Injure, are toxic to, or produce adverse physiological or behavioral responses in humans or aquatic life; or
- c) Exceed site-specific safe exposure levels determined by bioassay using sensitive species.

These criteria guided the entire Ten Mile River Program and were used as the basis for determining required effluent limitations.

The Ten Mile River Basin is complex ecological system which has a very minimal natural background flow, receives numerous wastewater discharges and has been subjected to decades of severe water quality degradation. These factors require that water quality management programs be very strong and that aggressive, innovative solutions will be necessary. The basin has witnessed significant water quality improvement in the past 15 years from the construction and operation of treatment facilities for municipal and industrial wastewaters. Untreated wastewater discharges are no longer found; however, the improvement has not been sufficient to achieve the water use goals established through the Massachusetts Water Quality Standards and significant problems remain. The 1984 Ten Mile River Program was designed to ultimately achieve those water quality goals. The first component of attainment of those goals was the successful reissuance of the NPDES permits for all significant discharges. The process could have ranged from simply reissuing the same limits as were in the expired permit to, on the the other extreme, the disallowance of any discharge to the Ten Mile River, which would reflect (literally) the zero discharge goal contained in the Federal Clean Waters Act. Neither of these options seemed rational and thus, the Ten Mile River Program was developed to design a carefully planned approach which would lead to a successful, timely, and justifiable program for the NPDES permit issuance.

The magnitude of the problem required the implementation of a "team approach" and the development of a program action plan. These are depicted in Figures 2 and 3. The "team" involved personnel from appropriate federal and state agencies, private contract consultants, and the individual permittees. An "Ad Hoc" Committee was formed and held its initial meeting on January 5, 1984 and continued to meet periodically to discuss progress, problems, and future direction and actions. A total of 11 meetings were held during the entire Ten Mile River Program. The meetings offered an excellent forum for: reviewing program elements; discussing program components such as survey procedures; evaluating data; and determination of required effluent limitations. (The agenda, list of attendees, and an outline of the major topics of discussion for each meeting are available upon request).

FIGURE 2
TEN MILE RIVER BASIN PROJECT
TEAM APPROACH

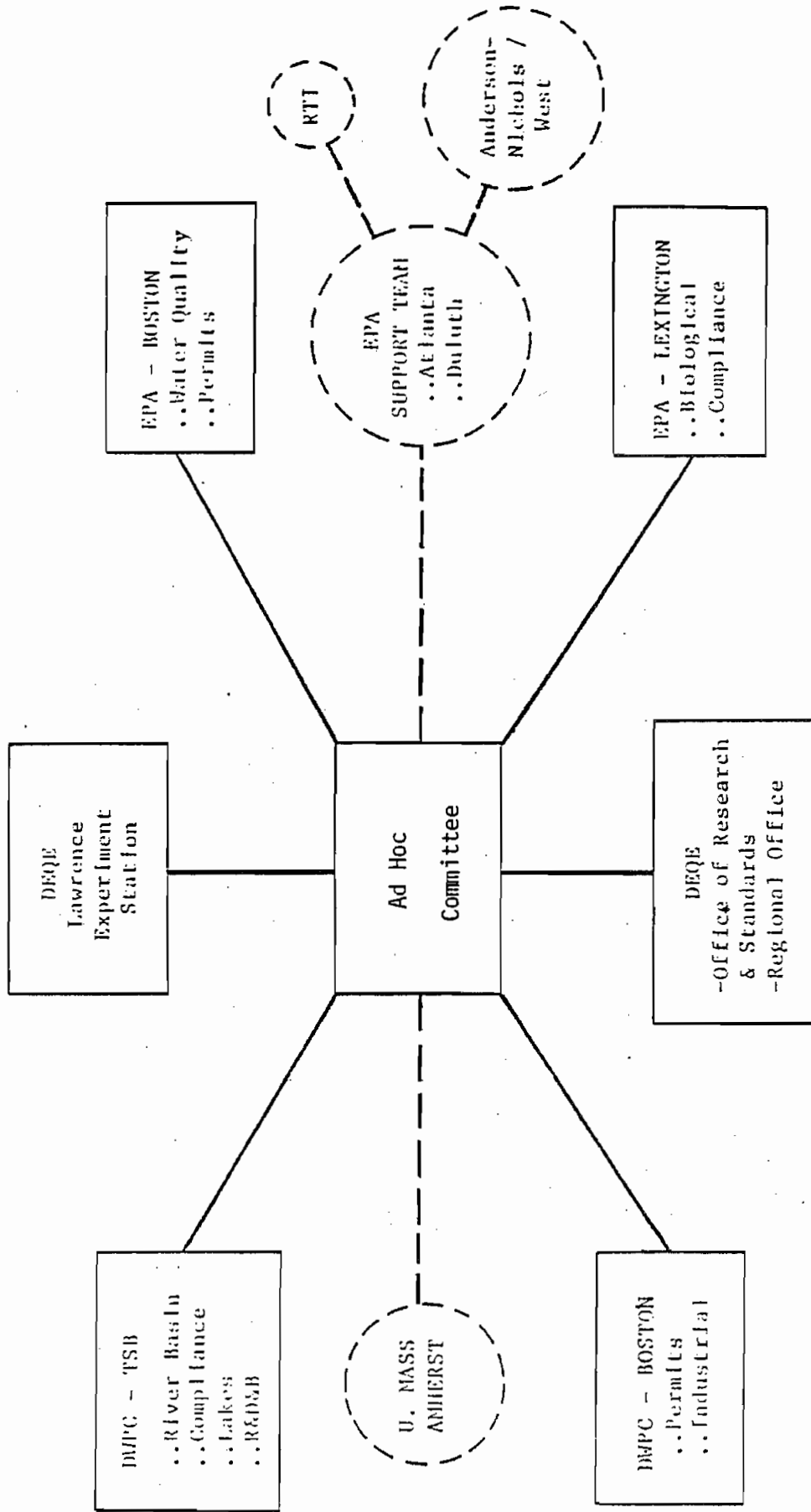
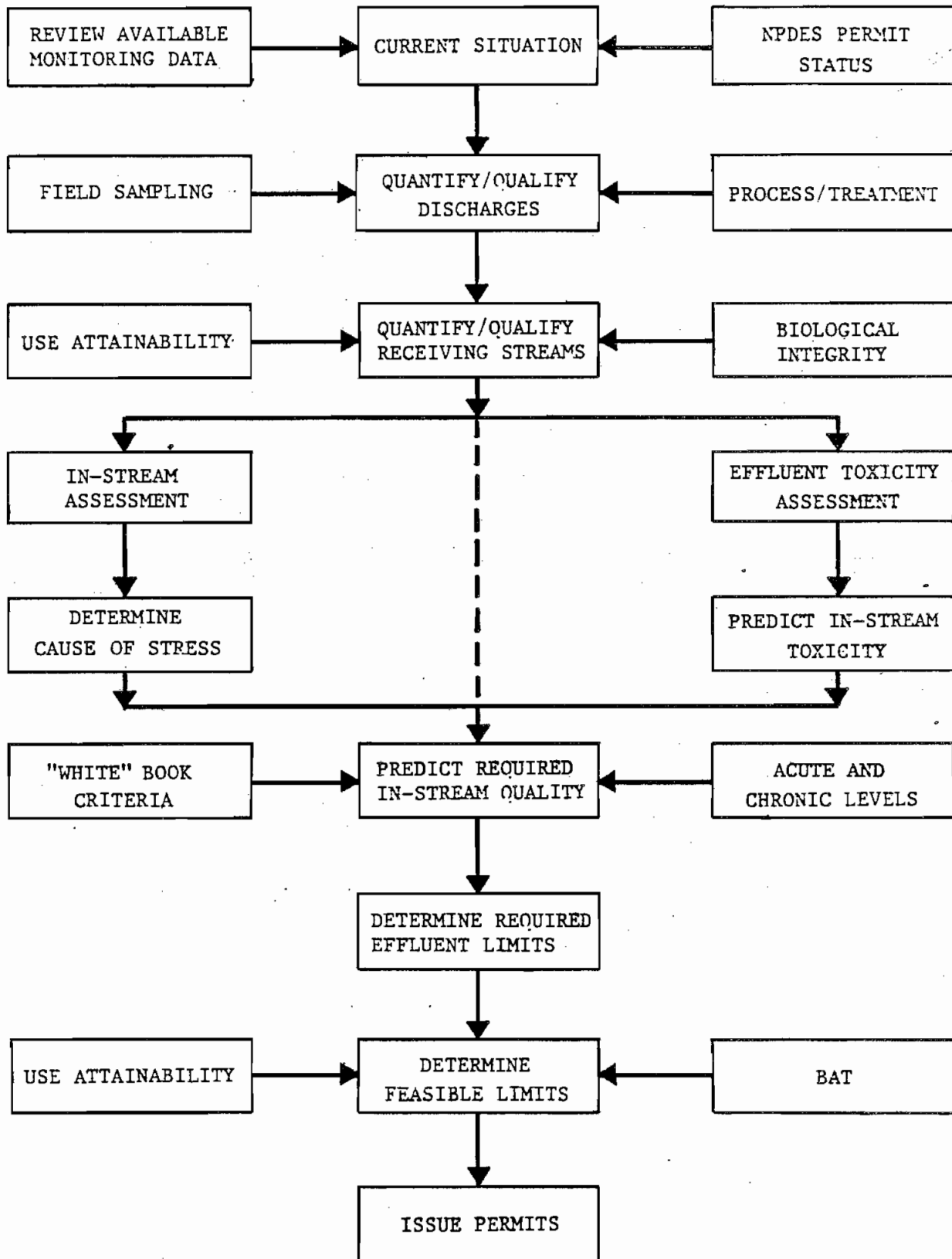


FIGURE 3
 TEN MILE RIVER PROGRAM 1984
 PROJECT FLOW CHART



II. 1984 SURVEY PROGRAM

In order to determine the condition of all environmental components of the Ten Mile River Basin, a very intensive monitoring program was developed and conducted throughout 1984. The program was designed to address many factors which influence the water quality and biological integrity of the Ten Mile River. The components which were evaluated include:

- a) impact of wastewater discharges
- b) stream water quality
- c) integrity and diversity of biological communities
- d) impoundment water quality, eutrophication, and sediment quality
- e) hydraulic conditions
- f) toxicity conditions

Each of these components interacts with the other and the quality of each is important to the overall environmental conditions of the Ten Mile River. The following discussions will briefly describe the individual component of the 1984 Ten Mile River Program.

A. Wastewater Discharges

The first aspect of this program was to document the existence of all wastewater discharges to the Ten Mile River, determine those discharges which would be included in the monitoring program, and to determine the quality and quantity of those discharges.

1. Wastewater Discharge Investigation/Interviews - Documentation and investigation of all dischargers was required because most NPDES permits were expired, industry openings and closings were quite prevalent in the jewelry, and plating industry and expansion of the sewerage systems could have tied discharges into the municipal system. It was necessary to characterize existing discharges to develop the monitoring program and to conduct personal interviews with each discharger to allow the state and federal agencies to explain the program to the dischargers which hopefully generated an awareness of the conditions of the Ten Mile River.

A list of existing and former NPDES permits in the Ten Mile River was obtained; each discharger was contacted by telephone; the program was explained; and an initial screening was conducted. Appointments were made to visit the facility, interviews were conducted with the proper personnel and industrial waste inspection checklist were completed (Appendix B). The interview process was intended to determine the type of pollutants present to the industry's wastewater, the source of those

pollutants, the mode of wastewater treatment, and to discuss any plans or problems with the wastewater treatment system.

Forty-seven wastewater discharges (either former or existing) were contacted and detailed interviews were conducted with 22 industries. Some industries had gone out of business, many had connected to the municipal system and two were discharging without an NPDES permit. The industrial wastewater survey summary is included in Appendix C. The inspection checklists are on file at the Division's Technical Services Branch.

The interview/inspection component laid the foundation for the next step in the overall program - the sampling of each discharger to determine the characteristics of the wastewater discharges to the Ten Mile River.

2. Monitoring Program of the Wastewater Discharges - The monitoring of the wastewater discharges was conducted in three major phases. The first phase was conducted during April and May of 1984 during which each significant discharger determined from the interview process was evaluated. The discharges were sampled for a three-day period, with sampling conducted according to the duration of their discharge to the river. A total of 22 facilities were sampled during this phase. The facilities are listed in Table 1 and shown in Figure 4.

The second phase of the sampling took place in conjunction with the five river monitoring surveys which occurred during the summer of 1984. The determination of the pollutant loading from discharges to the receiving waters at the time of sampling was necessary to evaluate the effect upon the rivers.

The third phase of sampling was conducted in concert with the acute toxicity testing program of each discharge. It was necessary to measure wastewater chemical characteristics at the same time as toxicity testing in order to relate components thought to cause the toxicity.

Composite samples were collected with ISCO model 1680 automatic samplers. In most cases a 28-bottle base was used and discrete samples were taken once per hour. If adequate flow records were available, samples were composited proportionally according to flow. Without adequate flow records, time proportioned samples were collected. All sampling was conducted according to Standard Operating Procedures (SOP) developed by the Division and all analyses were conducted at the Department of Environmental Quality Engineering, Lawrence Experiment Station according to U.S. EPA approved methods. The SOP are included in Appendix D and the analyses conducted are included in Appendix E.

The data from the wastewater discharge sampling program is contained in the document, Ten Mile River Basin, 1984. B. Wastewater Discharge

TABLE 1
 TEN MILE RIVER BASIN
 1984 SURVEY
 LOCATION OF WASTEWATER DISCHARGES

<u>DISCHARGER</u>	<u>LOCATION</u>	<u>RECEIVING STREAM</u>	<u>RIVER MILE</u>
1. Whiting & Davis	Plainville	Ten Mile River	19.9
2. Hilsinger Corporation	Plainville	Ten Mile River	19.7
3. Cook-Horton	North Attleborough	Unnamed tributary	19.0, 0.1
4. North Attleborough Tap	North Attleborough	Ten Mile River	18.2
5. Handy & Harman EM	North Attleborough	Ten Mile River	18.1
6. L.G. Balfour Plant #2	North Attleborough	Ten Mile River	17.9
8. C. Ray Randall	North Attleborough	Ten Mile River	16.7
9. B&J Jewelry Manufacturing	North Attleborough	Ten Mile River	16.3
10. North Attleborough WWTP	North Attleborough	Ten Mile River	15.4
11. Walton & Lonsbury	Attleboro	Unnamed tributary	14.3, 0.3
12. Mount Vernon Silver	Attleboro	Ten Mile River	14.0
13. L.G. Balfour Plant #1	Attleboro	Ten Mile River	13.1
14. Foster Metal Products	Attleboro	Ten Mile River	12.95
15. Lambert Anodizing	Attleboro	Ten Mile River	12.9
16. Montrose-Heuser	Attleboro	Ten Mile River	12.7
17. Leavens Manufacturing	Attleboro	Ten Mile River	12.4
18. Leach & Garner, Inc.	Attleboro	Speedway Brook	11.9, 1.2
19. Swank Inc.	Attleboro	Speedway Brook	11.9, 1.1
20. Robbins Company	Attleboro	Speedway Brook	11.9, 0.8
21. Handy & Harman REF	Attleboro	Unnamed tributary	10.0, 0.5
22. Attleboro WWTP	Seekonk	Ten Mile River	7.8

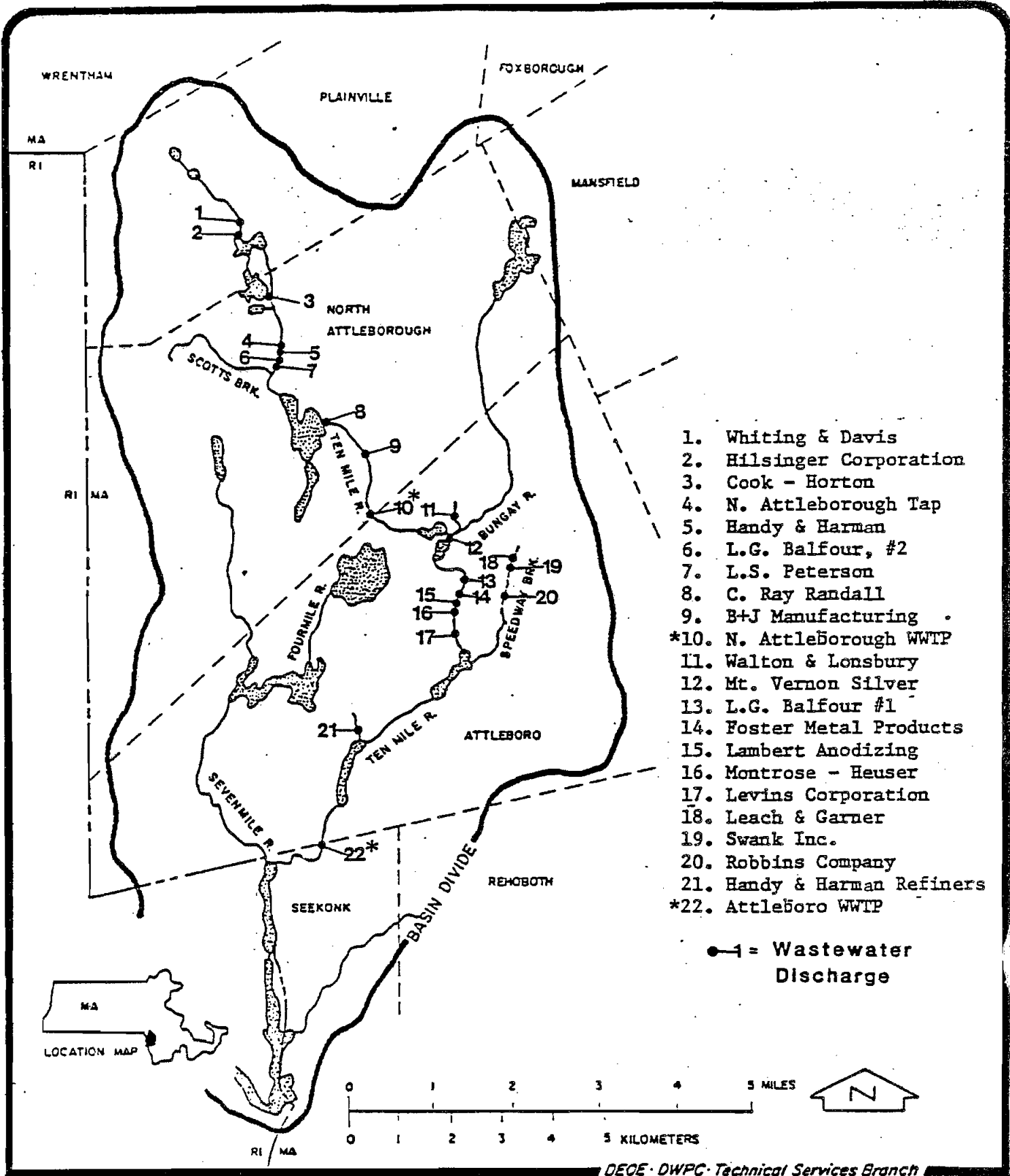


Figure 4

Ten Mile River Basin 1984 Survey
LOCATION OF WASTEWATER DISCHARGES

Data, published by the Division of Water Pollution Control. Copies of the report are available upon written request to the Division Technical Services Branch.

B. River Water Quality Surveys

1. Monitoring Program - The river monitoring program consisted of sampling at 19 locations on the Ten Mile River main stem, one location on the Bungay River, two locations on Speedway Brook, and two locations of the Seven Mile River. Surveys were conducted on the following dates: June 19-21, July 9-10, July 24-26, August 21-23 and September 18-20. The locations of the monitoring stations are listed in Table 2 and shown on Figure 5. The data from all analyses conducted on the samples are tabulated in the report, Ten Mile River Basin 1984 A. River Data. The report is available upon request from the Division's Technical Services Branch.

Each monitoring station was sampled four times per day during each survey with sampling done at equal six-hour intervals. During each day, the first sample was collected at the most upstream station at 0400. Dissolved oxygen and temperature measurement were collected each time yielding a total of 12 measurements per survey. Samples for chemical analysis were composited with equal volumes from four samples for the first two days of survey. Grab samples for metals analysis were collected during the 1000 sampling period in June and during the 0400 sampling during the remaining surveys. Total and fecal coliform bacteria samples were collected during the 0400 sampling period for each of the sampling days.

All field collection methods and techniques were conducted according to the Division's Standard Operating Procedures Manual which is included in Appendix D. These procedures have been reviewed by U.S. EPA and official approval is anticipated in 1986.

2. Laboratory Analysis/Quality Control - The parameters tested, method of preservation, parameter unit, and analytical technique are listed in Appendix E. All analyses, with the exception of dissolved oxygen were conducted at the Department of Environmental Quality Engineering-Lawrence Experiment Station, located in Lawrence, Massachusetts. The analyses were conducted by methods approved by the U.S. EPA. A copy of the Standard Operating Procedure Manual for the Lawrence Experiment Station Inorganics Laboratory is included in appendix D. The quality control procedures used by the laboratory are strictly adhered to during all analytical procedures. The levels of detection for the monitored parameters are found in Appendix D.

C. Biological Surveys

Evaluation of the biological integrity and diversity of the Ten Mile River and its tributaries was conducted during 1984 in the following areas: (a) macroinvertebrate sampling; (b) periphyton sampling; (c) phytoplankton analysis; and (d) fish sampling. The sampling was con-

TABLE 2
TEN MILE RIVER BASIN
1984 SURVEY
LOCATION OF RIVER MONITORING STATIONS

<u>STATION NUMBER</u>	<u>LOCATION</u>	<u>RIVER MILE</u>
Ten Mile River		
TM01	Fuller Street, Plainville	20.7
TM02	West Bacon Street, Plainville	19.8
TM03	Washington Street, North Attleborough	18.8
TM04	Route 1, Inlet Falls Pond, North Attleborough	17.4
TM05	Mount Hope Street, North Attleborough	16.6
TM06	Cedar Street, North Attleborough	15.6
TM07	West Street, Attleboro	14.2
TM07A	Mechanic Street, Attleboro	13.4
TM08	County Street, Attleboro	13.0
TM08A	Olive Street, Attleboro	12.6
TM09	Lamb Street, Attleboro	12.3
TM10	Thatcher Street, Attleboro	11.8
TM11	Tiffany Street, Attleboro	10.7
TM12	Bridge Street, below dam, Attleboro	9.4
TM13	Pond Street, Seekonk	8.6
TM14	Central Avenue, Pawtucket, RI	7.0
TM15	Armistice Boulevard, Pawtucket, RI	5.8
TM16	Route 152, East Providence, RI	3.2
TM17	Roger Williams Avenue, East Providence, RI	0.8
Bungay River		
BG02	Holden Street, Attleboro	14.0, 0.6
Speedway Brook		
SW00	Maple Street, Attleboro	11.9, 0.9
SW01	Route 152, Attleboro	11.9, 0.1
Seven Mile River		
SM00	Draper Avenue, North Attleborough	7.5, 5.0
SM01	County Street, Attleboro	7.5, 0.3

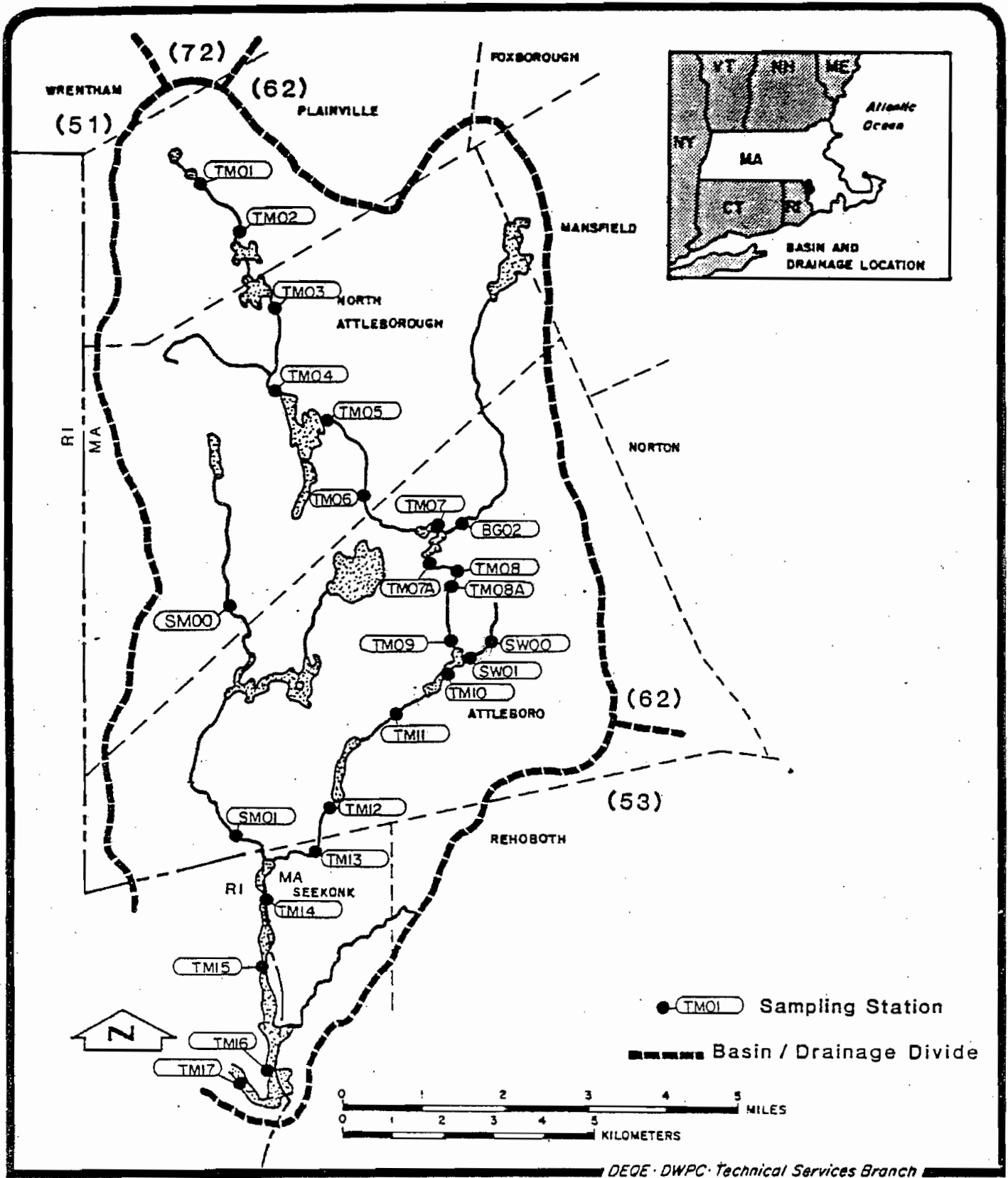


Figure 5

LOCATION OF
SAMPLING STATIONS - 1984

ducted according to protocol outlined in the Division's SOP Manual and identification of species was conducted at the Division's Technical Services Branch. Biological surveys are designed to evaluate the impact of pollutants upon the biota of the receiving water. According to Johnson et. al. (1985), if other environmental factors remain constant, a change in water chemistry resulting from the release of one or more toxicants to a receiving water will alter the structure and/or function of downstream aquatic communities.

Instream sampling for macroinvertebrate and periphyton communities was conducted during June 18-21 and September 17-20, 1984. Specimens were collected at eight locations in June and at nine locations during September. In addition, specimens were collected at two clean water reference sites during each survey. The sites were chosen as those which might potentially be impacted from municipal and industrial discharges. A Rapid Assessment (RA) method was used for sampling the macroinvertebrate communities of the Ten Mile River. Periphyton was sampled qualitatively by collecting a sample of each growth form encountered and collecting scrapings from substrate for identification of microscopic forms. The results, methods and analysis of this work are presented in the report, The Biological Assessment of Water Pollution in the Ten Mile River by Johnson et. al. (1985).

Fish surveys were conducted at eight stations on the Ten Mile River and one station on the Seven Mile River during 1984. Due to the variety of habitats represented by these stations, a variety of capture methods were employed. All fish were identified to species, weighed, measured and scaled for age and growth analysis. The edible fillets from five fish of similar species were composited and analyzed for heavy metals. All fish which were retained for metals analysis were examined for gross indications of abnormalities or disease, both externally and internally. The results and analysis of the fish survey are also presented in the report by Johnson et. al.

Phytoplankton samples were collected as part of the surveys conducted on the ten impoundments on the Ten Mile River. Each impoundment was sampled once during the four major river surveys. Samples were collected at the water surface and were analyzed for phytoplankton type and density. Chlorophyll a analyses were conducted for comparison with the species counts. The data from these analyses are contained in the report, Ten Mile River Basin, 1984, A. Impoundment Data.

D. Impoundment Surveys

During each of the four major surveys conducted on the Ten Mile River during 1984, ten impoundments were sampled once per survey in order to evaluate trophic state, water quality, and sediment distribution and quality. The data from those surveys are presented in the report, Ten Mile River Water Quality Data - 1984 A. Impoundment Data, published by the Division's Technical Services Branch.

Sampling stations at each impoundment were located at all inlets, outlet and at an open water location with the greatest depth.

Measurements for temperature, pH, dissolved oxygen and conductivity profiles were made "in situ" at each location with a Hydrolab™ meter. Samples for chemical, and coliform bacteria analyses were collected at each station and analyzed at the DEQE Lawrence Experiment Station. All field procedures and laboratory techniques were conducted according to approved procedures as previously mentioned for the other field sampling activities. Metals samples were collected at the deep water station using a Ponar dredge; sediment analysis included metals, nutrients and % volatile solids. A special study was conducted to determine the settling rate of solids in the impoundments. This experimental method was comprised of suspending a wide mouth glass bottle in a wire crate at the bottom of the impoundment and retrieving the sample one month later and measuring the accumulation of solids. Phytoplankton and chlorophyll a samples were collected from each impoundment and analyzed at the Division's Technical Services Branch. Aquatic macrophyton was located and mapped for each impoundment during each survey.

E. Hydraulic Surveys

During each of the river surveys conducted in 1984, in-stream flow measurements were taken at five locations on the Ten Mile River and at three tributary locations. The objective of the flow monitoring was to develop a hydraulic profile of the Ten Mile River which related stream flow to drainage area, determined the relative increment of runoff and to determine the flow at individual river and discharge locations. In addition, the 7-day 10-year low flow and 30-day 2-year low flow was developed in order to calculate effluent limitations for the NPDES permits for each discharger in the Ten Mile River Basin. The data and the methodology used to determine the low flow conditions are presented in the report, Ten Mile River Basin 1984 Hydraulic Profile (K.R. Anderson) published by the Division's Technical Services Branch.

F. Toxicity Testing Program

Chronic toxicity tests were conducted during June, August and September of 1984 on waters collected at various locations of the Ten Mile River. Ambient instream toxicity of the Ten Mile River was assessed by determination of test organism survival and reproduction or growth rates. The June and September tests which measured reproduction potential and survival of the daphnid, Ceriodaphnia sp. were conducted by the U.S. EPA Environmental Research Laboratory, Duluth, Minnesota. The results of this work are presented in the draft reports, A Report on the Chronic Toxicity of Selected Effluents Along the Ten Mile River in Massachusetts to Ceriodaphnia Affinis/Dubia June and September 1984, S. Heinritz. The August testing was conducted by the U.S. EPA New England Regional Laboratory and included Ceriodaphnia sp. and fathead minnow growth and survival tests. In addition, tests were conducted on a trial basis to measure deformities and survival of newly hatched minnows. The results of this testing are presented in the report, Chronic Toxicity Testing Program, Ten Mile River - 1984, P. Nolan, 1986.

According to Nolan, the objective of the instream toxicity testing was to: (1) identify impact zones and relate this information to point discharges or combinations of industrial and municipal discharges, and (2) to predict ecological harm to resident benthic and fish populations. Ambient instream toxicity was recorded throughout the study area and could be related to a discharge from one or a group of discharges.

Acute toxicity tests were conducted on 17 of the wastewater discharges to the Ten Mile River between May and October, 1984. The tests were conducted in the static acute mode over a 48-hour period using less than six-week old fathead minnows (Pimephales promelas) and less than 24-hour old crustaceans (Daphnia pulex). The test results were measured as LC50 values and NOAEL (No Observed Acute Effect Level) values. The tests were conducted according to methods recommended by Peltier and Weber. The results of this program are contained in the report, Ten Mile River - Acute Toxicity Testing 1984, M. Bilger, 1986.

The results of the testing program indicated that 11 industrial discharges were very acutely toxic to the Daphnia pulex, with LC50 values as low as 0.06%. The extreme toxicity associated with many of the discharges is reflected in the high level of heavy metals in the particular discharges. In order to eliminate the toxicity of the discharges, very stringent effluent limitations are required.

III. DETERMINATION OF EFFLUENT LIMITATION

The Clean Water Act stipulates a two-tiered approach for the development of effluent limitations. Under Section 301(b)(2), all industrial dischargers must provide "best available treatment economically achievable" (BAT) regardless of volume or location of discharge. This level of treatment is the minimum that must be provided in accordance with this section and regulations published pursuant to Section 304(b) which describe BAT limits for each industrial category.

The second tier, described in Section 301(b)(1)(C), mandates that dischargers shall apply "any more stringent limitation, including those necessary to meet water quality standards...established pursuant to any state law or regulations..." Effluent limits established under this Section are commonly referred to as "water quality based limits."

Massachusetts has regulations which closely parallel the CWA under 314 CMR 3 (Permit Regulations) and 314 CMR 4 (Water Quality Standards). The permit regulations establish the same two-tiered approach to deriving effluent limitations as in the CWA. Under 314 CMR 4.02, discharges will be regulated to assure that water quality standards will be attained or maintained. Where water quality based effluent limitations are developed the permitting authority must consider natural background conditions, existing dischargers, must protect existing downstream users and not interfere with the maintenance and attainment of beneficial uses in downstream waters. Further, "the Division [of Water Pollution Control] may provide a reasonable margin of safety to account for any lack of knowledge concerning the relationship between the pollutants being discharged and their impact on the quality of receiving waters."

A. Objectives

The Ten Mile River has been assigned a B classification in both Massachusetts and Rhode Island with a goal of protection and propagation of fish, other aquatic life and wildlife; and for recreation in and on the water. Both states, consistent with national goals, protect receiving waters from toxic substances. In Massachusetts, the standards in 314 CMR 4.03 read:

Waters shall be free from pollutants in concentrations or combinations that

- a) Exceed the recommended limits on the most sensitive receiving water use;
- b) Injure, are toxic to, or produce adverse physiological or behavioral responses in humans or aquatic life; or
- c) Exceed site-specific safe exposure levels determined by bioassay using sensitive species. (Emphasis added).

As discussed in the introduction to this section, effluents must satisfy either technology based or water quality requirements, whichever is more restrictive. Currently, some of the industries and two of the municipalities achieve limitations more stringent than the technology based guidelines. In spite of the high levels of treatment provided, water quality standards continue to be violated, primarily due to effluent and instream toxicity. Toxicity is evident in the water as well as the sediment. Thus, it is obvious that in order to meet water quality standards, the second tier--water quality based limits--must be used. The development of these water quality based limits is based on the analysis of chemical, physical and biological data from the 1984 survey of the dischargers and the receiving water.

B. Analytical Techniques

Where technology based BAT limits are sufficient to maintain water quality standards, a permit is easily written. However, if a determination is made that greater than BAT is required, the permit writing process can be lengthy and complicated. This is particularly true where there are multiple discharges with overlapping effects. Water quality based limits must take into account receiving water characteristics, existing and proposed water uses as well as the nature and location of the dischargers. Developing water quality based limits involves many steps and integrates many physical, chemical and biological components. Total maximum daily loads (TMDLs) are developed for the receiving water for each contaminant. In the case of multiple dischargers, wasteload allocations (WLAs) are calculated to assign permit limits to each discharger. The process is lengthy and entails a great deal of feedback between steps. A brief outline of the major steps is presented in Figure 6.

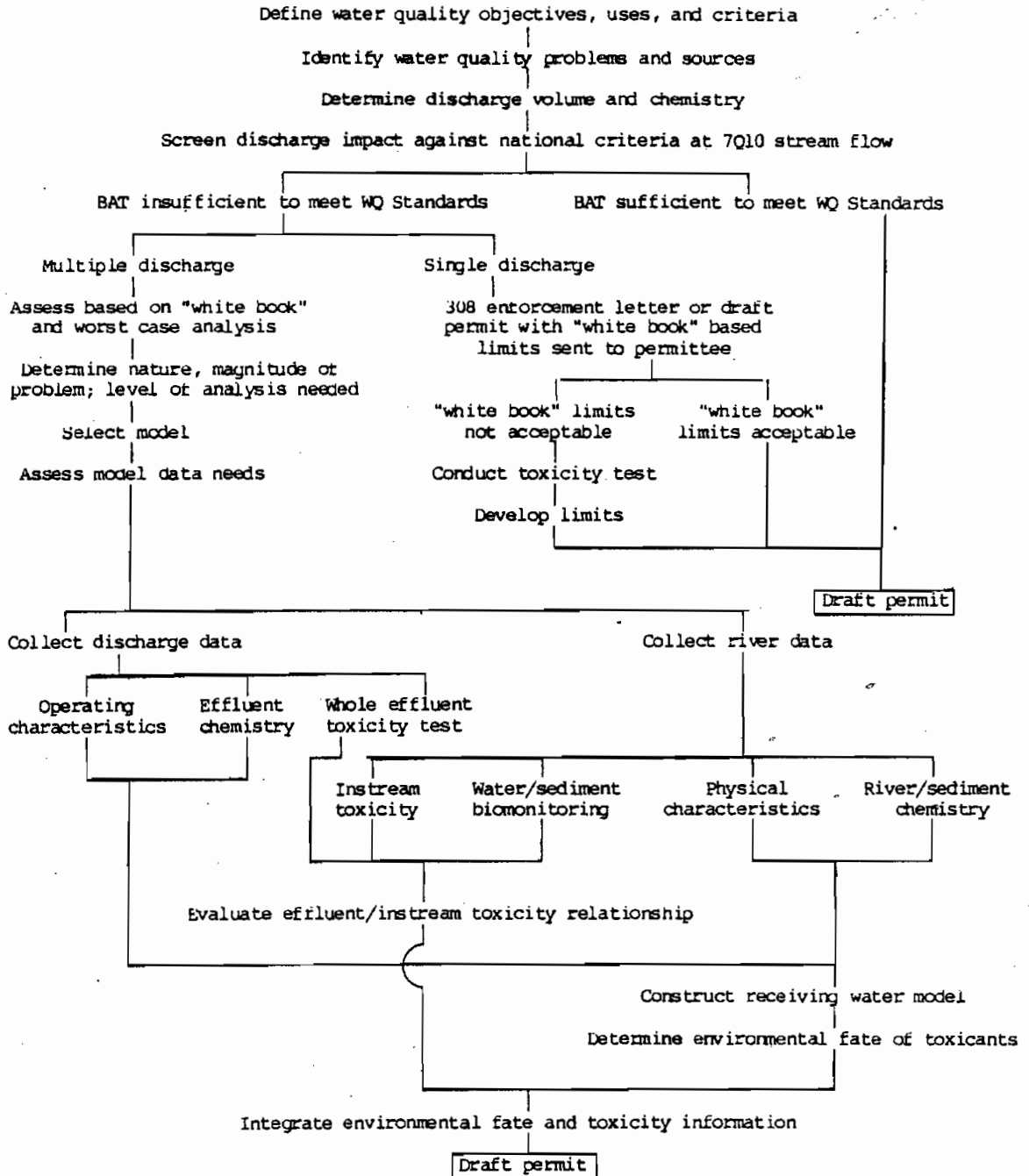
Three of the major considerations in developing NPDES limits--national criteria, toxicity testing and river modeling--are discussed. Following this is an integration of the various aspects of the study into effluent limits for each of the Ten Mile dischargers.

B(1) National Criteria

Section 304(a)(1) of the Clean Water Act requires that EPA publish criteria for water quality accurately reflecting the latest scientific knowledge on the nature and extent of all identifiable effects on health and welfare which may be expected from the presence of pollutants in any body of water. Considerations include but are not limited to plankton, fish, wildlife, plant life, aesthetics, recreational, human health, bioaccumulation and sedimentation.

The term "water quality criteria" is used in two sections of the Clean Water Act, Section 304(a)(1) and Section 303(c)(2). The term has a different program impact in each section. In Section 304, the term represents a non-regulatory scientific assessment of ecological

FIGURE 6



effects. Such water quality criteria associated with specific stream uses when adopted as state water quality standards under Section 303 become enforceable maximum acceptable levels of a pollutant in ambient waters. The water quality criteria adopted in the state water quality standards could have this same numerical limits as the criteria developed under Section 304. However, in many situations states have adjusted water quality criteria developed under Section 304 to reflect local environmental conditions and human exposure patterns before incorporation into water quality standards. It is not until their adoption as part of the state water quality standards that the criteria become regulatory.

Massachusetts in 314 CMR 4.03(2) states in part that the Division of Water Pollution Control will use 304(a)(1) criteria as "guidance in establishing case-by-case discharge limits... and for interpretation of narrative criteria." As mentioned earlier, Massachusetts has the traditional "free from" narrative criteria for toxicants which can either be based on the national criteria or site-specific modifications or toxicity tests.

The national criteria are commonly referred to as the "white book" or "white book numbers," a shorthand reference to the criterion documents. White book numbers have been developed for 65 substances including criteria for ammonia, arsenic, cadmium, chlorine, chromium, copper, cyanide, lead, mercury, nickel, silver and zinc--contaminants now or formerly discharged to the Ten Mile River. Table 3 is a summary of the above substances with the exception of ammonia which is dependent on water temperature and pH. A chart showing ammonia criteria at various stream conditions is presented in Table 4.

EPA has published a document, "Guidelines for Deriving Numerical National Water Quality Criteria for the Protection of Aquatic Organisms and Their Uses" outlining the process and data requirements for the development of national criteria. Derivation of numerical national water quality criteria for the protection of aquatic organisms and their uses is a complex process that uses information from many areas of aquatic toxicology. After a decision is made that a national criterion is needed for a particular material, all available information concerning toxicity to, and bioaccumulation by, aquatic organisms is collected, reviewed for acceptability, and sorted. If enough acceptable data on acute toxicity to aquatic animals are available, they are used to estimate the highest one-hour average concentration that should not result in unacceptable effects on aquatic organisms and their uses. This concentration is made a function of a water quality characteristic such as pH, salinity, or hardness if justified. Similarly, data on the chronic toxicity of the material to aquatic animals are used to estimate the highest four-day average concentration that should not cause unacceptable toxicity during a long-term exposure. When appropriate, this concentration is also related to a water quality characteristic.

Data on toxicity to aquatic plants are examined to determine whether plants are likely to be unacceptably affected by concentrations that

Table 3

POLLUTANT	WATER QUALITY CRITERIA METALS AND OTHER COMMON CONTAMINANTS				
	Hardness	FRESHWATER (ug/l)		SALTWATER (ug/l)	
		4 day avg./3 yr.	1 hr. avg./3 yr.	4 day avg./3 yr.	1 hr. avg./3 yr.
1) Ammonia		See attached table		#	#
2) Arsenic (III)		190	360	36	69
3) Cadmium**	20 50	0.32 0.66	0.64 1.8	9.3	43
4) Chlorine		11	19	7.5	13
5) Chromium (III) Chromium (VI)	20 50	55 120 11	465 980 16	# 50	# 1,100
6) Copper**	20 50	3.0 6.5	3.9 9.2	#	2.9
7) Cyanide		5.2	22	#	1.0
8) Lead**	20 50	0.41 1.3	11 34	5.6	140
9) Mercury		0.012	2.4	0.025	2.1
		24-hour average	Maximum	24-hour average	Maximum
10) Nickel**	20 50	28 56	319 641	7.1	140
11) Silver**	20 50	[0.12] [0.12]	0.09 0.44	#	2.3
12) Zinc**	20 50	47 47	74 159	58	170

** Numbers for the freshwater criteria for these compounds are derived from the equation on the following page.

Insufficient data to derive criteria.

[] Data indicate that toxicity may occur as low as 0.12 ug/l; this value is not a criterion.

Table 4

(1) One-hour average concentrations for ammonia.* (Acute)

pH	0 C	5 C	10 C	15 C	20 C	25 C	30 C
A. Salmonids or Other Sensitive Coldwater Species Present							
Un-ionized Ammonia (mg/liter NH ₃)							
6.50	0.0091	0.0129	0.0182	0.026	0.036	0.036	0.036
6.75	0.0149	0.021	0.030	0.042	0.059	0.059	0.059
7.00	0.023	0.033	0.046	0.066	0.093	0.093	0.093
7.25	0.034	0.048	0.068	0.095	0.135	0.135	0.135
7.50	0.045	0.064	0.091	0.128	0.181	0.181	0.181
7.75	0.056	0.080	0.113	0.159	0.22	0.22	0.22
8.00	0.065	0.092	0.130	0.184	0.26	0.26	0.26
8.25	0.065	0.092	0.130	0.184	0.26	0.26	0.26
8.50	0.065	0.092	0.130	0.184	0.26	0.26	0.26
8.75	0.065	0.092	0.130	0.184	0.26	0.26	0.26
9.00	0.065	0.092	0.130	0.184	0.26	0.26	0.26
Total Ammonia (mg/liter NH ₃)							
6.50	35	33	31	30	29	20	14.3
6.75	32	30	28	27	27	18.6	13.2
7.00	28	26	25	24	23	16.4	11.6
7.25	23	22	20	19.7	19.2	13.4	9.5
7.50	17.4	16.3	15.5	14.9	14.6	10.2	7.3
7.75	12.2	11.4	10.9	10.5	10.3	7.2	5.2
8.00	8.0	7.5	7.1	6.9	6.8	4.8	3.5
8.25	4.5	4.2	4.1	4.0	3.9	2.8	2.1
8.50	2.6	2.4	2.3	2.3	2.3	1.71	1.28
8.75	1.47	1.40	1.37	1.38	1.42	1.07	0.83
9.00	0.86	0.83	0.83	0.86	0.91	0.72	0.58
B. Salmonids and Other Sensitive Coldwater Species Absent							
Un-ionized Ammonia (mg/liter NH ₃)							
6.50	0.0091	0.0129	0.0182	0.026	0.036	0.051	0.051
6.75	0.0149	0.021	0.030	0.042	0.059	0.084	0.084
7.00	0.023	0.033	0.046	0.066	0.093	0.131	0.131
7.25	0.034	0.048	0.068	0.095	0.135	0.190	0.190
7.50	0.045	0.064	0.091	0.128	0.181	0.26	0.26
7.75	0.056	0.080	0.113	0.159	0.22	0.32	0.32
8.00	0.065	0.092	0.130	0.184	0.26	0.37	0.37
8.25	0.065	0.092	0.130	0.184	0.26	0.37	0.37
8.50	0.065	0.092	0.130	0.184	0.26	0.37	0.37
8.75	0.065	0.092	0.130	0.184	0.26	0.37	0.37
9.00	0.065	0.092	0.130	0.184	0.26	0.37	0.37
Total Ammonia (mg/liter NH ₃)							
6.50	35	33	31	30	29	29	20
6.75	32	30	28	27	27	26	18.6
7.00	28	26	25	24	23	23	16.4
7.25	23	22	20	19.7	19.2	19.0	13.5
7.50	17.4	16.3	15.5	14.9	14.6	14.5	10.3
7.75	12.2	11.4	10.9	10.5	10.3	10.2	7.3
8.00	8.0	7.5	7.1	6.9	6.8	6.8	4.9
8.25	4.5	4.2	4.1	4.0	3.9	4.0	2.9
8.50	2.6	2.4	2.3	2.3	2.3	2.4	1.81
8.75	1.47	1.40	1.37	1.38	1.42	1.52	1.18
9.00	0.86	0.83	0.83	0.86	0.91	1.01	0.82

* To convert these values to mg/liter N, multiply by 0.822.

TABLE 4 (CONTINUED)

(2) 4-day average concentrations for ammonia.* (Chronic)

pH	0 C	5 C	10 C	15 C	20 C	25 C	30 C
A. Salmonids or Other Sensitive Coldwater Species Present							
Un-Ionized Ammonia (mg/liter NH ₃)							
6.50	0.0007	0.0009	0.0013	0.0019	0.0019	0.0019	0.0019
6.75	0.0012	0.0017	0.0023	0.0033	0.0033	0.0033	0.0033
7.00	0.0021	0.0029	0.0042	0.0059	0.0059	0.0059	0.0059
7.25	0.0037	0.0052	0.0074	0.0105	0.0105	0.0105	0.0105
7.50	0.0066	0.0093	0.0132	0.0186	0.0186	0.0186	0.0186
7.75	0.0109	0.0153	0.022	0.031	0.031	0.031	0.031
8.00	0.0126	0.0177	0.025	0.035	0.035	0.035	0.035
8.25	0.0126	0.0177	0.025	0.035	0.035	0.035	0.035
8.50	0.0126	0.0177	0.025	0.035	0.035	0.035	0.035
8.75	0.0126	0.0177	0.025	0.035	0.035	0.035	0.035
9.00	0.0126	0.0177	0.025	0.035	0.035	0.035	0.035
Total Ammonia (mg/liter NH ₃)							
6.50	2.5	2.4	2.2	2.2	1.49	1.04	0.73
6.75	2.5	2.4	2.2	2.2	1.49	1.04	0.73
7.00	2.5	2.4	2.2	2.2	1.49	1.04	0.74
7.25	2.5	2.4	2.2	2.2	1.50	1.04	0.74
7.50	2.5	2.4	2.2	2.2	1.50	1.05	0.74
7.75	2.3	2.2	2.1	2.0	1.40	0.99	0.71
8.00	1.53	1.44	1.37	1.33	0.93	0.66	0.47
8.25	0.87	0.82	0.78	0.76	0.54	0.39	0.28
8.50	0.49	0.47	0.45	0.44	0.32	0.23	0.17
8.75	0.28	0.27	0.26	0.27	0.19	0.15	0.11
9.00	0.16	0.16	0.16	0.16	0.13	0.10	0.08
<hr/>							
B. Salmonids and Other Sensitive Coldwater Species Absent†							
Un-Ionized Ammonia (mg/liter NH ₃)							
6.50	0.0007	0.0009	0.0013	0.0019	0.0026	0.0026	0.0026
6.75	0.0012	0.0017	0.0023	0.0033	0.0047	0.0047	0.0047
7.00	0.0021	0.0029	0.0042	0.0059	0.0083	0.0083	0.0083
7.25	0.0037	0.0052	0.0074	0.0105	0.0148	0.0148	0.0148
7.50	0.0066	0.0093	0.0132	0.0186	0.026	0.026	0.026
7.75	0.0109	0.0153	0.022	0.031	0.043	0.043	0.043
8.00	0.0126	0.0177	0.025	0.035	0.050	0.050	0.050
8.25	0.0126	0.0177	0.025	0.035	0.050	0.050	0.050
8.50	0.0126	0.0177	0.025	0.035	0.050	0.050	0.050
8.75	0.0126	0.0177	0.025	0.035	0.050	0.050	0.050
9.00	0.0126	0.0177	0.025	0.035	0.050	0.050	0.050
Total Ammonia (mg/liter NH ₃)							
6.50	2.5	2.4	2.2	2.2	2.1	1.46	1.03
6.75	2.5	2.4	2.2	2.2	2.1	1.47	1.04
7.00	2.5	2.4	2.2	2.2	2.1	1.47	1.04
7.25	2.5	2.4	2.2	2.2	2.1	1.48	1.05
7.50	2.5	2.4	2.2	2.2	2.1	1.49	1.06
7.75	2.3	2.2	2.1	2.0	1.98	1.39	1.00
8.00	1.53	1.44	1.37	1.33	1.31	0.93	0.67
8.25	0.87	0.82	0.78	0.76	0.76	0.54	0.40
8.50	0.49	0.47	0.45	0.44	0.45	0.33	0.25
8.75	0.28	0.27	0.26	0.27	0.27	0.21	0.16
9.00	0.16	0.16	0.16	0.16	0.17	0.14	0.11

* To convert these values to mg/liter N, multiply by 0.822.

† Site-specific criteria development is strongly suggested at temperatures above 20 C because of the limited data available to generate the criteria recommendation, and at temperatures below 20 C because of the limited data and because small changes in the criteria may have significant impact on the level of treatment required in meeting the recommended criteria.

should not cause unacceptable effects on animals. Data on bioaccumulation by aquatic organisms are used to determine if residues might subject edible species to restrictions by the U.S. Food and Drug Administration or if such residues might harm some wildlife consumers of aquatic life. All other available data are examined for adverse effects that might be biologically important.

If a thorough review of the pertinent information indicates that enough acceptable data are available, numerical national water quality criteria are derived for fresh water or salt water or both to protect aquatic organisms and their uses from unacceptable effects due to exposures to high concentrations for short periods of time (acute level), lower concentrations for longer periods of time (chronic level), and combinations of the two.

White book values for several substances, notably cadmium, copper, lead, nickel and silver, were exceeded in the Ten Mile River in 1984. These readings taken at river flows greater than 7-Q-10, indicate a serious problem exists in the Ten Mile River during low flow periods. Copper values exceeded the national copper criterion the most frequently and by the largest margin of the chemicals analyzed. Instream copper ranged from undetectable up to 470 ug/l with an average value of 65 ug/l. This is ten times greater than the national chronic criterion for copper, and seven times greater than the acute criterion. These factors increase in those periods when flow approach 7-Q-10 values and create the potential for severe chronic and lethal effects.

It is the policy of both EPA Region I and the Massachusetts Division of Water Pollution Control that white book criteria be met instream at flows greater than or equal to the 7-Q-10 flow. Where meeting this requirement will result in greater than BAT effluent limits for a discharge or a group of dischargers, the permittees may undertake site-specific effluent toxicity testing. The results of the toxicity tests may either confirm national criteria or support alternative limitations. In the case of the fifteen industrial and two municipal discharges to the Ten Mile River, draft permits based on application of white book numbers at 7-Q-10 flows results in extremely stringent limitations. Since greater than 90% of the river flow at 7-q-10 is treated wastewater, and since natural copper levels in the Basin range from 5 to 20 ug/l, maintenance of national criteria in stream would require that white book values or less be met at the "end of the pipe" at each discharge. The possibility of additive effects of toxicants must be taken into account in effluents containing several contaminants and can result in requiring less than individual white book values for each constituent in a complex effluent. For example, if an effluent contains copper, lead and cadmium each limited based on its white book limit, there is the potential for the additive effects of the individually safe metals to cause mortality instream. Considering additivity, a permit would be drafted with one-third of the white book value for each of the three metals so that the total effect of the three toxicants would not exceed unity. Additivity has been observed in the laboratory but varies depending on the consti-

trients in the sample, their ratios in the solution, and other substances in the water such as suspended solids or hardness. The most direct manner in which to assess effluent toxicity and additivity is to conduct toxicity tests using different dilutions of effluent in receiving water. Since there are numerous interrelated dischargers to the Ten Mile River, each with complex effluents, use of the white book criteria alone may not result in appropriate limits.

A more detailed analysis involving toxicity testing and stream modeling is used to supplement information provided by the national criteria documents.

B(2) Toxicity Testing

Due to the complex relationship between the Ten Mile River dischargers and instream toxicity, EPA and DWPC determined at the outset of the study to integrate toxicity tests into the overall analysis. Further, it was decided to supplement effluent toxicity tests with chronic toxicity tests run on Ten Mile River water at various sampling stations throughout the basin. A complete discussion of the toxicity testing protocol and result is found in the reports by Nolan and Bilger (1986).

Effluent acute toxicity tests were conducted in 1984 and 1985 while instream chronic toxicity tests were conducted only in 1984. These tests demonstrated that the potent toxicity of the majority of the dischargers carried over into the stream environment as chronic and acute toxicity.

The whole effluent acute toxicity tests were carried out in accordance with the EPA Regional policy on toxicity testing. Briefly, effluent samples are serially diluted with clean, upstream receiving water to form the test samples. In the acute tests, daphnia pulex and fathead minnows are added to the samples with survival tracked for 48 hours. Mortality is calculated for each of the dilutions, compared with the control sample and the LC-50 and NOAEL are calculated. The LC-50 is the concentration which is lethal to 50% of the organisms and is sometimes reported as the EC-50 or the concentration which effectively immobilizes or injures beyond recovery 50% of the organisms. The NOAEL is the "no observed acute effect level" or the concentration which causes no mortality relative to the control sample. The NOAEL for the more sensitive organism, daphnia or minnow, is used to describe the toxicity of the effluent.

A chemical analysis is conducted on each sample so that the levels of the potential toxicants can be evaluated to determine, based on dilution, what concentrations are lethal. In most cases, one or maybe two substances can be identified as being the causative factor in the effluent's toxicity. For the Ten Mile River discharges, copper was the major toxicant with silver, chlorine and total dissolved solids present in lethal concentrations in some effluents. In order to develop a relationship between individual effluent toxicity and instream

allowable levels of effluent, comparisons have been made between the various discharger's copper levels at each discharger's NOAEL. As an example, Whiting and Davis had an effluent copper concentration of 2.0 mg/l with an NOAEL of less than 0.1%. An NOAEL of 0.1% indicates the need for a ratio of 1000 parts river water to 1 part effluent. By dividing the effluent concentration of 2 mg/l (2000 ug/l) by the dilution factor of 1000, a "safe" instream value of 2 ug/l is calculated. These calculations were done using the toxicity test results for 1984 (performed by EPA) and for 1985 (performed by the dischargers or their consultants) and are summarized in Table 5.

Using all of the 1984 data points result in a mean of 31 ug/l copper with a standard deviation of 28 ug/l. Examination of discharge data indicate that the POTW's had high levels of calcium carbonate hardness, not seen in 1985, which reduced toxicity in addition to the mitigation caused by suspended and dissolved organic material. If this value is dropped from the calculation, the mean is reduced to 25 ug/l copper with a standard deviation of 23 ug/l.

For 1985, the calculations indicate a mean safe level for copper of 14 ug/l with a standard deviation of 13 ug/l. However, close examination of the data show that five of the lowest NOAEL values for copper may have been skewed by other potent contaminants. Handy and Harman REF and Balfour #1 appear to be toxic due primarily to silver while Leach and Garner seems to be affected by cyanide and silver. Finally, the Handy and Harman Refinery effluent has an exceptionally high total dissolved solids content which yields a very low NOAEL. When these very low NOAEL's are used to back calculate safe concentrations of copper, misleadingly low values can be obtained. If the NOAEL calculations were to be strictly used, then the Handy and Harman EM plant would exhibit copper toxicity at less than 1 ug/l. Since these extremely low copper values for Handy and Harman and the other four dischargers reflect silver or other toxicity, they were dropped from the calculations. Without these lower figures, the mean safe level for copper is 21 ug/l with a standard deviation of 11 ug/l.

The combined effluent toxicity data for 1984 and 1985, when reduced to safe copper concentrations, indicate that 20 to 25 ug/l copper is the average maximum level the aquatic community can withstand without experiencing mortality. For an expected calcium carbonate hardness in the Ten Mile River of 50 mg/l at low flow conditions, the national criterion for acute toxicity due to copper is 9.2 ug/l. However, during the surveys, periods of between 40 to 60 mg/l hardness, it has been shown that the Ten Mile River, with its unique chemistry, can tolerate about twice the copper level suggested by the white book. This is based on the toxicity to the daphnia, the more sensitive of the two test organisms. In order to protect the spectrum of aquatic life in the stream, the more sensitive species must be protected. This is particularly important where the sensitive species are at the bottom of the food chain.

Laboratory cultured daphnia pulex and fathead minnows were used as the test species to ascertain sensitivity of both vertebrates and inver-

TABLE 5
 "SAFE" COPPER LEVELS BASED ON 1984 AND 1985
 WHOLE EFFLUENT TOXICITY TESTS

DISCHARGER	1984			1985		
	EFF. CU mg/L	NOAEL %	NOAEL CU. ug/L	EFF. CU. mg/L	NOAEL %	NOAEL CU. ug/L
Whiting & Davis	2.0	<0.1	2	1.4	1.0	14
Handy & Harman EM	2.5	<0.1	2.5	0.14	<0.05 ^a	0.07 ^b
L.G. Balfour Plant #1	0.89	1.0	9	0.92	0.1	0.92 ^b
B&J Jewelry	---	---	---	0.36	10	36
N. Attleborough WWTP	0.08	100 ^a	80	0.011	45 ^a	5
Walton & Lonsbury	0.07	100	70	---	---	---
L.G. Balfour Plant #2	1.6	1.0	16	0.59	1.0	6
Lambert Anodizing	0.05	100	50	---	---	---
Foster Metal	1.9	---	---	0.28	10 ^a	28
Leach & Garner	0.28	5.0	14	0.16	0.05	0.08 ^c
Swank Inc	3.1	1.0	31	0.11	10 ^a	11
Robbins Company	3.5	1.0	35	0.62	0.5 ^a	3
Handy & Harman REF	---	---	---	0.55	<0.05	0.28 ^d
Attleboro WWTP	0.16	50 ^a	80	0.25	10 ^a	25
Mean			31			14
Standard deviation			28			13
Mean			25 ^e			21 ^f
Standard deviation			23 ^e			11 ^f

- a - Dechlorinated
 b - Low copper reported due to silver toxicity
 c - Low copper reported due to cyanide and silver toxicity
 d - Low copper reported due to extremely high TDS
 e - Corrected, dropping 1984 POTW data
 f - Corrected, dropping data from Handy & Harman EM, Balfour #1, Leach & Garner and Handy & Harman REF.

tebrates. The use of laboratory cultured organisms as opposed to actual resident species is considered appropriate for many reasons. According to Dr. William Brungs of EPA's Narragansett, R.I. toxicology laboratory, extensive testing has shown that the range of sensitivity of laboratory organisms represents the range found in resident species. Sensitivity of various species within a genus is very similar. While the particular daphnia pulex used in the tests did not originate in the Ten Mile River, the toxicological response of the laboratory organisms is representative of "in situ" organisms. The Massachusetts Division of Water Pollution Control, in recognition of this, specifies in their water quality standards that "sensitive" species rather than "resident" species be used to evaluate toxicity.

Arguments that resident species be used in the Ten Mile River analysis have been made based on the idea that there may have been adaptation to the metals discharged over the years. According to Dr. Charles E. Stephan of EPA's Environmental Research Laboratory in Duluth, MN it is possible for adaptation to occur but is it nearly impossible to demonstrate, particularly in organisms with rapid generation such as daphnia. Adaptation is lost more quickly than it is gained, usually within a generation of two. Further, for metal contamination, avoidance is a more common phenomenon than adaptation or genetic selection.

In addition to the scientific basis for discounting adaptation as a factor, there are a number of logistic reasons for doing so. First there is no quality control in the use of resident species. Age determination is difficult, previous stress cannot be described, sufficient numbers of organisms are hard to obtain. Substantial stress is encountered in the organism collection of wild species which imparts uncertainty in the test results. Often mortality can occur during a test due to collection and transfer that will be recorded as toxicity, skewing the results against the discharger. In order to obtain consistency between tests and to develop sufficient numbers of test animals, the resident species must be culture in the laboratory to generate organisms of common age and stress. In so doing, resistance, if any, is lost.

For the above reasons, adaptation or selection is not considered important in the decision to use laboratory organisms. However, even if the sensitive organisms at the bottom of the food chain do exhibit the ability to acclimate to high concentrations of a metal, it is not a reason to allow the higher levels. Increases over the predicted safe levels in either the water or the sediment will result in an increased body burden to not only the sensitized organism but will be passed on to the wildlife and human consumers. This is not acceptable.

The predicted toxic copper levels from effluent tests are borne out by the wealth of information used by researchers in developing the national criterion for copper. There is evidence that the presence of natural or anthropogenic substances in stream water may mitigate metal toxicity. Further it is postulated that certain forms of metal may be

more toxic than others. For instance it is believed that dissolved metal is more bioavailable and therefore more toxic than particulate metal and that with the aggregate of dissolved metal, some ionic forms are more potent than others. Dissolved copper in the plus 2 valence state is considered to be the most toxic form of copper in many cases. The toxicity test results are based on total copper. Therefore, the 20 to 25 ug/l reported as the NOAEL may actually represent the toxicity of a lower concentration of dissolved copper. This can also explain the range of results obtained from the various tests since different effluents have different ratios of copper forms.

However, the partitioning between particulate and dissolved copper and the ratios of different valence states in the effluent mixture are not permanent and not necessarily indicative of conditions to be found downstream or even at different times at the same location. Particulate metal in the effluent can be altered in the receiving water to the potentially more toxic dissolved state and vice versa. In addition, the effluent particulate metal or that dissolved fraction which becomes particulate during stream transport may settle to the stream bed where it serves as a reservoir of metal. This sediment metal can be redissolved into the overlying water or can cause stress or mortality to benthic organisms. Settling is the major if not only metal removal mechanism from the water in the Ten Mile River. The metal measured as lost from the water is that which is gained by the sediment.

Whether the effluent toxicity tests actually represent instream toxicity was examined through the use of samples of Ten Mile River water for toxicity testing. Since the effluents are diluted and altered by the river's physical and chemical characteristics and since there is a concern instream not only about mortality but about the organisms' ability to reproduce and grow, chronic toxicity tests were conducted. The chronic tests can detect the more subtle effects of impairment or toxicity which reflect the real world long term exposure of the aquatic organisms to contamination. The chronic test analyses by Nolan (1986) indicate a high correlation between effluent toxicity results and instream toxicity. Other studies have corroborated these findings. The EPA Office of Water in its "Complex Effluent Testing Program" carried out with the Office of Research and Development (ORD), examined ten sites in the country. Through the studies extensive biosurveys were conducted, instream concentration isopleths were calculated and results compared to measured effluent toxicity. The studies showed that when exposure is adequately assessed, effluent toxicity correlates directly to instream impact. Three of the reports have been printed and are available from ORD Duluth, MN: Lima, Ohio (EPA 600/2-84-080); Circleville, Ohio (EPA 600/3-85-044); and Birmingham, Alabama (EPA 600/8-85-015).

Even though the chronic tests were conducted to measure the effects on growth and reproduction, most of the tests also indicated serious instream acute toxicity even after transport, dilution and settling. This points out that the wastes are extremely potent and that the river is unable to assimilate the metals.

One important factor the chronic tests illustrated was the effect of the impoundments on water quality and toxicity. There are segments in the river where instream toxicity was diminished corresponding to the lower portions of impoundments or those reaches immediately below impoundments but upstream of discharges. Comparing toxicity information to water and sediment chemistry indicated that during quiescent flow, metal concentrations were reduced to levels as low as 5 ug/l. This was due to the settling of the particulate fraction. Examination of the sediment data showed a buildup of metals in the impoundment deposits related to the disappearance from the water column. Biological analyses of the sediment correlate the increase in sediment metal concentration to the absence of a balanced, indigenous benthic community or even in some cases to an apparently sterile environment.

Since settling results in the removal of metals from the water, arguments have been made that settling is an acceptable reason for allowing higher effluent metal concentrations. However, this removal from the water to the sediment can have serious adverse impacts. In addressing the benefits to water quality due to settling, the negative effect on sediment quality and the food chain must be considered. This is very important in the Ten Mile River because the sediments are already heavily contaminated as revealed in the sediment toxicity tests discussed in the report, Ten Mile River Sediment Microtox™ Study, D. Atkinson et. al. 1986.

In the selection of a "safe" level of discharge to the Ten Mile River, several factors have been considered:

1. National criteria for several metals.
2. Protection of the aquatic community, including the benthic community, from acute toxicity and chronic toxicity.
3. Site specific acute and chronic tests using laboratory cultured organisms.
4. Upstream, long term background copper concentration of 20 ug/l.
5. The 7-Q-10 flow was used for the basis of evaluating acute toxicity.
6. At 7-Q-10, the Ten Mile River flow is 90% effluent.
7. Metal is removed from the water column only by settling.
8. Removal from water to the sediment is not beneficial and does not constitute a form control of treatment.

In addition the following assumptions have been made:

1. Additivity, synergism and antagonism are accounted for through the use of whole effluent toxicity tests.

2. Laboratory, sensitive species accurately reflect biological impact on indigenous species.
3. Metal, regardless of its form (particulate, dissolved, etc.) in the effluent or at a particular stream point, is potentially toxic.
4. Copper is the primary toxicant and control of copper will lead to appropriate control of the other toxicants.

Integration of the above factors and assumptions resulted in a finding that the allowable level of instream copper is 20 ug/l, higher than the national criterion but no higher than the background. Although the site specific acute tests indicated for some industries that greater than 20 ug/l could be allowed in the Ten Mile River, it was also apparent that any increase above background will be reduced to background levels through settling. This reduction is accomplished by deposition to an already extremely contaminated river bottom. Since restoration of the river's uses and values require both clean water and clean sediment, this cannot be allowed.

The data collected during the surveys related to conditions experienced only in those periods. The dilution, transport, partitioning, settling, etc. were examined at discharge and streamflow conditions not necessarily representative of discharge design and critical streamflow conditions. In order to make the transition from survey to design conditions and to assess the impacts of various combinations of discharge quality and streamflow, a model was constructed. The development and use of the stream model is described in the attached report, Ten Mile River Modeling Report, E. Woo 1985.

IV. RECOMMENDED EFFLUENT LIMITATIONS

The development of effluent limitations for the dischargers in the Ten Mile River Basin, as described in Section III, was a difficult and labor intensive task. The nature of the Ten Mile River - low natural stream flow, numerous discharges with overlapping effects, multiple impoundments - made determination of permit limitations a process which can be challenged and one which will be subjected to further work for years to come. However, the Ten Mile River Program was the most intensive and far reaching study ever conducted in Massachusetts. The program evaluated the major components affecting the Ten Mile River and determined the effect upon the biological integrity of the Ten Mile River. The effluent limitations required for direct discharge to the Ten Mile River are, by necessity, very restrictive. The extreme toxicity displayed by many of the discharges justifies the need for restrictive limits and also the inclusion of a toxicity limitation. The average monthly and daily maximum limitations for each discharge permit are listed in Table 6.

In addition to the limitations listed in Table 6, the following limits apply to all dischargers:

- pH (Standard Unit) = 6.0-9.0 (Handy & Harman REF = 7.0-9.5)
- Total Toxic Organic = 2.13 ug/l maximum daily
- Oil and Grease = 15 mg/l maximum daily
- No Observed Acute Effect Level (NOAEL) \geq 90%
- Total Suspended Solids = 30 mg/l maximum daily
20 mg/l average monthly

The permits require monitoring, both chemical and biological, which will enable the dischargers and the regulatory agencies to continually evaluate the treatment performance and the reduction of metals loadings to the receiving waters and elimination of toxicity in the effluents. The permits can be modified; that is, parameters added or deleted, limitations increased or decreased, at any time. Evidence to support any change must be provided and all federal and state regulations must be followed.

Each draft NPDES permit contains a fact sheet which includes a description of the discharge; permit and administrative order limitations and conditions; a description of the method used to determine the limitation for each parameter; a discussion of a schedule of compliance; a table listing upstream clean water levels, chronic water quality criteria, acute water quality criteria and the proposed permit level.

It is also recommended that Handy & Harman EM have limitations for ammonia-nitrogen and total phosphorus due to the extremely high levels of these constituents in their wastewater. The limitations should be 1.0 mg/l monthly average and 1.5 mg/l daily maximum for both parameters.

TABLE 6

TEN MILE RIVER BASIN

METALS AND CYANIDE EFFLUENT LIMITATIONS

DISCHARGE	NPDES NUMBER	FLOW (MGD)	AVERAGE MONTHLY VALUE											
			Al (ug/l)	Cd (ug/l)	Cr (ug/l)	Cu (ug/l)	Fe (ug/l)	Pb (ug/l)	Ni (ug/l)	Ag (ug/l)	Zn (ug/l)	Cn (ug/l)	Sn (ug/l)	Cr+6 (ug/l)
Attleboro WWT	0100595	8.50	210	9	63	30	900	60	84	3	150	6.3	--	--
L.G. Balfour Plant #1	0004766	0.045	--	--	42	20	600	--	56	2	100	4.1	--	--
L.G. Balfour Plant #2	0001589	0.035	--	--	--	20	--	--	56	2	--	4.2	--	--
B&J Manufacturing	0000736	0.025	--	--	--	20	600	40	56	2	100	4.2	--	--
Cook-Horton	0003603	0.015	140	--	42	20	--	--	56	2	100	4.2	--	--
Foster Metals	0005584	0.0044	--	--	--	20	--	--	56	2	100	4.2	--	--
Handy & Harman REF	0000159	0.1	140	6	42	20	600	40	56	2	100	--	--	--
Handy & Harman EM	0002445	--	140	6	42	20	600	40	56	2	100	4.2	2000	--
Lambert Anodizing	0000027	0.001	140	--	--	20	--	--	56	--	--	--	--	--
Leach & Garner	0001058	0.03	140	--	--	20	--	40	56	2	100	--	--	--
Mt. Vernon Silver	0005045	0.004	--	--	--	20	600	40	56	2	100	--	--	--
N. Attleborough WWT	0101036	4.61	140	6	42	20	600	40	56	2	100	4.2	--	--
C. Ray Randall	0002399	0.05	--	--	--	20	600	40	56	2	100	4.2	--	--
Robbins Company	0002046	0.035	140	--	--	20	600	40	56	2	100	4.2	2000	--
Swank Inc.	0004227	0.08	140	--	--	20	--	--	56	2	--	4.2	--	--
Walton & Lonsbury	0001040	0.03	--	--	42	20	--	40	56	--	100	--	--	7
Whiting & Davis	0002401	0.04	--	--	42	20	--	--	56	2	100	4.2	--	--

TABLE 6 (CONTINUED)

TEN MILE RIVER BASIN

METALS AND CYANIDE EFFLUENT LIMITATIONS

MAXIMUM DAILY VALUE

DISCHARGE	NPDES NUMBER	FLOW (MGD)	Al (ug/l)	Cd (ug/l)	Cr (ug/l)	Cu (ug/l)	Fe (ug/l)	Pb (ug/l)	Ni (ug/l)	Ag (ug/l)	Zn (ug/l)	Cn (ug/l)	Sn (ug/l)	Cr+6 (ug/l)
Attleboro WWTP	0100595	--	210	9	1305	30	1500	60	1650	3	270	33	--	--
L.G. Balfour Plant #1	0004766	0.05	--	--	870	20	1000	--	1100	2	180	22	--	--
L.G. Balfour Plant #2	0001589	0.05	--	--	--	20	--	--	1100	2	--	22	--	--
B&J Manufacturing	0000736	0.03	--	--	--	20	1000	40	1100	2	180	22	--	--
Cook-Horton	0003603	0.02	140	--	870	20	--	--	1100	2	180	22	--	--
Foster Metals	0005584	0.0077	--	--	--	20	--	--	1100	2	180	22	--	--
Handy & Harman REF	0000159	0.13	140	6	870	20	1000	40	1100	2	180	--	--	--
Handy & Harman EM	0002445	0.25	140	6	870	20	1000	40	1100	2	180	22	3000	--
Lambert Anodizing	0000027	0.005	140	--	--	20	--	--	1100	--	--	--	--	--
Leach & Garner	0001058	0.045	140	--	--	20	--	40	1100	2	180	22	--	--
Mt. Vernon Silver	0005045	0.005	--	--	--	20	1000	40	1100	2	180	--	--	--
N. Attleborough WWTP	0101036	--	140	6	870	20	1000	40	1100	2	180	22	--	--
C. Ray Randall	0002399	0.08	--	--	--	20	1000	40	1100	2	180	22	--	--
Robbins Company	0002046	0.05	140	--	--	20	1000	40	1100	2	180	22	4000	--
Swank Inc.	0004227	0.1	140	--	--	20	--	--	1100	2	--	22	--	--
Walton & Lonsbury	0001040	0.04	--	--	870	20	--	40	1100	--	180	--	--	11
Whiting & Davis	0002401	0.05	--	--	870	20	--	--	1100	2	180	22	--	--

V. MANAGEMENT CONCEPTS

The ultimate solution to the problems of the Ten Mile River Basin will require innovative approaches and a cooperative management concept. There are several issues in addition to the issuance of the NPDES permits which should be part of the final solution. The following discussion will focus upon some of those issues.

A. Water Supply Control

The water supply systems for the communities in the Ten Mile River represent the origin of the entire wastewater cycle. The supplies contain a certain level of trace metals in the raw water and can capture additional metals in the distribution system. This is particularly true in the case of copper which is present in the raw water source and can leach out of the copper piping typically used in water distribution systems. Testing between 1983-1985 of the North Attleborough water supply has shown that total copper levels averaged 0.07 mg/l with a range of 0.00 to 0.30 mg/l for 21 tests from seven sources. The Attleboro system showed a mean level of 0.01 mg/l with a range of 0.00 to 0.07 mg/l. These copper levels are, in some cases, in exceedance of the recommended water quality criteria levels. Thus, the water being supplied to the industrial and municipal water users is above required levels before the water is used in any process and subjected to any treatment.

This situation creates a dilemma both from the philosophical and technical sides of the issue. On the one hand, the domestic water supply levels of copper are adequate for human consumption, as copper is a micro-nutrient for humans and the maximum allowable level in domestic water supply is 1.0 mg/l (1000 ug/l). On the other hand, copper is an extremely toxic metal to aquatic organisms with a recommended chronic maximum level of 0.0065 mg/l (6.5 ug/l) or 150 times less than for human consumption. For this particular parameter, the level of copper discharged to a receiving stream is much lower than that acceptable for human consumption. This is a scientific fact but one which is very difficult for many people to comprehend.

To achieve the necessary reduction of copper (and other toxic metals) discharged to the Ten Mile River, close attention must be paid to the public water supply and distribution systems. For example, adjustments in pH levels are a common practice in water treatment systems; the amount of copper leached to the distribution system can be significantly affected by the pH level. Some water supply sources may have a significantly higher background level than other sources and thus, their use should be reviewed. Control and reduction of metals levels at the water supply source should be a high priority of all communities within the Ten Mile River Basin, particularly Attleboro and North Attleborough. In order to achieve these goals, the communities should:

1. review all historical data of its water supply sources and distribution systems;

2. monitor regularly the levels of metals in all supply sources and at various points in the distribution system;
3. optimize chemical addition practices to minimize corrosion and the release of metals into the water supply system; and
4. upgrade water distribution systems so that the metal levels are reduced as much as possible.

B. Pretreatment Programs

The communities of North Attleborough and Attleboro were required by U.S. EPA and Massachusetts DWPC to develop and implement an industrial pretreatment program which would reduce pollutant loadings to the municipal wastewater treatment system. The program for North Attleborough was approved on September 30, 1985, while the Attleboro program was approved on September 24, 1984. To date, 18 significant industries are connected to the North Attleborough system, all of which are metal bearing wastewater and all of which have pre-treatment. In Attleboro, 32 metal industries discharge to sewerage systems, 26 of which have approved pretreatment. There are six industries which are on implementation to provide treatment and all industries are scheduled to be in compliance by December 1986.

The control of pollutant loadings at the source before discharge to the sewer system is a critical aspect of the overall pollution reduction program. Untreated industrial discharges can cause severe upsets at the wastewater treatment facilities by causing toxic conditions in the activated sludge systems. In addition, proper treatment of the existing discharges to the sewer systems will enhance the ability of the facilities to accept the treated wastewater from those facilities who currently discharge directly to the Ten Mile River.

The North Attleborough facility receives approximately 0.2 MGD from industrial sources which represents 5-10% of the average current flow treated and 4% of the design capacity of the facility. The nine discharges which could tie into the system would represent an increase of approximately 0.25 MGD or 12% increase in flow. The magnitude of the metals loadings can be handled by the treatment facility but should be documented and reviewed and some additional monitoring will be conducted to fully determine the loading increases.

The Attleboro receives approximately 2.5 MGD from industrial sources much of which is domestic sewage, which represents 50% of the average current flow and 30% of the design flow. The discharges currently discharging to the Ten Mile River and tributaries would represent an increase in flow of approximately 0.2 MGD.

In order to document the percentage of metal bearing industrial flow and to determine the increase in metal loadings with additional tie-ins to the facility, a cooperative program has been established between the two facilities and the DWPC to determine the actual loadings to the treatment facilities and to determine the relative loadings from all

sources. The program's first phase at the Attleboro facility has been completed and will be conducted in the spring of 1986 at the North Attleborough WWTP. This project is a very important component in the overall program.

C. Residual Waste Disposal

The removal of heavy metals from wastewaters creates a residual sludge which can have significant levels of metals and must be properly disposed. The two municipal treatment facilities in the Ten Mile River Basin accumulate large volumes of sludge from primary clarification and biological sludge from mixed liquor solids. Sludge accumulated at industrial treatment facilities are confined on site and periodically taken by a private contractor for processing. There are few facilities capable of treatment in Massachusetts, thus much of the waste sludge is transported out of state.

The North Attleborough facility currently landfills its treated sludge at the town owned landfill. This facility has a projected capacity sufficient to handle sludge disposal for approximately five to ten years. The landfill is unlined and there is no leachate collection system. There are no well fields in the vicinity of the landfill and no groundwater contamination have been attributed to this landfill. However, a long term sludge management plan needs to be developed for the treatment plant sludge as well as the rest of the communities' solid wastes. The treatment facility has attempted to make a contractual agreement with a private landfill, Laidlaw Landfill, in the town of Plainville, to allow disposal of their sludge. The treatment facility has had toxicity tests (EP Toxicity) conducted on its sludge and it has not been shown to be toxic. The Laidlaw facility has a leachate collection system which stores and transports the leachate to the North Attleborough facility for treatment. The town of Plainville Board of Public Health has denied the application for sludge disposal at the Laidlaw Landfill. This situation dictates that North Attleborough develop a feasible long-term sludge disposal plan. Possibilities include the construction of a secure landfill at a site adjacent to the treatment facility, renegotiation with the town of Plainville, combined disposal with the Attleboro facility, and inclusion in any regional solid waste facility which is constructed in the area.

The residual waste sludge from the Attleboro wastewater treatment facility is currently stockpiled at a site adjacent to the treatment facility. This practice is not environmentally sound and will be changed in the immediate future. The facility has three options for ultimate sludge disposal: (1) incineration of sludge at the facility utilizing an incinerator constructed as part of the advanced wastewater treatment facility; (2) disposal of the sludge at a secure landfill which has been constructed near the facility for disposal of residual ash from the incinerator or process sludge without incineration; and (3) sludge removal and processing for heavy metals removal by a private company.

who has made a contract with the facility. Each of these options appears to be acceptable for sludge disposal but each has not been implemented for a number of reasons. The facility must choose its desired option and proceed immediately. The residual waste sludge stockpiled on-site must be evaluated and if it is determined to be an existing or potential problem, it must be removed and properly processed.

The potential for increased heavy metal wastewaters to the two treatment facilities mandates that a sludge management program be developed for each facility.

VI. FUTURE ACTIVITIES

In order to achieve the necessary reduction in pollutant loadings to the Ten Mile River and to successfully achieve the required NPDES permit requirements, the industrial and municipal dischargers in the Ten Mile River Basin must undertake an in-depth evaluation of their wastewater and residual solid waste generation and determine their ultimate method of treatment and their final disposal options for those wastes. In addition, the state and federal regulatory agencies must develop a comprehensive program to address and correct the other factors affecting the quality and biological integrity of the Ten Mile River, particularly non-point source pollutant loadings and the residual sediment in the Ten Mile impoundments. The following discussion will address the key points of these activities, each of which must be studied in detail and become an integral component of the overall success of improving the quality of the Ten Mile River.

A. Evaluation of Waste Generation

Each discharger should review and document the source and ultimate fate of all components of their waste generation. This process should include documentation of: all raw materials used; quantity of metals and chemicals used; source and quality of water supply; production process; water recycle options; possible changes in operation to reduce or eliminate pollutant sources. This is the first major step which must be undertaken before treatment options and disposal options are considered. It is much more prudent and generally more cost-effective to reduce the quantity of wastewater which needs to be treated. It is recommended that each discharger hire a consultant to conduct this evaluation if in-house personnel do not have the proper experience.

B. Wastewater Treatment Options

In order to achieve the very stringent effluent limitations required for dischargers to the Ten Mile River, treatment systems will be required which provide greater metals removal than conventional chemical addition-precipitation systems which most dischargers currently utilize. Systems are available which can achieve the required limitations; these systems are multiple stage, utilize sophisticated technology and are quite expensive to construct and require highly trained personnel to operate. If a discharger determines that it wishes to pursue this option, it should hire a consultant to design their treatment system and provide properly trained personnel to operate the system.

In lieu of direct discharge to the Ten Mile River, the dischargers can pursue the option of connecting to the two municipal wastewater facilities in North Attleborough and Attleboro. Approval for a connection to these facilities is not automatic, as each facility has regulations concerning industrial wastewater connections to their collection system. Each facility has a pre-treatment program which regulates the

wastewater connections and has effluent requirements for each discharger. The facilities have sufficient hydraulic capacity to allow connection of all wastewater discharges but are concerned with the increased metals loadings which would occur with additional industrial connections. The Division, as discussed in Section V, has begun a program to evaluate the current loadings to the facilities and to project the loadings with all industrial discharges tied into the municipal facilities. The regulatory agencies are confident that connection to the municipal facilities is a viable option for all industrial dischargers and that this option would be the best environmental solution and the most cost-effective.

Residual sludge disposal will be a concern irregardless of the final treatment options chosen by the dischargers in the Ten Mile River Basin. Industries will generate residual wastes whether operating a highly advanced treatment system or a pre-treatment system. The disposal of these wastes must be done in a proper, environmentally acceptable, and legal manner. It is suggested that the industries in the area consider the formation of a consortium system to address sludge disposal. It might prove cost-effective to have a single approach to sludge disposal rather than individual methods for the numerous generators in the basin. This consortium could be organized through such organizations as the Chamber of Commerce or could be formed by the industries themselves. The municipal facilities, as previously mentioned, must address the residual sludge disposal options immediately.

C. Non-Point Source and Residual Sediment Programs

The problems with the quality of the Ten Mile River Basin will not be solved by only addressing and reducing the loadings from the point source dischargers in the basin. Non-point source contributions of pollutants, such as storm water runoff and groundwater inflow, can contribute pollutant loadings to the Ten Mile River. For example, loadings of lead can be significant from highway runoff, particularly interstate highways such as those which transverse the Ten Mile River Basin. The regulatory agencies will evaluate the source and magnitude of non-point source loadings to the Ten Mile River. The re-authorization of the Federal Clean Waters Act, which will be finalized by Congress in 1986, will contain authorization for a nationwide non-point source program. This program could provide the impetus and financial support to evaluate and control non-point source problems in the Ten Mile River.

The deposition and accumulation over decades of metal-laden sediment in the impoundments of the Ten Mile River has created a significant problem and a severe stress to the biological communities of the Ten Mile River. The sediment contains very high levels of metals which have reduced or even eliminated biological communities from the impoundments. This problem must be corrected as part of the overall clean-up of the Ten Mile River. The regulatory agencies must document the extent of the problem, evaluate methods to correct or eliminate

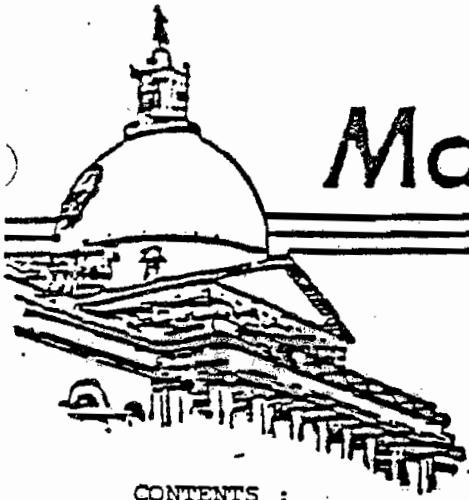
the problem and seek ways to provide financial support for the required programs. This process will be a difficult, expensive, and lengthy one but is critical to the overall success of the recovery of the Ten Mile River.

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APPENDIX 1
MASSACHUSETTS SURFACE WATER QUALITY STANDARDS

Massachusetts Register



PUBLISHED BY MICHAEL JOSEPH CONNOLLY , SECRETARY OF STATE

SUPPLEMENTAL ISSUE NO. 447 DATE 12/20/84

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314 CMR

WATER POLLUTION CONTROL

4.00

Massachusetts Surface Water Quality Standards

1

\$3.50



(A TRUE COPY ATTEST) *Health of Massachusetts*
Richard Joseph Conolly
 Secretary of State
 12/20/84 *A. J. J.*

REGULATION FILING AND PUBLICATION

1. REGULATION CHAPTER NUMBER AND HEADING: 314 CMR 4.00: MASSACHUSETTS SURFACE WATER QUALITY STANDARDS

2. NAME OF AGENCY: Division of Water Pollution Control

3. READABLE LANGUAGE SUMMARY: State the general purposes and requirements of this regulation as well as the persons, organizations and businesses affected.

The Massachusetts Division of Water Pollution Control is amending its regulations at 314 CMR 4.00, the "Massachusetts Surface Water Quality Standards." The amendments include several changes to conform the standards to revisions to 314 CMR adopted in October 1983, including changes in the definition section, clarification of certain technical criteria, and updating various references to technical standards and Federal guidance documents. Other changes include the replacement of the river basin classification maps and tables in 314CMR 4.05 with new figures and tables which better describe the drainage basins and assigned classifications, and upgrading of one river segment on the Blackstone River from Class C to Class B.

4. AGENCY CONTACT FOR ADDITIONAL INFORMATION: Mark Pare
 Address: One Winter Street, Boston, MA 02108 Telephone 292-5673

5. STATUTORY AUTHORITY: G.L. c. 21, ss. 27(5), 27(12)

The Regulations Division will complete the following 6. and 7.

6. PUBLICATION: Massachusetts Register Number SUPPLEMENTAL 447 Date 12/20/84
 Code of Massachusetts Regulation Volume 12A Page -

7. EFFECTIVE DATE: 12/20/84

8. FISCAL EFFECT STATEMENT Section 5: Estimate the fiscal effect of this regulation including that on the public and private sector, for the first and second year, and a projection over the first five-year period, or a statement of no fiscal effect: There is no fiscal effect of these amendments. These amendments will not result in the imposition of any additional restrictions to discharges to waters of the Commonwealth.

314 CMR: DIVISION OF WATER POLLUTION CONTROL

- 1) 314 CMR 4.01(5) is hereby amended by adding between the definitions of "segment" and "warm water fishery", the following new definition:

"Surface waters - all waters other than ground waters within the jurisdiction of the Commonwealth, including, without limitation, rivers, streams, lakes, ponds, springs, impoundments, estuaries, wetlands and coastal waters."

- 2) 314 CMR 4.01(5) is hereby further amended by striking from the definition of "Waters of the Commonwealth" the words "and coastal waters, but not including ground waters" and by inserting in place thereof the following words: "wetlands, coastal waters, and ground waters."
- 3) 314 CMR 4.01 is hereby further amended by striking therefrom subsections (7) and (8).
- 4) 314 CMR 4.02(1) is hereby amended by striking from the first sentence thereof the words "waters of the Commonwealth", and by inserting in place thereof the words "surface waters".
- 5) 314 CMR 4.02(3) is hereby amended by striking from the second sentence thereof the words "waters of the Commonwealth", and by inserting in place thereof the words "surface waters".
- 6) 314 CMR 4.02(4) is hereby amended by striking from the first sentence thereof the word "fourteenth", and by inserting in place thereof the word "fifteenth".
- 7) 314 CMR 4.03 is hereby amended by striking therefrom subsection (1) and by inserting in place thereof the following new subsection:

"(1) Description of Contents. 314 CMR 4.03 sets forth the Classes to be used by the Division in classifying the surface waters according to the uses for which the waters shall be enhanced, maintained and protected. For each class, the most sensitive beneficial uses are identified and minimum criteria for water quality in the water column are established. In interpreting and applying the minimum criteria in 314 CMR 4.03(4), the Division shall consider local conditions including, but not limited to:

- a) the characteristics of the biological community;
- b) temperature, weather, flow, and physical and chemical characteristics; and
- c) synergistic and antagonistic effects of combinations of pollutants."

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- 8) 314 CMR 4.03(2) is hereby amended by striking from the first sentence thereof the words "the EPA publication entitled "Quality Criteria for Water, EPA-440/9-76-023", and by inserting in place thereof the words "EPA criteria established pursuant to Section 304(a)(1) of the Federal Act".
- 9) 314 CMR 4.03(3) is hereby amended by striking from the first sentence thereof the words "waters of the Commonwealth" and by inserting in place thereof the words "surface waters".
- 10) 314 CMR 4.03(4) is hereby amended by striking from the first and second sentences thereof the words "waters of the Commonwealth" and by inserting in place thereof in both sentences the words "surface waters".
- 11) 314 CMR 4.03(4)A.7(c) is hereby amended by striking therefrom the word "resident".
- 12) 314 CMR 4.03(4)C. is hereby amended by inserting after the word "Temperature" as it appears in the criteria for classes SA, SB, and SC the word "increase".
- 13) 314 CMR 4.04(1) is hereby amended by striking therefrom the words "waters of the Commonwealth" and by inserting in place thereof the words "surface waters".
- 14) 314 CMR 4.04(5) is hereby amended by striking from the first sentence thereof the words "waters of the Commonwealth", and by inserting in place thereof the words "surface waters".
- 15) 314 CMR 4.05(2) is hereby amended by striking from the second sentence thereof the words "waters of the Commonwealth" and by inserting in place thereof the words "surface waters".
- 16) 314 CMR 4.05(4) is hereby amended by striking therefrom the second paragraph and by inserting in place thereof the following new paragraph:

"Where the Division determines that natural or irreversible conditions prevent the attainment of water quality capable of supporting a warm water fishery, a use designation of aquatic life has been made. In each segment so designated in 314 CMR 4.05(5), the criteria for a warm water fishery apply for all constituents except those affected by the natural or irreversible condition, which constituents shall be governed by the most sensitive resident species as determined by the Director in consultation with the Massachusetts Division of Fisheries and Wildlife."

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- 17) 314 CMR 4.05(5) is hereby amended by striking therefrom the first sentence, and by inserting thereof the following new sentence: , ,

"For the purpose of applying the Massachusetts Surface Water Quality Standards, the surface waters are hereby classified as shown in the following figures and tables which are a part of these regulations."

- 18) 314 CMR 4.05(5) is hereby further amended by striking therefrom the sixth and seventh sentences, and by inserting in place thereof the following:

"Segments and their classifications are shown on figures for general orientation. In cases of inconsistency between the tables and the figures, the data contained in the tables shall control."

- 19) 314 CMR 4.05(5) is hereby further amended by striking therefrom all of the classification tables and maps, and by inserting in place thereof the following new figures and tables:

314 CMR 4.00: MASSACHUSETTS SURFACE WATER QUALITY STANDARDS

Section

- 4.01: General Provisions
- 4.02: Application of Standards
- 4.03: Minimum Water Quality Criteria and Associated Uses
- 4.04: Antidegradation Provisions
- 4.05: Basin Classifications and Maps

4.01: General Provisions

(1) Title. 314 CMR 4.00 shall be known as the "Massachusetts Surface Water Quality Standards."

(2) Organization of Standards. These standards comprise five (5) units: General Provisions (314 CMR 4.01), Application of Standards (314 CMR 4.02), Water Quality Criteria (314 CMR 4.03), Antidegradation Provisions (314 CMR 4.04), and Basin Classifications and Maps (314 CMR 4.05).

(3) Authority. The Massachusetts Surface Water Quality Standards are adopted by the Division pursuant to the provisions of M.G.L. c. 21, s. 27.

(4) Purpose. The Massachusetts Act charges the Division with the duty and responsibility to enhance the quality and value of the water resources of the Commonwealth and directs the Division to take all action necessary or appropriate to secure to the Commonwealth the benefits of the Federal Act. The objective of the Federal Act is the restoration and maintenance of the chemical, physical and biological integrity of the Nation's waters. To achieve the foregoing requirements the Division has adopted the Massachusetts Water Quality Standards which designate the uses for which the various waters of the Commonwealth shall be enhanced, maintained and protected; which prescribe the water quality criteria required to sustain the designated uses; and which contain regulations necessary to achieve the designated uses and maintain existing water quality including, where appropriate, the prohibition of discharges.

(5) Definitions. As used in these standards, the following words have the following meanings:

Artificial conditions - Those conditions resulting from human alteration of the chemical, physical or biological integrity of waters.

Beneficial use - Any use not impairing the most sensitive use designated in the classification tables contained in 314 CMR 4.05; except that in no case shall the assimilation or transport of pollutants be deemed a beneficial use.

Cold water fishery - Waters whose quality is capable of sustaining a year-round population of cold water trout (salmonidae).

Division - The Massachusetts Division of Water Pollution Control, as established by M.G.L. c. 21, s. 26.

Discharge - Any addition of any pollutant to the waters of the Commonwealth.

EPA - The United States Environmental Protection Agency.

Federal Act - The Federal Water Pollution Control Act, as amended, 33 U.S.C. s. 1251, et seq.

4.01: continued

Massachusetts Act - The Massachusetts Clean Waters Act, as amended, M.G.L. c. 21, ss. 26 - 53.

Pollutant - Any element or property of sewage, agricultural, industrial or commercial waste, runoff, leachate, heated effluent, or other matter, in whatever form and whether originating at a point or major nonpoint source, which is or may be discharged, drained or otherwise introduced into any sewerage system, treatment works or waters of the Commonwealth.

Primary contact recreation - Any recreation or other water use, such as swimming and water skiing, in which there is prolonged and intimate contact with the water sufficient to constitute a health hazard.

Seasonal cold water fishery - Waters whose quality is capable of sustaining only an extremely limited cold water population on a year-round basis, with cold-water fish in these streams provided largely by stocking.

Secondary contact recreation - Any recreation or other water use in which contact with the water is either incidental or accidental, such as fishing, boating and limited contact incident to shoreline activities.

Segment - A finite portion of a water body established by the Division for the purpose of classification.

Surface waters - All waters other than ground waters within the jurisdiction of the Commonwealth, including, without limitation, rivers, streams, lakes, ponds, springs, impoundments, estuaries, wetlands, and coastal waters.

Warm water fishery - Waters whose quality is not capable of sustaining a year-round cold water or seasonal cold water fishery.

Waters of the Commonwealth - All waters within the jurisdiction of the Commonwealth, including, without limitation, rivers, streams, lakes, ponds, springs, impoundments, estuaries, wetlands, coastal waters, and ground waters.

(6) Severability. If any provision of these standards is held invalid, the remainder of these standards shall not be affected thereby.

4.02: Application of Standards

(1) Establishment of Effluent Limitations. In regulating discharges of pollutants to surface waters, the Division will limit or prohibit such discharges to insure that the water quality standards of the receiving waters will be maintained or attained. The determination by the Division of the applicable level of treatment for an individual discharger will be made in the establishment of effluent limitations in the individual discharge permits in accordance with 314 CMR 3.10(3), (4), (5) and (6). In establishing water quality based effluent limitations, the Division must consider natural background conditions, existing discharges, must protect existing downstream uses, and not interfere with the maintenance and attainment of beneficial uses in downstream waters. Toward this end, the Division may provide a reasonable margin of safety to account for any lack of knowledge concerning the relationship between the pollutants being discharged and their impact on the quality of the receiving waters.

(2) Mixing Zones. In applying these standards, the Division may recognize, where appropriate, a limited mixing zone or zone of initial dilution on a case-by-case basis. The location, size and shape of these zones shall provide for the maximum protection aquatic resources. At a minimum, mixing zones must:

4.02: continued

- (a) Meet the criteria for aesthetics;
- (b) Be limited to an area or volume that will minimize interference with the designated uses or established community of aquatic life in the segment;
- (c) Allow an appropriate zone of passage for migrating fish and other organisms; and
- (d) Not result in substances accumulating in sediments, aquatic life or food chains to exceed known or predicted safe exposure levels for the health of humans or aquatic life.

(3) Hydrologic Conditions. The Division will determine the most severe hydrologic condition at which water quality standards must be met. In classifying the inland surface waters and in applying these standards to such waters, the critical low flow condition at and above which these standards must be met is the average minimum consecutive seven day flow to be expected once in ten years, unless otherwise stated by the Division in these standards. In artificially regulated waters, the critical low flow will be established by the Division through agreement with the Federal, State or private interest controlling the flow. The minimum flow established in such agreement will become the critical low flow under 314 CMR 4.02 for those waters covered by the agreement.

(4) Procedures for Sampling and Analysis. For the purpose of collecting, preserving and analyzing samples in connection with these water quality standards, the fifteenth edition of Standard Methods for the Examination of Water and Wastewater published by the American Public Health Association, or Methods for Chemical Analysis of Water and Wastes published by the U.S. Environmental Protection Agency should be used. Where a method is not given in these publications, the latest procedures of the American Society for Testing Materials (ASTM) shall be used, or any other equivalent method approved by the Director.

4.03: Minimum Water Quality Criteria and Associated Uses

(1) Description of Contents. 314 CMR 4.03 sets forth the Classes to be used by the Division in classifying the surface waters according to the uses for which the waters shall be enhanced, maintained and protected. For each class, the most sensitive beneficial uses are identified and minimum criteria for water quality in the water column are established. In interpreting and applying the minimum criteria in 314 CMR 4.03(4), the Division shall consider local conditions including, but not limited to:

- (a) the characteristics of the biological community;
- (b) temperature, weather, flow, and physical and chemical characteristics; and
- (c) synergistic and antagonistic effects of combinations of pollutants.

(2) Coordination with Federal Criteria. The Division will use EPA criteria established pursuant to Section 304(a)(1) of the Federal Act as guidance in establishing case-by-case discharge limits for pollutants not specifically listed in these standards but included under the heading "Other Constituents" in 314 CMR 4.03(4), for identifying bioassay application factors and for interpretations of narrative criteria. Where the minimum criteria specifically listed by the Division in 314 CMR 4.03 differ from those contained in the federal criteria, the provisions of the specifically listed criteria in 314 CMR 4.03 shall apply.

(3) Classes and Designated Uses. The surface waters will be assigned to one of the classes listed below. Each class is defined by the most sensitive, and therefore governing, uses which it is intended to protect. The classes are:

4.03: continued

Classes for Inland Waters

Class A - Waters assigned to this class are designated for use as a source of public water supply.

Class B - Waters assigned to this class are designated for the uses of protection and propagation of fish, other aquatic life and wildlife; and for primary and secondary contact recreation.

Class C - Waters assigned to this class are designated for the uses of protection and propagation of fish, other aquatic life and wildlife; and for secondary contact recreation.

Classes for Coastal and Marine Waters

Class SA - Waters assigned to this class are designated for the uses of protection and propagation of fish, other aquatic life and wildlife; for primary and secondary contact recreation; and for shellfish harvesting without depuration in approved areas.

Class SB - Waters assigned to this class are designated for the uses of protection and propagation of fish, other aquatic life and wildlife; for primary and secondary contact recreation; and for shellfish harvesting with depuration (Restricted Shellfish Areas).

Class SC - Waters assigned to this class are designated for the protection and propagation of fish, other aquatic life and wildlife; and for secondary contact recreation.

(4) Minimum Criteria. The following minimum criteria are adopted and shall be applicable to all surface waters.

A. These minimum criteria are applicable to all ^{surface} waters of the Commonwealth, unless criteria specified for individual classes are more stringent.

<u>Parameter</u>	<u>Criteria</u>
1. Aesthetics	All waters shall be free from pollutants in concentrations or combinations that: (a) Settle to form objectionable deposits; (b) Float as debris, scum or other matter to form nuisances; (c) Produce objectionable odor, color, taste or turbidity; or (d) Result in the dominance of nuisance species.
2. Radioactive Substances	Shall not exceed the recommended limits of the United States Environmental Protection Agency's National Drinking Water Regulations.
3. Tainting Substances	Shall not be in concentrations or combinations that produce undesirable flavors in the edible portions of aquatic organisms.
4. Color, Turbidity, Total Suspended Solids	Shall not be in concentrations or combinations that would exceed the recommended limits on the most sensitive receiving water use.
5. Oil and Grease	The water surface shall be free from floating oils, grease and petrochemicals and any concentrations or combinations in

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4.03: continued

<u>Parameter</u>	<u>Criteria</u>
	the water column or sediments that are aesthetically objectionable or deleterious to the biota are prohibited. For oil and grease of petroleum origin the maximum allowable discharge concentration is 15 mg/l.
6. Nutrients	Shall not exceed the site-specific limits necessary to control accelerated or cultural eutrophication.
7. Other Constituents	Waters shall be free from pollutants in concentrations or combinations that <ul style="list-style-type: none"> (a) Exceed the recommended limits on the most sensitive receiving water use; (b) Injure, are toxic to, or produce adverse physiological or behavioral responses in humans or aquatic life; or (c) Exceed site-specific safe exposure levels determined by bioassay using sensitive species.

B. Inland Waters - the following additional minimum criteria are applicable to inland water classifications.

For Class A waters:

<u>Parameter</u>	<u>Criteria</u>
1. Dissolved Oxygen	Shall be a minimum of 5.0 mg/l in warm water fisheries and a minimum of 6.0 mg/l in cold water fisheries.
2. Temperature	Shall not exceed 83°F (28.3°C) in warm water fisheries or 68°F (20°C) in cold water fisheries nor shall the rise resulting from artificial origin exceed 4.0°F (2.2°C).
3. pH	As naturally occurs.
4. Total Coliform Bacteria	Shall not exceed a log mean for a set of samples of 50 per 100 ml during any monthly sampling period.
5. Turbidity	None other than of natural origin.
6. Total Dissolved Solids	Shall not exceed 500 mg/l.
7. Chlorides	Shall not exceed 250 mg/l.
8. Sulfates	Shall not exceed 250 mg/l.
9. Nitrate	Shall not exceed 10 mg/l as nitrogen.

4.03: continued

For Class B waters:

<u>Parameter</u>	<u>Criteria</u>
1. Dissolved Oxygen	Shall be a minimum of 5.0 mg/l in warm water fisheries and a minimum of 6.0 mg/l in cold water fisheries.
2. Temperature	Shall not exceed 83°F (28.3°C) in warm water fisheries or 68°F (20°C) in cold water fisheries, nor shall the rise resulting from artificial origin exceed 4.0°F (2.2°C).
3. pH	Shall be in the range of 6.5 - 8.0 standard units and not more than 0.2 units outside of the naturally occurring range.
4. Fecal Coliform Bacteria	Shall not exceed a log mean for a set of samples of 200 per 100 ml, nor shall more than 10% of the total samples exceed 400 per 100 ml during any monthly sampling period, except as provided in 314 CMR 4.02(1).

For Class C waters:

<u>Parameter</u>	<u>Criteria</u>
1. Dissolved Oxygen	Shall be a minimum of 5.0 mg/l in warm water fisheries and a minimum of 6.0 mg/l in cold water fisheries.
2. Temperature	Shall not exceed 83°F (28.3°C) in warm water fisheries or 68°F (20°C) in cold water fisheries, nor shall the rise resulting from artificial origin exceed 4.0°F (2.2°C).
3. pH	Shall be in the range of 6.5-9.0 standard units and not more than 0.2 units outside of the naturally occurring range.
4. Fecal Coliform Bacteria	Shall not exceed a log mean for a set of samples of 1000 per 100 ml, nor shall more than 10% of the total samples exceed 2,500 per 100 ml during any monthly sampling period, except as provided in 314 CMR 4.02(1).

C. Coastal and Marine Waters - the following additional minimum criteria are applicable to coastal and marine waters.

For Class SA waters:

<u>Parameter</u>	<u>Criteria</u>
1. Dissolved Oxygen	Shall be a minimum of 85 percent of saturation at water temperatures above 77°F (25°C) and shall be a minimum of 6.0 mg/l at water temperatures of 77°F (25°C) and below.

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4.03: continued

<u>Parameter</u>	<u>Criteria</u>
2. Temperature Increase	None except where the increase will not exceed the recommended limits on the most sensitive water use.
3. pH	Shall be in the range of 6.5-8.5 standard units and not more than 0.2 units outside of the naturally occurring range.
4. Total Coliform Bacteria	Shall not exceed a median value of 70 MPN per 100 ml and not more than 10% of the samples shall exceed 230 MPN per 100 ml in any monthly sampling period.

For Class SB waters:

<u>Parameter</u>	<u>Criteria</u>
1. Dissolved Oxygen	Shall be a minimum of 85 percent of saturation at water temperatures above 77°F (25°C) and shall be a minimum of 6.0 mg/l at water temperatures of 77°F (25°C) and below.
2. Temperature Increase	None except where the increase will not exceed the recommended limits on the most sensitive water use.
3. pH	Shall be in the range of 6.5-8.5 and not more than 0.2 units outside of the naturally occurring range.
4. Total Coliform Bacteria	Shall not exceed a median value of 700 MPN per 100 ml and not more than 20% of the samples shall exceed 1000 MPN per 100 ml during any monthly sampling period, except as provided in 314 CMR 4.02(1).

For Class SC waters:

<u>Parameter</u>	<u>Criteria</u>
1. Dissolved Oxygen	Shall be a minimum 85 percent of saturation at water temperatures above 77°F (25°C) and shall be a minimum of 6.0 mg/l at water temperatures of 77°F (25°C) and below.
2. Temperature Increase	None except where the increase will not exceed the recommended limits on the most sensitive water use.
3. pH	Shall be in the range of 6.5-8.5 standard units and not more than 0.2 units outside the naturally occurring range.
4. Fecal Coliform Bacteria	Shall not exceed a log mean for a set of samples of 1000 MPN per 100 ml, nor shall more than 10% of the total samples exceed 2500 MPN per 100 ml during any monthly sampling period, except as provided in 314 CMR 4.02(1).

4.04: Antidegradation Provisions

(1) Protection of Existing Uses. In all cases, from and after the date these regulations become effective, the quality of the surface waters shall be maintained and protected to sustain existing beneficial uses.

(2) Protection of High Quality Waters. From and after the date these regulations become effective, waters designated by the Division in 314 CMR 4.05(5) whose quality is or becomes consistently higher than that quality necessary to sustain the national goal uses shall be maintained at that higher level of quality unless limited degradation is authorized by the Division. Limited degradation may be allowed by the Division as a variance from this regulation as provided in 314 CMR 4.04(6).

(3) Protection of Low Flow Waters. Certain waters will be designated by the Division in 314 CMR 4.05(5) for protection under 314 CMR 4.04 due to their inability to accept pollutant discharges. New or increased discharges of pollutants to waters so designated are prohibited unless a variance is granted by the Division as provided in 314 CMR 4.04(6).

(4) National Resource Waters. Waters which constitute an outstanding national resource as determined by their outstanding recreational, ecological and/or aesthetic values shall be preserved. These waters shall be designated for preservation by the Division in 314 CMR 5.05(5). Waters so designated may not be degraded and are not subject to a variance procedure. New discharges of pollutants to such waters are prohibited. Existing discharges shall be eliminated unless the discharger is able to demonstrate that:

- (a) Alternative means of disposal are not reasonably available or feasible; and
- (b) The discharge will not affect the quality of the water as a national resource.

(5) Control of Eutrophication. The discharge of nutrients, primarily phosphorus or nitrogen, to surface waters will be limited or prohibited by the Division as necessary to prevent excessive eutrophication of such waters. There shall be no new or increased discharges of nutrients into lakes and ponds, or tributaries thereto. Existing discharges containing nutrients which encourage eutrophication or growth of weeds or algae shall be treated. Activities which may result in non-point discharges of nutrients shall be conducted in accordance with the best management practices reasonably determined by the Division to be necessary to preclude or minimize such discharges of nutrients.

(6) Variances. A variance to authorize a discharge in water designated for protection under 314 CMR 4.04(2) may be allowed by the Division where the applicant demonstrates that:

- (a) The proposed degradation will not result in water quality less than specified for the class; and
- (b) The adverse economic and social impacts specifically resulting from imposition of controls more stringent than secondary treatment to maintain the higher water quality are substantial and widespread in comparison to other economic factors and are not warranted by a comparison of the economic, social and other benefits to the public resulting from maintenance of the higher quality water. In making such evaluation, the Division will apply, where appropriate, guidance documents published by EPA.

In addition to 314 CMR 4.04(6)(a) and (b), the applicant for a variance to authorize a discharge into waters designated for protection under 314 CMR 4.04(3) must demonstrate that:

- (c) Alternative means of disposal are not reasonably available or feasible.

In any proceeding where such variance is at issue, the Division shall circulate a public notice in accordance with the procedures set

4.04: continued

forth in M.G.L. c. 30A, s. 3. Said notice shall state that a variance is under consideration by the Division, and indicate the Director's tentative determination relative thereto. To the extent feasible, the variance proceeding shall be conducted as part of any pending discharge permit proceedings pursuant to M.G.L. c. 21, s. 43. In any variance procedure, the burden of proof relative to justifying the variance shall be on the party requesting the variance. Any variance granted pursuant to this regulation shall not extend beyond the expiration date of the permit.

4.05: Basin Classifications and Maps

(1) Description of Contents. 314 CMR 4.05 sets forth the procedures and guidelines the Division must follow in classifying the waters of the Commonwealth, and the classifications themselves. The procedural rules for classifying are contained in 314 CMR 4.05(2) through 4.05(4). 314 CMR 4.05(5) contains maps and tabulations identifying the assignment by the Division of each segment to one of the classes set forth in 314 CMR 4.03(3), the designation of uses and associated criteria for that segment and the imposition of special limitations in 314 CMR 4.04(2) through 4.04(4) to that segment.

(2) Designation of Uses. In determining the appropriate classification for a particular water, the Division must fulfill its statutory mandate as set forth in 314 CMR 4.01(4). Wherever attainable, the Division shall designate the national goal uses of protection and propagation of fish, shellfish, aquatic life and wildlife and recreation in and on the waters in classifying the surface waters. In determining whether the national goal uses are attainable for a given water, the Division has considered limitations imposed by natural conditions, irreversible artificial conditions and the availability of feasible technological treatment methods and designated the optimum number of beneficial uses attainable in the circumstances.

(3) Other Applicable Standards. Waters classified by the Division in 314 CMR 4.05 may be subject to additional restrictions pursuant to Federal or Massachusetts statutes and regulations. Where such additional restrictions are known they are noted in the classifications in 314 CMR 4.05. Where these restrictions impose requirements more stringent than required under the Massachusetts or Federal Acts, e.g. public health restrictions relative to water supplies, such restrictions shall be considered and applied by the Division in classifying the waters to the extent authorized in the Massachusetts Act.

(4) Fisheries Designations. For inland waters certain specific criteria become applicable on the basis of their designation as a particular type of fishery. Therefore, inland segments are designated as cold water, seasonal cold water or warm water fisheries. In seasonal cold water fisheries criteria for cold water fisheries apply during the period of September 15 through June 30 annually, and criteria for warm water fisheries apply at all other times.

Where the Division determines that natural or irreversible conditions prevent the attainment of water quality capable of supporting a warm water fishery, a use designation of aquatic life has been made. In each segment so designated in 314 CMR 4.05(5), the criteria for a warm water fishery apply for all constituents except those affected by the natural or irreversible condition, which constituents shall be governed by the most sensitive resident species as determined by the Director in consultation with the Massachusetts Division of Fisheries and Wildlife.

(5) Classifications. For the purpose of applying the Massachusetts Surface Water Quality Standards, the surface waters are hereby classified as shown in the following figures and tables which are a part of

4.05: continued

these regulations. Columns 1 and 2 of the tables describes the segment. Column 3 identifies the applicable classification of the segment. Column 4 identifies the use or uses for which the segment is designated; (P&S) means primary and secondary contact recreation, (Sn) means seasonal fishery, (O) means open shellfishing, (R) means restricted shellfishing. Column 5 identifies the applicable provisions of 314 CMR 4.04 and 314 CMR 4.05(3).

Segments and their classifications are shown on figures for general orientation. In cases of inconsistency between the tables and the figures, the data contained in the table shall control.

APPENDIX 2
INDUSTRIAL WASTE INSPECTION CHECKLIST

SECTION A - GENERAL INFORMATION

existing discharge

proposed discharge

1. Business Name of Applicant: _____
2. Mailing Address: _____
_____ Zip Code: _____
3. Facility Address (if different than mailing address): _____
_____ Zip Code: _____
4. Person to whom permit should be mailed. Name: _____ Title: _____
5. Person to contact concerning information provided herein. Name: _____
Title: _____ Telephone No.: () _____

SECTION B. - PRODUCT OR SERVICE INFORMATION

1. Indicate principal products manufactured and/or services rendered:

Industry Name: _____

Section B - Product/Service Information (Cont'd)

3. List raw materials.

Include all liquids which are used or stored in bulk or in containers which have a capacity of greater than 5 gallons:

<u>Raw Material</u>	<u>Quantity Used Per Year</u>	<u>Raw Material</u>	<u>Quantity Used Per Year</u>
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____

SECTION C. - PLANT OPERATIONAL CHARACTERISTICS

- Shift information: (a) number of shifts per work day: 1 2 3
(b) work days per week: 4 5 6 7
(c) average number of employees per shift: 1st _____ 2nd _____ 3rd _____
(d) shift start times: 1st _____ 2nd _____ 3rd _____
- Is operation subject to seasonal variation: yes no
(a) If yes, indicate months of peak operation: _____
- Does operation shut down for vacation, maintenance, or other reasons? yes no
(a) If yes, indicate period when shutdown occurs: _____
- Are major processes: batch continuous
(a) Average number of batches per work day: _____
- Is a Spill Prevention Control and Countermeasure Plan prepared for the facility? yes no

SECTION D. - WATER CONSUMPTION

- Check all that apply: MDC City/Town Private Well Surface Water
 Private Contract Other (specify): _____

Industry Name: _____

Section D - Water Consumption (Cont'd)

2. List past twelve months water consumption from water bills:

(a) 1st 6 month period, 19____: _____

(b) 2nd 6 month period, 19____: _____

Units are in: gpd 100 cf cf other (specify): _____

(c) Volume from other sources: _____ (list units)

SECTION E. - Storm Drain and Outfall Connection Information

1. List plant drain connections (assign a sequential connection number to each connection starting with No. 1). If more than 3, attach additional connection information on another sheet of 8 1/2 x 11 paper):

<u>Connection Number</u>	<u>Drain Size</u> (inches)	<u>Descriptive Location of Connection or Discharge Point</u>	<u>Average Flow</u> (gpd)
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____

2. Attach a scaled drawing of the industrial complex, if available, showing location of ^{connections} referenced in E-1. Show location of possible sampling points for process effluents. For reference and field orientation, buildings, streets, alleys, and other pertinent physical structures should be included.

Industry Name: _____

SECTION F. - WASTEWATER INFORMATION

1. Quantities in the table below may be expressed in the following units: check the units you will use and complete the table below:

- gallons per day cubic feet per day per cent of total daily usage

Usage Type	Quantity	Pretreatment		Connection Number*				Discharge Location		Other (Specify)
		Yes	No	1	2	3	Other	Sanitary/Combined Sewer	No Discharge	
Sanitary (domestic)	_____	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	_____	<input type="checkbox"/>	<input type="checkbox"/>	_____
Process	_____	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	_____	<input type="checkbox"/>	<input type="checkbox"/>	_____
Cooling Water/ Uncontaminated Water	_____	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	_____	<input type="checkbox"/>	<input type="checkbox"/>	_____
Boiler	_____	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	_____	<input type="checkbox"/>	<input type="checkbox"/>	_____
In Product	_____	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	_____	<input type="checkbox"/>	<input type="checkbox"/>	_____
Other (specify): _____	_____	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	_____	<input type="checkbox"/>	<input type="checkbox"/>	_____

2. Seasonal, batch, and intermittent discharges. Check applicable boxes.

Type	Frequency (check one)				Quantity per Discharge (include units)	Pretreatment		Discharge to Connection Number*			
	Daily	Weekly	Monthly	Yearly		Yes	No	1	2	3	Other
Boiler Blowdown	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	_____	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	_____
Cooling System Blowdown	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	_____	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	_____
Plant Washdown	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	_____	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	_____
Equipment Washdown	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	_____	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	_____
Spent Chemical Solutions	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	_____	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	_____
Backwash	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	_____	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	_____
Other (specify): _____	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	_____	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	_____

*Box numbers 1, 2, 3 correspond to connection numbers in Section E above. If more than 3 drain or outfall connections, enter the proper connection number in "other" column.

Industry Name: _____

SECTION H. - NON-DISCHARGED WASTES

1. Are any waste liquids or sludges removed from facility site? Yes No

If "yes", these may best be described and quantified as:

Type	Estimated Gallons/Year
<input type="checkbox"/> Waste Solvent	_____
<input type="checkbox"/> Waste Product	_____
<input type="checkbox"/> Oil	_____
<input type="checkbox"/> Grease	_____
<input type="checkbox"/> Pretreatment Sludge	_____
<input type="checkbox"/> Inks/Dyes	_____
<input type="checkbox"/> Thinner	_____
<input type="checkbox"/> Paints	_____
<input type="checkbox"/> Acids and Alkalies	_____
<input type="checkbox"/> Plating Wastes	_____
<input type="checkbox"/> Pesticides	_____
<input type="checkbox"/> Other (specify): _____	_____
_____	_____
_____	_____

2. Does your company remove the above wastes from the facility? Yes No

If no, state the name(s) and address(es) of all waste haulers.

a. _____

_____ Zip Code: _____
Permit No. (if applicable) _____

b. _____

_____ Zip Code: _____
Permit No. (if applicable) _____

3. Are any sludges, liquids, etc. placed with trash for disposal? Yes No

Describe: _____

Industry Name: _____

SECTION I. - CHARACTERISTICS OF DISCHARGES

1. If any wastewater analyses have been performed on the wastewater discharges from your facilities attach a copy of the most recent data to this application. Be sure to include the date of the analysis, name of laboratory performing the analysis and location(s) from which sample(s) were taken (attach sketches, plans, etc. as necessary).
2. Please indicate by placing an "X" in the appropriate box by each listed chemical whether it is "Suspected to be Present", or "Known to be Present" in your manufacturing or service activity or generated as a byproduct. Some compounds are known by other names.

ITEM NO.	CHEMICAL COMPOUND	SUSPECTED PRESENT	KNOWN PRESENT
1.	ammonia		
2.	asbestos (fibrous)		
3.	cyanide (total)		
4.	antimony (total)		
5.	arsenic (total)		
6.	barium (total)		
7.	cadmium (total)		
8.	chromium (total)		
9.	copper (total)		
10.	lead (total)		
11.	mercury (total)		
12.	nickel (total)		
13.	selenium (total)		
14.	silver (total)		
15.	thallium (total)		
16.	zinc (total)		
17.	acenaphthene		
18.	acenaphthylene		
19.	acrolein		
20.	acrylonitrile		
21.	aldrin		
22.	anthracene		
23.	benzene		
24.	benzidine		
25.	benzo (a) anthracene		
26.	benzo (a) pyrene		
27.	benzo (b) fluoranthene		
28.	benzo (g,h,i) perylene		
29.	benzo (k) fluoranthene		
30.	α-BHC (alpha)		
31.	β-BHC (beta)		
32.	δ-BHC (delta)		
33.	γ-BHC* (gamma)		
34.	bis (2-chloroethyl) ether		
35.	bis (2-chloroethoxy) methane		
36.	bis (2-chloroisopropyl) ether		
37.	bis (chloromethyl) ether		

ITEM NO.	CHEMICAL COMPOUND	SUSPECTED PRESENT	KNOWN PRESENT
38.	bis (2-ethylhexyl) phthalate		
39.	bromodichloromethane		
40.	bromoform		
41.	bromomethane		
42.	4-bromophenylphenyl ether		
43.	butylbenzyl phthalate		
44.	carbon tetrachloride		
45.	chlordane		
46.	4-chloro-3-methylphenol		
47.	chlorobenzene		
48.	chloroethane		
49.	2-chloroethylvinyl ether		
50.	chloroform		
51.	chloromethane		
52.	2-chloronaphthalene		
53.	2-chlorophenol		
54.	4-chlorophenylphenyl ether		
55.	chrysene		
56.	4,4' - DDD		
57.	4,4' - DDE		
58.	4,4' - DDT		
59.	dibenzo (a,n) anthracene		
60.	dibromochloromethane		
61.	1,2-dichlorobenzene		
62.	1,3-dichlorobenzene		
63.	1,4-dichlorobenzene		
64.	3,3'-dichlorobenzidine		
65.	dichlorodifluoromethane		
66.	1,1-dichloroethane		
67.	1,2-dichloroethane		
68.	1,1-dichloroethene		
69.	trans-1,2-dichloroethene		
70.	2,4-dichlorophenol		
71.	1,2-dichloropropane		
72.	(cis & trans) 1,3-dichloropropane		
73.	dieldrin		
74.	diethyl phthalate		
75.	2,4-dimethylphenol		

APPENDIX 3
INDUSTRIAL WASTEWATER SURVEY SUMMARY

INDUSTRIAL WASTE INVESTIGATIONS

Importance

Field investigation of existing industrial dischargers to the Ten Mile River was considered necessary for several reasons. It was assumed that the four-year old NPDES industry list needed updating, due to industry openings and closings and with the expansion of the sewerage system. By inspecting with staff members from the DWPC Compliance and Monitoring Section, industries that required monitoring, as well as sampling points, could be determined efficiently. It was also considered important to characterize current discharges for the benefit of monitoring efforts and later analyses. As a bonus, the face-to-face contact with the business community allowed for a full explanation of what the state intended to do, allayed fears and hopefully generated an increased awareness of the river's health.

Methodology

A list of existing and former NPDES permits was obtained. This list was screened by telephoning each industry and explaining our intended program. Appointments were made to visit or a note was made explaining why a NPDES permit was not needed. Two or three inspections per day were planned, the first at 9:00 and the second at 1:30. If it was thought the first inspection would be quick, two inspections were planned for the morning.

Two staff members, one from the Basin Planning Section and the other from the Compliance and Monitoring Section, conducted the surveys. At times a third or fourth member accompanied as observers. Inspections were conducted by first interviewing the industry contact (president, plant manager, et.). At this time the program was explained and the type of information we were looking for outlined. The Industrial Waste Inspection checklist was filled out as far as possible and a copy left for later completion. A tour of the facility was then performed. Special emphasis was placed on the treatment system, outfall pipe location and sampling point location.

The next step was to interview town officials to confirm recent industrial hookups to the sewerage system and to possibly discover new dischargers to the river. Additional sites were visited as necessary.

Results

Many of the existing industries and virtually all of the new industries in the area now discharge to their towns' sewerage system. Two new industries now occupy the building of a former NPDES permit holder and discharge non-contact cooling water.

The Attleboro Industrial Pretreatment Program became official in April 1984. Town officials were most cooperative and informative. The North Attleborough Industrial Pretreatment Program, however, was in development at the time of inspection. Records were either incomplete or unavailable. Both cities are old with antiquated storm drains and sewer systems. Many pipes discharge to the river and records are either out of date or do not exist. Accordingly, heavy reliance was placed on city officials' judgement on whether an industry discharged to the sewer system or storm drain. Table 1 summarizes the results of the surveys. The individual Industrial Waste Inspection checklists are included as well.

Septage is received at both wastewater treatment facilities. It was observed that only minimal information is collected, such as frequency and volume. The potential exists for illegal discharge of hazardous waste.

Recommendations

Inspection teams should be limited to no more than three people, two optimum. The greater the crowd, the less efficient the inspection. Limited information was available regarding chemicals on site. With the recent implementation of the Right To Know law, future inspectors should obtain a complete list easily.

TABLE 1

TEN MILE RIVER BASIN

1984 SURVEY

INDUSTRIAL WASTE SUMMARY

NAME	VOLUME DISCHARGED (GPD)	TYPE WASTE	COMMENTS
Handy and Harman N. Attleborough MA0002445	85,000-200,000	Plating waste	
Attcum Properties Attleboro MA0022381	100,000	Cooling water	
B&J Jewelry N. Attleborough MA0000736	15,000-20,000	Plating waste	
Bristol Nursing Home Attleboro MA0023426	5,000	Domestic	
C. Ray Randall Mfg. N. Attleborough MA0002399	65,000	Plating	
Craft Inc. Attleboro MA0002364	5,600	Cooling water	
Crown Yarn Dye Co. Inc. Attleboro MA0002283	300,000	Cooling water	No discharge at time of inspection

INDUSTRIAL WASTE SUMMARY (CONTINUED)

NAME	VOLUME DISCHARGED (GPD)	TYPE WASTE	COMMENTS
Cumberland Engineering Co., Inc. MA0000311	-	-	
Cook-Horton Co. N. Attleborough MA0003603	15,000	Plating	
Englehand Industries Div. Plainville MA0026905	-	-	Sewered only
Fortifiber Corp. Attleboro MA0003701	5,000	Cooling water	Inadequate sampling points Apparent lubricating oil discharge
Foster Metals Products Attleboro MA0005584	2,000	Plating	
H.F. Barrows N. Attleborough MA0002062	-	-	Sewered only
Handy and Harman Attleboro MA0000159	18,000	Plating	Batch discharge 7 times per month
L.S. Peterson N. Attleboro MA0002461	2,000	Plating	Batch discharge every month

INDUSTRIAL WASTE SUMMARY (CONTINUED)

NAME	VOLUME DISCHARGED (GPD)	TYPE WASTE	COMMENTS
L.G. Balfour Co. Inc. Attleboro MA0004766	75,000	Plating	
L.G. Balfour Co. Inc. N. Attleborough MA0001589	22,000	Plating	
Lambert Anodizing Co., Inc. Attleboro MA0000027	500	Anodizing	
Leach & Garner Co. Attleboro MA0001058	7,000-10,000	Plating	
Leavens Mfg. Co. Attleboro MA0005363	-	-	Sewered as of November 1984
Mt. Vernon Silver Co. Attleboro MA0005045	1,500	Plating	
N. Attleboro Taps Inc. N. Attleborough MA0025623	600	Plating	Batch discharge every three months
Plainville Stock Co. Plainville MA0005207	-	-	Sewered only

INDUSTRIAL WASTE SUMMARY (CONTINUED)

NAME	VOLUME DISCHARGED (GPD)	TYPE WASTE	COMMENTS
RJM Chemicals Inc. Attleboro MA0005703	-	-	Out of business
Robbins Co. Attleboro MA0002046	30,000	Plating	
Swank Inc. Attleboro MA0004227	65,000	Plating	
Texas Instruments Inc. Attleboro MA0001791	200,000	Non-contact cooling water, storm runoff	
Walton & Lonsbury Attleboro MA0001040	22,000	Cooling water and plating	
Whiting & Davis Plainville MA0002402	34,000	Plating	
A&J Tool & Findings Plainville	-	Domestic	Cesspool. Pipe to river still in place
R.Alviti Plating Co. Attleboro	-	Plating	Sewered only
V.H. Blackington & Co., Inc. N. Attleborough	-	-	Sewered only

INDUSTRIAL WASTE SUMMARY (CONTINUED)

NAME	VOLUME DISCHARGED (GPD)	TYPE WASTE	COMMENTS
Dodgeville Corp. Attleboro	-	-	Out of business
Hilsinger Corp. Plainville	21,000	Anodizing	
Kilmartin Tool Co. Attleboro	-	-	Sewered only
Mantrorse-Haeuser Co. Attleboro	200,000	Cooling water	
U.S. Fish & Wildlife N. Attleborough	?	Nutrients	Located in stream
Reeves Co. Attleboro	-	-	Sewered only
W.H. Riley N. Attleborough	-	Oil seperator over- flow	
Teknor-Apex Attleboro	-	-	Sewered only
Dante Inc. Attleboro	-	-	Out of business
Krew Inc. Attleboro	-	-	Sewered only
Ripley & Gowen Attleboro	-	-	Sewered only

INDUSTRIAL WASTE SUMMARY (CONTINUED)

NAME	VOLUME DISCHARGED (GPD)	TYPE WASTE	COMMENTS
Attleboro Dyeing & Finishing Seekonk	-	-	Out of business
Hampshire Lead Crystal Dighton	-	-	
Tardif Plastics Seekonk	30,000	Cooling water	NPDES required
Thergen Inc. Seekonk	4,500	Cooling Water	NPDES required

APPENDIX 4
STANDARD OPERATING PROCEDURES

DEQE/DWPC

STANDARD OPERATING PROCEDURE

I. INTRODUCTION

Obtaining representative samples and then maintaining the integrity of the constituents is an integral part of any monitoring or enforcement program. Standardization of the analytical techniques has been well established, but the result of analysis is only as good as the sampling and the sample preservation. The purpose of this reference manual is to document the standard operating procedure employed by the Technical Services Branch of the Division of Water Pollution Control in all phases of field sampling, monitoring, and analyses of water and wastewater.

The references cited in this manual present the most effective and current laboratory and field practices for specific applications. The procedures and techniques described are by no means the only methods available, but are rather those which are to be followed in any and all water quality investigations conducted by personnel of the Technical Services Branch. For those occasions in which specific techniques are required which may be unique to a particular type of sampling for which accepted methods do not appear in the literature, a brief narrative or outline is presented. These procedures have been developed by Division personnel who have had extensive sampling experience in these specific situations.

The sampling technique to be employed is determined by the type of water or wastewater to be sampled. For the activities of the Technical Services Branch the following areas are addressed in this manual:

1. Stream Sampling
2. Ground Water Sampling
3. Biological Sampling
4. Lake Sampling
5. Industrial and Municipal Wastewater Sampling

II. STREAM SAMPLING - INTRODUCTION

Streams are sampled to determine the effects of wastewaters that are discharged to them and how to best protect them against those effects so that they remain useful for other purposes such as water supply, irrigation, swimming, boating, and fish and wildlife propagation.

Most water quality studies fall into one of two general categories. One is designed to determine water quality at a single point or at isolated points. This involves one or more unrelated sampling stations on a stream system. Sampling may be occasional--perhaps at weekly, monthly, or even quarterly intervals. These are commonly referred to as "mini-surveys." Laboratory analyses may range from coliform bacteria only, to a rather complete series of mineral, sanitary, chemical bacteriological and biological analyses where baseline water quality is being determined.

The other category of stream studies is designed to determine changing water quality throughout a reach as the water travels downstream. This category is referred to as "intensive water quality sampling." This involves a series of related sampling stations, selected to reflect both instantaneous changes in water quality as waste discharges or major tributaries enter, and the slower changes that result from natural purification. Samples may be collected at frequent intervals, usually four (4) or six (6) times a day, for a limited period, usually three (3) consecutive days. Laboratory determinations are those that reflect changes in constituents that result from natural purification and those that reveal effects of constituents of wastewater discharged to the reach.

A. Water Quality

1. General Introduction

The importance of a good water quality sampling program cannot be over-emphasized. The heart of the sampling program is field operations. If proper precautions and care are not exercised in the field procedures, the entire sampling program will become meaningless despite adequate planning, analytical facilities, and personnel. The key to the success of a water quality field sampling program lies in proper planning, collection of representative samples, proper handling and preservation of samples, and appropriate chain of custody procedures.

a. Objectives -

There are four major reasons for a sampling and analyses program: planning, research or design, process control, and regulation. These objectives in an overall water quality program are interrelated and cover different stages from planning to enforcement. Since the objectives of a program directly affect sampling and laboratory analyses, specifying the objectives is the first step in planning a sampling program. A water quality program monitors to:

1. Establish representative baseline water quality conditions;
2. Determine assimilative capacities of waterbodies;
3. Follow effects of a particular project or activity;
4. Identify pollutant source(s);
5. Assess long term trends;

6. Allocate waste load(s); or
7. Project future water quality.

These examples of possible objectives reflect the wide range of operations that may be involved in water quality studies. They emphasize the necessity of a clear definition of objectives for a particular study. The objectives should be put in writing for several reasons. The act of putting them on paper requires careful consideration of what the objectives actually should be. The written work is far less apt to be misunderstood by those involved in the operations than is a verbal statement. The written objectives should define not only the purposes of the study but also the limits, and thus should discourage the pursuit of interesting but nonessential bypaths. They fix the responsibility of those charged with supervision of the study. They provide a basis of judging the extent to which the results of the study meet the needs that justified the undertaking.

Further discussion of water quality objectives can be found in the following references:

Handbook for Sampling and Sample Preservation of Water and Wastewater.
Environmental Monitoring and Support Laboratory, Office of Research and Development, United States Environmental Protection Agency. Cincinnati, Ohio. EPA-600/4-82-029. April 1982.
p 2, sec. 2.1; p 37, sec. 2.6.1; p 195, sec. 8.2

National Handbook of Recommended Methods for Water Data Acquisition.
Office of Water Data Coordination, United States Geological Survey. Reston, Virginia. January 1982.
sec. 5B-2-b-1, p 5-9

A Practical Guide to Water Quality Studies of Streams. F.W. Kittrell, United States Department of the Interior, Federal Water Pollution Control Administration. Cincinnati, Ohio. 1969.
p 3, 4

b. Personnel Requirements -

1. Obviously the number of personnel required for any particular water quality survey depends largely on the scope of the survey. However, general guidelines apply to almost any survey. Every water quality sampling crew should consist of a minimum of two (2) people. This applies to flow crews also. The potential hazards encountered in both situations does not make it worth sending out one individual, particularly on night sampling runs.
2. In some cases, the scope of the survey will depend largely on the personnel available. Therefore, it is in the best interest of the coordinator to maximize the efficiency of the personnel available but without sacrificing the safety of those in the field.
3. Additional references to personnel requirements in water quality studies can be found in:

Handbook for Sampling and Sample Preservation of Water and Waste-water.

Environmental Monitoring and Support Laboratory, Office of Research and Development, United States Environmental Protection Agency. Cincinnati, Ohio. EPA-600/4-82-029. April 1982. p 357, sec. 16.3

National Handbook of Recommended Methods for Water Data Acquisition. Office of Water Data Coordination, United States Geological Survey. Reston, Virginia. January 1982. sec. 5-B-2, p 5-10

Procedures for Handling and Chemical Analysis of Sediment and Water Samples. Russell H. Plumb, Jr., Environmental Laboratory, United States Army Engineer Waterways Experiment Station. Vicksburg, Mississippi. Technical Report EPA/CE-81-1. May 1981. sec. 1, pp 1-25

c. Survey Logistics -

1. Consideration of the reasons for the proposed stream water quality study and the budget, personnel, and facilities available to carry it out constitute the first step in planning a study. The first activity of the survey coordinator should be the collection and review of all readily available information on the stream. Data concerning sources of pollution, water uses and stream characteristics and water quality are needed to serve as a basis for a preliminary plan. This plan should include the number of sampling locations, number of samples to be collected, analytical determinations to be made, and distances to be traveled, these criteria should be based on such considerations as the locations of water uses, locations of wastewater discharges, and marked changes in stream characteristics, such as impoundments or rapids.
2. To complete the preliminary survey plan, the coordinator should conduct a field reconnaissance of the area. Ideally, he should be accompanied by persons with expertise in specific areas of the general water quality study, such as a biologist or industrial waste engineer. Their input may have an important influence on the final comprehensive survey plan, such as eliminating sampling locations that may provide data of minimal value or adding locations of significant importance that may have been previously overlooked.
3. The survey coordinator should become thoroughly familiar with characteristics of the water body. A trip throughout the study area by boat, if the waterbody is deep enough, provides the best opportunity for observation. Access to the water body may be limited to bridges and roads that parallel the stream if a boat cannot be used. An overall view of the water body may be obtained from a plane or helicopter, but observation of detail from the height involved is limited.
4. Detailed notes of observations should be made promptly, for memory alone is not dependable. Notes should include general impressions of

depths, currents, velocities, bends, widths, types of bottom, water uses, waste discharges and mixing of wastes, availability of access, and sensory evidences of pollution, such as excessive plankton or attached growth, floating materials, oil, color, suspended matter, sludge deposits, gas bubbles and odor. Special attention should be paid to tentative sampling stations selected in the preliminary planning. Accessibility of stations, as well as suitability for sampling, must be considered. Stations should be marked or otherwise identified to ensure sample collection at the proper points. For example, the sampling station number may be painted on bridges, with arrows indicating the sampling points.

5. A dry run of the sampling route or routes should be made and timed. This information will be needed in estimating the number of sample collectors that will be necessary. The routes should be marked on a map, and notes made of any check points that will assist in following the route. At least one member of each sampling crew should be present on a dry run.
6. Laboratory analyses are usually performed at the facilities located at the Westborough office building and at the Lawrence Experiment Station. However, facilities may be established in the laboratory of a local wastewater treatment plant, high school, university, or industrial plant as a substitute for a mobile laboratory. The survey coordinator should review such local facilities to determine their adequacy and what additional equipment and supplies will be needed. Sources of needed supplies should be located. Supplies may include ice, distilled water, hardware, and laboratory reagents and minor equipment. Availability of repair services, such as automotive, out-board motor, electrical and plumbing should be determined.
7. Coordination with other state agencies and local organizations such as universities, conservation clubs, etc. may be useful in providing additional personnel for sampling, boat operation, or transporting samples to the laboratory. Such assistance may be particularly valuable on surveys conducted away from the office.
8. Convenient living quarters and eating places reasonably near the survey area should be located as far in advance of the survey period as possible. Billing arrangements should also be explained and agreed upon as far in advance as possible. Special rates may be available for a sizable field crew.
9. All personnel who will be involved in the study should be assembled for a briefing on the study plan. This may include laboratory personnel who will be assigned to analyze samples for stable constituents or those that can be preserved satisfactorily. In addition, experienced personnel not assigned to the study may attend the briefing to offer constructive comments on the plan of study.
10. At the briefing session definite assignments of responsibilities to specific individuals for various phases of the operation should be made. Copies of the study plan, provided to all personnel, should be discussed both in terms of the entire operation and of individual

responsibilities so there can be no misunderstanding and no oversight of pertinent items.

11. Arrangements for communication with all individuals should be established. Telephone numbers at which individuals can be reached day or night should be listed at a central location, such as the laboratory. Those who travel around the area should leave information on their plans, including points where they can be reached. It may be advantageous for key personnel to call in from time to time. Inability to locate a key individual at times may seriously disrupt the study, or even bring portions of it to a halt until he/she can be found.
12. More material concerning water quality survey logistics can be found in the references listed below:

National Handbook of Recommended Methods for Water Data Acquisition.
Office of Water Data Coordination, United States Geological Survey.
Reston, Virginia. January 1982.
p 30, sec. 2.5

A Practical Guide to Water Quality Studies of Streams. F.W. Kittrell,
United States Department of the Interior, Federal Water Pollution
Control Administration. Cincinnati, Ohio. 1969.
p 39, 110-121

d. Safety Considerations -

Standardized safety precautions should be used at all times during a water quality survey. The general concepts of safety to be used during a water quality survey can be found in:

Microbiological Methods for Monitoring the Environment. United
States Environmental Protection Agency. Washington, D.C.
EPA-600/8-78-017. 1978.
Part V, sec. C-3, p 263; sec. 3.3, p 264; sec. 4.1, p 265;
sec. 4.2, p 266

2. Frequency of Sampling

The frequency of sampling is often determined by the type of sampling program. For example, if daily trends in water quality are to be analyzed, hourly samples may be called for. However, time, personnel, and laboratory constraints usually limit such frequent sampling to very site specific situations. Generally, the frequency of sample collection is determined by the specific needs of the water quality survey. Intensive surveys may require sampling at four to six hour intervals for several days whereas background surveys may need only one sample. Further discussion of the frequency of sampling can be found in:

Handbook for Sampling and Sample Preservation of Water and Wastewater.
Environmental Monitoring and Support Laboratory, Office of
Research and Development, United States Environmental Protection
Agency. Cincinnati, Ohio. EPA-600/4-82-029. April 1982.
p 144, sec. 4.3; pp 339-340

National Handbook of Recommended Methods for Water Data Acquisition.
Office of Water Data Coordination, United States Geological Survey.
Reston, Virginia. January 1982.
sec. 5-B-3, p 5-11

3. Methodology of Sampling

Samples can be collected manually or with automatic samplers. Whichever technique is adopted, the success of the sampling program is directly related to the care exercised in the sample collection. Optimum performance will be obtained using trained personnel. The type of sample collected depends on the variability of flow, variability of water or wastewater quality, the accuracy required and the availability of funds for carrying out the sampling and analytical programs. Additional general considerations can be found in the following references:

Handbook for Sampling and Sample Preservation of Water and Wastewater.
Environmental Monitoring and Support Laboratory, Office of Research and Development, United States Environmental Protection Agency.
Cincinnati, Ohio. EPA-600/4-82-029. April 1982.
p 6, sec. 2.3; p 141, sec. 4.2; pp 326-333; p 177, sec. 5.8;
p 292, sec. 12.1; p 186, sec. 6-8; pp 206-207

National Handbook of Recommended Methods for Water Data Acquisition.
Office of Water Data Coordination, United States Geological Survey.
Reston, Virginia. January 1982.
sec. 5-B-4, p 5-11, 5-14; pp 3.35-3.40

Procedures for Handling and Chemical Analysis of Sediment and Water Samples. Russell H. Plumb, Jr., Environmental Laboratory, United States Army Engineer Waterways Experiment Station. Vicksburg, Mississippi. Technical Report EPA/CE-81-1. May 1981.
pp 2.2-2.4

a. Sample Site Location -

Usually, the sampling program objectives define the approximate locations for sampling (e.g., effluent to a wastewater treatment plant). Often, however, the sampling program objectives give only a general indication (e.g., the effect of a surface runoff on water quality). Since water quality varies from place to place in most water systems, locations appropriate to the information needs of a particular program must be selected. The selection of the sampling locations must consider:

1. Homogeneity of water or wastewater:
 - a. At significant outlets and inputs of lakes, impoundments, estuaries or coastal areas that exhibit eutrophic characteristics.
 - b. At locations upstream and downstream of major population and/or industrial centers which have significant discharges into a flowing stream.
 - c. Upstream and downstream of representative land use areas and morphologic zones.

- d. From several locations to obtain the required information.
2. General characteristics of water or wastewater:
 - a. At representative sites in mainstream of rivers, estuaries, coastal areas, lakes or impoundments.
 - b. In major water use areas, such as public water supply intakes, commercial fishing areas and recreational areas.

The following references contain additional discussion of the location of sample sites on water quality surveys:

Handbook for Sampling and Sample Preservation of Water and Wastewater. Environmental Monitoring and Support Laboratory, Office of Research and Development, United States Environmental Protection Agency. Cincinnati, Ohio. EPA-600/4-82-029. April 1982.
p 4, sec. 2.2; p 195, sec. 8.4

National Handbook of Recommended Methods for Water Data Acquisition. Office of Water Data Coordination, United States Geological Survey. Reston, Virginia. January 1982.
sec. 5-8, p 5-8

Procedures for Handling and Chemical Analysis of Sediment and Water Samples. Russell H. Plumb, Jr., Environmental Laboratory, United States Army Engineer Waterways Experiment Station. Vicksburg, Mississippi, Technical Report. EPA/CE-81-1. May 1981.
sec. 2, 8-2, p 5-8, p 4, p 11

A Practical Guide to Water Quality Studies of Streams. F.W. Kittrell, United States Department of the Interior, Federal Water Pollution Administration. Cincinnati, Ohio. 1969.
p 20

Handbook for Analytical Quality Control in Water and Wastewater Laboratories. Environmental Monitoring and Support Laboratory, United States Environmental Protection Agency, Cincinnati, Ohio. EPA-600/4-79-019. March 1979.
p 10.3

b. Types of samples -

1. Grab sample

A grab sample is defined as an individual discrete sample collected over a period of time not exceeding 15 minutes. It can be taken manually, using a pump, bucket, vacuum, or other suitable device. The collection of a grab sample is appropriate when it is desired to:

1. Characterize water quality at a particular time;
2. Provide information about minimum and maximum concentrations;

3. Allow collection of variable sample volume;
4. Corroborate composite samples;
5. Meet a requirement of a discharge permit.

2. Composite Sample

A composite sample is defined as a sample formed by mixing discrete samples taken at periodic points in time or a continuous proportion of the flow. The number of discrete samples which make up the composite depends upon the variability of pollutant concentration and flow. A sequential composite is defined as a series of periodic grab samples each of which is held in an individual container, then composited to cover a longer time period. Six methods are used for compositing samples. Table 1 lists those methods with their advantages and disadvantages. Choice of composite type is dependent on the program and relative advantages and disadvantages of each composite type.

3. Selection of Sample Type

Use grab samples when:

- a. The waterbody does not flow continuously (such as batch discharges);
- b. The water or waste characteristics are relatively constant;
- c. The parameters to be analyzed are likely to change with storage such as dissolved gases, residual chlorine, soluble sulfide, oil and grease, microbiological parameters, organics, and pH;
- d. Information on maximum, minimum or variability is desired;
- e. The history of water quality is to be established based on relatively short time intervals;
- f. The spatial parameter variability is to be determined, for example, the parameter variability throughout the cross section and/or depth of a stream or large body of water.

Use composite samples when:

- a. Determining average concentrations;
- b. Calculating mass/unit time loading;

4. Guidelines for Representative Sample

To obtain representative samples, the following guidelines should be adhered to:

- a. Collect the sample where water is well mixed, that is near a Parshall flume or at a point of hydraulic turbulence such as down-

TABLE 1 COMPOS

Sample Mode	Compositing Principle	Advantages	Disadvantages	Comments
Continuous	Constant pumping rate	Minimal manual effort, requires no flow measurement	Requires large sample capacity; may lack representativeness for highly variable flows	Practical but not widely used
Continuous	Sample pumping rate proportional to stream flow	Most representative for highly variable flows; minimal manual effort	Requires accurate flow measurement equipment, large sample volume, variable pumping capacity, and power	Not widely used
Periodic	Constant sample volume, constant time interval between samples	Minimal instrumentation and manual effort; requires no flow measurement	May lack representativeness especially for highly variable flows	Widely used in both automatic and manual sampling
Periodic	Constant sample volume, time interval between samples proportional to stream flow	Minimal manual effort	Requires accurate flow measurement/reading equipment Manual compositing from flow chart	Widely used in automatic as well as manual sampling

TABLE I (Continued)

Sample Mode	Compositing Principle	Advantages	Disadvantages	Comments
Periodic	Constant time interval between samples, sample volume proportional to total stream flow since last sample	Minimal instrumentation	Manual compositing from flow chart In absence of prior information on the ratio of minimum to maximum flow, there is a chance of collecting either too small or too large individual discrete samples for a given composite volume	Not widely used in automatic samplers but may be done manually
Periodic	Constant time interval between samples, sample volume proportional to total stream flow at time of sampling	Minimal instrumentation	Manual compositing from flow chart In absence of prior information on the ratio of minimum to maximum flow, there is a chance of collecting either too small or too large individual discrete samples for a given composite volume	Used in automatic samplers and widely used as manual method

stream of a hydraulic jump. Certain types of weirs and flumes tend to enhance the settling of solids upstream and accumulate floating solids and oil downstream, therefore such locations should be avoided as a sample source. For low level turbulence except when dissolved gases or volatile materials are being sampled.

- b. In a wide channel, divide the channel cross section into different vertical sections so that each section is equal width. Take a representative sample in each vertical section.
- c. In a deep waterbody, collect the samples at different depths. In those cases of wide and deep streams the samples can be composited or analyzed individually depending upon the program objective.
- d. When manual sampling with bottles, place the mouth of the collecting container below the water surface and facing flow to avoid an excess of floating material. Keep the hand away from the mouth of the jar as far as possible.
- e. Additional guidelines for manual sampling:
 - i. Sample facing upstream to avoid contamination;
 - ii. Force sampling vessel through the entire cross section of the waterbody wherever possible;
 - iii. Be certain that the sampler closes and opens at the proper time when sampling with a depth integrating sampler; with a point sampler, be certain that sampler opens at a proper depth. If a doubt exists, discard the sample and re-sample.
- f. When sampling, it is necessary to fill the bottles completely if the samples are to be analyzed for volatile organics, O₂, CO₂, NH₃, H₂S, free chlorine, pH, hardness, SO₂, Fe⁺⁺, oil and grease, acidity or alkalinity. When sampling for bacteria or suspended solids, it is necessary to leave an airspace in the sample container to allow mixing before subsampling.
- g. Collect sufficient volume to allow duplicate analyses and quality assurance testing (split or spiked samples). The required sample volume is a summation of that required for each parameter of interest. Refer to the Chief of Laboratory at the Lawrence Experiment Station for minimum volumes to be collected.
- h. Maintain an up-to-date log book which notes possible interferences, environmental conditions and problem areas.
- i. Since mathematical relationship between volumetric flow and height (or depth) of flow is nonlinear, composite flow proportional samples in relation to the total volume of flow as opposed to gauge height or raw measurement of a secondary device.
- j. If samples are taken from a closed conduit via a valve or faucet arrangement, allow sufficient flushing time to insure that the sample is representative of the supply, taking into account the diameter, length of the pipe to be flushed and the velocity of the flow.

Additional references concerning the type of water quality sample are listed below:

Handbook for Sampling and Sample Preservation of Water and Wastewater.
Environmental Monitoring and Support Laboratory, Office of Research and Development, United States Environmental Protection Agency. Cincinnati, Ohio. EPA-600/4-82-029. April 1982.
p 19, sec. 2.4; p 196

National Handbook of Recommended Methods for Water Data Acquisition.
Office of Water Data Coordination, United States Geological Survey. Reston, Virginia. January 1982.
sec. 5-B-4, pp 5-11

4. Container Type

The following are the generally used container types:

- a. Dissolved Oxygen - 300 ml glass BOD bottle with glass stopper;
- b. Chemical - Thoroughly cleaned plastic or glass bottles (1 liter $\frac{1}{2}$ gallon, or 1 gallon) fitted with plastic screw caps;
- c. Bacteria - Sterilized 200 ml glass bottle with plastic screw cap;
- d. Algae/chlorophyll a - a liter polyethylene bottle with screw cap.
- e. Special
 1. Metals - $\frac{1}{2}$ gallon glass bottle with plastic screw cap;
 2. Oil & Grease - same as metals;
 3. Phenols - same as metals;
 4. Cyanide - same as metals;
 5. Organics (trace) - 60 ml amber bottle with teflon-silicon lined screw caps;
 6. Sediment - 1 quart wide mouth plastic/glass container with snap lid/screw cap (plastic).
 7. EP Toxicity - 1 pint glass jar with plastic screw cap (or plastic lined metal screw cap).
 8. Elutriate - 2 liter widemouth glass container with screw cap (plastic).

More information concerning standard container types can be found in:

Handbook for Sampling and Sample Preservation of Water and Wastewater.
Environmental Monitoring and Support Laboratory, Office of Research and Development, United States Environmental Protection

Agency. Cincinnati, Ohio. EPA-600/4-82-029. April 1982.
p 178, sec. 5.9; p 205; pp 326-327

National Handbook of Recommended Methods for Water Data Acquisition.
Office of Water Data Coordination, United States Geological Survey.
Reston, Virginia. January 1982.
sec. 5-B-6, pp 5-16, 5-16a

5. Preservation, Handling, and Analyses

Deteriorated samples negate all the efforts and cost expended in obtaining good samples. In general, the shorter the time that elapses between the collection of a sample and its analysis, the more reliable will be the analytical results. For certain constituents and physical values, immediate analysis in the field is required in order to obtain reliable results because the composition of the sample almost certainly will change before it arrives at the laboratory. However, some samples can be satisfactorily preserved by chilling or by adding suitable acid or germicide or by other special treatment. They may then be allowed to stand for a longer period of time before analysis.

Samples should be either analyzed in the field (D.O., temp., etc.) or transported to the Lawrence Experiment Station (LES) as soon after collection as possible. Chemical, bacteria, and special samples should be correctly tagged with DEQE/LES white sample tags completely filled out including Town/City, Source (stream/WWTP), Station Location (station number), Collector (coordinator's name), Date, Time (military time), Type of Sample (grab, composite, etc.), Purpose of Test (Water quality survey), Analysis Required (actual parameters); refrigerated (iced); and delivered before 15:00 to the LES. Ample time should be allowed for travel to the laboratory, the unloading of samples, and the procurement of additional sample containers, reagents, etc. from the laboratory. Often samples cannot be delivered by 15:00 and provisions must be made in the field to store/refrigerate samples overnight. Nearby WWTP's may be able to provide refrigerators or storage space in this event.

Careful survey planning is essential to insure sample integrity. Therefore, the above procedures must be followed and a memorandum to the Chief of Laboratory at the LES detailing the date(s) of the survey, the purpose of the survey, the number and locations of sampling stations, the type(s) of sample(s) to be collected, and the number of samples to be delivered and on which date(s). If special analyses or collection/preservation techniques are required, these should be discussed with the Chief of Laboratory as far in advance of the survey as possible. (A follow-up telephone call to the written survey notification is recommended two (2) to three (3) days prior to the survey).

More detailed information concerning the preservation, handling, and analyses of water quality samples can be found in the following references:

Handbook for Sampling and Sample Preservation of Water and Wastewater.
Environmental Monitoring and Support Laboratory, Office of
Research and Development, United States Environmental Protection

Agency. Cincinnati, Ohio. EPA-600/4-82-029. April 1982.
p 217, sec. 8.10; p 306, sec. 12.6; p 178, sec. 5.10; p 343;
pp 368-397; p 195, sec. 8.3; p 177, sec. 5.6; p 183, sec. 6.6

National Handbook of Recommended Methods for Water Data Acquisition.
Office of Water Data Coordination, United States Geological Survey.
Reston, Virginia. January 1982.
sec. 5-B-6, p 5-16; pp 3.45-3.48

Procedures for Handling and Chemical Analysis of Sediment and Water
Samples. Russell H. Plumb, Jr., Environmental Laboratory, United
States Army Engineer Waterways Experiment Station. Vicksburg,
Mississippi, Technical Report. EPA/CE-81-1. May 1981.
sec. 2, pp 2-11, 2-15; sec. 1 pp 1-5

Methods for Chemical Analysis of Water and Wastes. Environmental
Monitoring and Support Laboratory, United States Environmental
Protection Agency. Cincinnati, Ohio. EPA-600/4-79-019. March 1979.

Standard Methods for the Examination of Water and Wastewater.
15th Edition. APHA-AWWA-WPCF, Washington, D.C. 1980.

U.S.G.S. Techniques of Water Resource Investigations, Volume I.
Municipal Environmental Research Laboratory, Office of Research
and Development, United States Environmental Protection Agency,
Cincinnati, Ohio. EPA-600/9-76-014. July 1976.
Chapter C1, pp 1-56

B. Flow

1. General Introduction

Every aspect of the hydrologic cycle--particularly the surface water environment--is extremely dynamic in nature. Stream flow is one of the primary factors in water quality. Both natural water quality and the effects of wastewater in a stream vary as stream flow changes. To acquire good factual data and information from stream flow can be very expensive in terms of equipment and manpower. Stream flow measurements also require planning, organization and cooperation, coupled with some ingenuity and imagination.

Inaccuracy in flow measurements will eventually be reflected in the results of a sampling program. Inaccurate flow measurements will lead to inaccurate flow proportional composite samples which, in turn, will lead to inaccurate results. Therefore, due care and effort must be exercised in selecting the type of flow measurement equipment to be employed and in selecting the flow measurement site.

a. Objectives -

More information concerning the general objectives of flow surveys are found in:

National Handbook of Recommended Methods for Water Data Acquisition.
Office of Water Data Coordination, United States Geological

Survey. Reston, Virginia. January 1982.
pp 1.1-1.2

A Practical Guide to Water Quality Studies of Streams. F.W. Kittrell,
United States Department of the Interior, Federal Water Pollution
Control Administration. Cincinnati, Ohio. 1969.
p 47, 53

Water Measurement Manual. United States Department of the Interior,
Bureau of Reclamation. Denver, Colorado. 1975.
p 1

"Techniques of Water Resources Investigations of the United States
Geological Survey - Measurement of Time of Travel and Dispersion
In Streams by Dye Tracing" Book #3, Chapter A-9 United States
Department of the Interior, Geological Survey. Washington, D.C.
1982.
p 1.4

U.S.G.S. Techniques of Water Resource Investigations. Volume II.
Municipal Environmental Research Laboratory, Office of Research and
Development, United States Environmental Protection Agency.
Cincinnati, Ohio. EPA-600/9-76-014. July 1976.
Chapter A6, pp 1-2

b. Personnel Requirements -

Personnel requirements for flow surveys are similar to those found in II.
A.1.b. and additional information can be found in the following
references:

Microbiological Methods for Monitoring the Environment. United States
Environmental Protection Agency. Washington, D.C. EPA-600/8-78-017.
1978.
Part V, Sec. C-3.3, p 264

"Techniques of Water Resources Investigations of the United States
Geological Survey - Measurement of Time of Travel and Dispersion in
Streams by Dye Tracing" Book #3, Chapter A-9 United States Department
of the Interior, Geological Survey. Washington, D.C. 1982
p 21

c. Survey Logistics -

Flow survey logistics are the same as those discussed in II.A.1.c. with
additional information found in:

A Practical Guide to Water Quality Studies of Streams. F.W. Kittrell,
United States Department of the Interior, Federal Water Pollution
Control Administration. Cincinnati, Ohio. 1969.
p 47, 53

"Techniques of Water Resources Investigations of the United States
Geological Survey - Measurement of Time of Travel and Dispersion

in Streams by Dye Tracing" Book #3, Chapter A-9 United States Department of the Interior, Geological Survey. Washington, D.C. 1982.
p 15

d. Safety Considerations -

Flow survey safety considerations are generally standard as discussed in the following references:

Microbiological Methods for Monitoring the Environment. United States Environmental Protection Agency. Washington, D.C. EPA-600/8-78-017. 1978.
Part V, Sec. C-3.5, p 265.

Methods for Chemical Analysis of Water and Wastes. Environmental Monitoring and Support Laboratory, United States Environmental Protection Agency. Cincinnati, Ohio. EPA-600/4-79-019. March 1979.
p 125

2. Frequency of Measurement

The considerations involved in determining the frequency of flow measurement are practically identical to those found in II.A.2. Additional information concerning the frequency of flow measurement can be found in:

A Practical Guide to Water Quality Studies of Streams. F.W. Kittrell, United States Department of the Interior, Federal Water Pollution Control Administration. Cincinnati, Ohio. 1969.
p 47, 51, 53

"Techniques of Water Resources Investigations of the United States Geological Survey - Measurement of Time of Travel and Dispersion in Streams by Dye Tracing" Book #3, Chapter A-9 United States Department of the Interior, Geological Survey. Washington, D.C. 1982.
p 20

3. Methodology of Measurement

General discussions concerning the methodology of flow measurement are found in:

A Practical Guide to Water Quality Studies of Streams. F.W. Kittrell, United States Department of the Interior, Federal Water Pollution Control Administration. Cincinnati, Ohio. 1969.
p 54

Water Measurement Manual. United States Department of the Interior Bureau of Reclamation. Denver, Colorado. 1975.
p 126

"Techniques of Water Resources Investigations of the United States Geological Survey - Measurement of Time of Travel and Dispersion in Streams by Dye Tracing" Book #3, Chapter A-9 United States

Department of the Interior, Geological Survey. Washington, D.C. 1982.
pp 15, 21, 22

a. Sample Site Location -

The considerations involved in determining flow sample site locations are found in II.A.3.a. with additional information available in the following references:

A Practical Guide to Water Quality Studies of Streams. F.W. Kittrell, United States Department of the Interior, Federal Water Pollution Control Administration. Cincinnati, Ohio. 1969.
p 49

Water Measurement Manual. United States Department of the Interior, Bureau of Reclamation. Denver, Colorado. 1975.
p 107

"Techniques of Water Resources Investigations of the United States Geological Survey - Measurement of Time of Travel and Dispersion in Streams by Dye Tracing" Book #3, Chapter A-9 United States Department of the Interior, Geological Survey. Washington, D.C. 1982.
p 15

U.S.G.S. Techniques of Water Resource Investigations. Volume I. Municipal Environmental Research Laboratory, Office of Research and Development, United States Environmental Protection Agency. Cincinnati, Ohio. EPA-600/9-76-014. July 1976.
Chapter A9

U.S.G.S. Techniques of Water Resource Investigations. Volume II. Municipal Environmental Research Laboratory, Office of Research and Development, United States Environmental Protection Agency. Cincinnati, Ohio. EPA-600/9-76-014. July 1976.
Chapter A6, pp 2-3

Methods for Chemical Analysis of Water and Wastes. Environmental Monitoring and Support Laboratory, United States Environmental Protection Agency. Cincinnati, Ohio. EPA-600/4-79-019. March 1979.
pp 107-108

b. Methods of Measurement -

1. USGS Stream Gaging Station

- a. Continuous Monitoring Station - Average daily flow data for all USGS gaging stations in the Commonwealth are available from the USGS, 150 Causeway Street, Boston, MA 02114 (Telephone: (617) 223-2822).
- b. Staff Gages - Instantaneous staff gage reading, should be recorded by field personnel whenever possible during the survey period. Conversion tables (gage height vs. flow in cfs) are available in house for all active USGS gages.

2. Instream Flow Measurements

Current-Meter Measurement Procedure. The first step in making a current-meter measurement is to select a reach of stream containing the following characteristics:

- a. A straight reach with the threads of velocity parallel to each other;
- b. Stable stream-bed free of large rocks, weeds, and protruding obstructions such as piers, which would create turbulence;
- c. A flat stream-bed profile to eliminate vertical components of velocity;

It is usually not possible to satisfy all of these conditions. Select the best possible reach using these criteria and then select a cross section.

After the cross section has been selected, determine the width of the stream. String a tag line or measuring tape for measurements. String the line at right angles to the direction of flow to avoid horizontal angles in the cross section. Next determine the spacing of the verticals, generally using about 25 to 30 partial sections. With a smooth cross section and good velocity distribution, fewer sections may be used but this is not encouraged. Space the partial sections so that no partial section has more than 10 percent of the total discharge in it. The ideal measurement is one in which no partial section has more than 5 percent of the total discharge in it, but this is very seldom accomplished when 25 partial sections are used. Equal widths of partial sections across the entire cross section are not recommended unless the discharge is well distributed. Make the width of the partial sections less as depths and velocities become greater.

After the cross section has been selected and the stationing determined, assemble the appropriate equipment for the current-meter measurement and prepare the measurement note sheets to record the observations.

- i. Name of stream and location to correctly identify the established gaging station; or name of stream and exact location of site for a miscellaneous measurement;
- ii. Date, party, type of meter suspension, and meter number;
- iii. Time measurement is started using military time;
- iv. Bank of stream that is the starting point;
- v. Control conditions;
- vi. Gage heights and corresponding times;
- vii. Water temperature;

- viii. Other pertinent information regarding the accuracy of the discharge measurement and conditions which might affect the stage-discharge relation.

Identify the stream bank by either LEW or REW (left edge of water or right edge of water, respectively, when facing upstream). Record the time in the notes periodically, during the course of the measurement. When the measurement is completed, record the time and the bank of the stream where the section ends.

After the equipment and the note sheet have been readied, begin the measurement. Indicate on the note sheet the distance from the initial point to the edge of the water. Measure and record the depth at the edge of water.

After the depth is known and recorded, determine the method of velocity measurement. Normally the two-point method or the 0.6-depth method is used. Compute the setting of the meter for the particular method to be used at that depth. Record the meter position (as 0.8, 0.6, 0.2,). After the meter is placed at the proper depth, permit it to become adjusted to the current before starting the velocity observation. The time required for such adjustment is usually only a few seconds if the velocities are greater than 1 fps, but for lower velocities, particularly if the current meter is suspended by a cable, a long period of adjustment is needed. After the meter has become adjusted to the current, count the number of revolutions made by the rotor for a period of 40-70 seconds. Start the stopwatch simultaneously with the first signal or click, counting "zero," not "one." End the count on a convenient number given in the meter rating table column heading. Stop the stopwatch on that count and read the time to the nearest second, or to the nearest even second if the hand is on a half-second mark. Record the number of revolutions and the time interval.

If the velocity is to be observed at more than one point in the vertical, determine the meter setting for the additional observation, time the revolutions, and record the data. Move to each of the verticals and repeat this procedure; record the distance from initial point, depth, meter-position depth, revolutions, and time interval, until the entire cross section has been traversed.

If the direction of flow is not at right angles to the cross section find the velocity vector normal to the section. Measure the cosine of the horizontal angle by holding the note sheet in a horizontal position with the point of origin (0) on the left edge of the note sheet over the tag line, bridge rail, or any other feature parallel to the cross section. With the long side of the note sheet parallel to the direction of flow, the tag line or bridge rail will intersect the value of the cosine of the angle a on the top, bottom, or right edge of the note sheet. Multiply the measured velocity by the cosine of the angle to determine the velocity component normal to the measuring section.

3. Rod Methods

Current meter measurements by wading instream are preferred, if conditions permit. Wading measurements offer the advantage over measurements from bridges in that it is usually possible to select the best of several available cross sections for the measurement.

The Division employs two (2) types of current meters for instream flow measurements: (1) Price-Pygmy Meter, (2) Digital current meter. Both meters are of the type that is attached to a supporting rod. The Price-Pygmy meter is a bucket wheel device (similar to an anamometer) that rotates in flowing water which is connected to a cam device for determining the number of revolutions. As the bucket wheel rotates, an electrical contact is closed on either a single-contact cam, or a penta gear. If a headset is attached to the single contact post, a signal is produced each time the bucket wheel completes a revolution. If the headset is connected to the penta-contact post, a signal is produced once every five revolutions. The penta-contact is very useful in streams with high velocities (e.g., >1.0 fps).

The velocity at the point of the current meter is measured by counting the number of signals (revolutions in a specified time interval). Thus, a standard piece of equipment accompanying the use of a current meter is a stopwatch. Each meter is calibrated by the supplier and an equation for the relationship between velocity and revolutions per unit time derived. For the Price meters, the meter is supplied with a rating table which shows the velocity for a given number of revolutions in a given time interval.

The Weathermeasure digital current meter is also used for instream flow measurements. It too is a rod mounted device and requires the same transect procedures as the pygmy meter. The advantages of this meter are that it is virtually maintenance free and there is no conversion tables involved. Flow readings are instantaneously provided on a digital display in either feet per second (fps) or meters per second (mps). However, velocity is not integrated over time so the user must approximate the tenths or hundredths readings over a short interval.

The following procedures should be followed when making an instream flow measurement regardless of which type of meter is used:

- a. Stand in a position that least affects the velocity of the water passing the current meter. This position is usually obtained by facing the bank, with the water flowing against the side of the leg. Holding the wading rod at the tag line, stand from 1 to 3 inches downstream from the tag line and 18 inches or more from the wading rod. Avoid standing in the water if feet and legs would occupy a considerable percentage of the cross section of a narrow stream. In small streams where the width permits, stand on a plank or other support rather than in the water.
- b. Keep the wading rod in a vertical position and the meter parallel to the direction of flow while observing the velocity.

If the flow is not a right angles to the tag line, measure the angle coefficient carefully.

- c. Water depth is measured using the support rod. The rod is marked in 0.1 foot increments. Depth readings should be made before each velocity measurement.

4. Cable Methods

Current-meter measurements from bridges. When a stream cannot be waded, bridges may be used to obtain current-meter measurements. Many measuring sections under bridges are satisfactory for current-meter measurements.

No set rule can be given for choosing between the upstream or downstream side of the bridge when making a discharge measurement.

The advantages of using the upstream side of the bridge are:

- a. Hydraulic characteristics at the upstream side of bridge openings usually are more favorable.
- b. Approaching drift can be seen and be more easily avoided.
- c. The streambed at the upstream side of the bridge is not likely to scour as badly as at the downstream side.

The advantages of using the downstream side of the bridge are:

- a. Vertical angles are more easily measured because the sounding line will move away from the bridge.
- b. The flow lines of the stream may be straightened out by passing through a bridge opening with piers.

Whether to use the upstream side or the downstream side of a bridge for a current-meter measurement should be decided individually for each bridge after considering the factors mentioned above and the physical conditions at the bridge, such as location of the walkway, traffic hazards, and accumulation of trash on piles and piers.

Use a sound reel supported by a bridge board to suspend the current meter and sounding weight from bridges.

Keep equipment several feet from piers and abutments if velocities are high. Estimate the depth and velocity next to the pier or abutment on the basis of the observations at the vertical nearest the pier.

If there are piers in the cross section, it is usually necessary to use more than 25-30 partial sections to get results as reliable as those from a similar section without piers. Piers will often cause horizontal angles that must be carefully measured. Piers also cause rapid changes in the horizontal distribution in the section.

The Price type-AA current meter is generally used when making discharge measurements from a bridge. The depth is measured by using a sounding reel and the velocity is measured by setting the meter at the proper position in the vertical.

Velocity measurements are made in the same manner as with the Pygmy meter--x number of revolutions (clicks) counted for a time interval between 40 and 70 seconds. Conversion tables are used to obtain the point velocity. Please note that there are separate tables for the Pygmy and Price meters. Tables are clearly marked but be sure to use the correct table with the corresponding meter.

The Stevens Sounding Reel is equipped with a computing depth indicator. To use the computing spiral, set the indicator (handle pulls out to adjust indicator) when the center of the current-meter rotor (cups) is at the water surface. Lower the sounding weight (lead sinker) and meter until the weight touches the streambed. A 30 C.75 suspension is used which requires that 8 inches or 0.75 feet is added to the depth indicator reading to obtain the total water depth. If, for example, the indicator reads 18.0 feet when the sounding weight touches bottom, the actual depth would be 18.75 feet. To move the meter to the 0.8-depth observation position, simply raise the weight until the hand on the indicator is pointing to 15.0 feet ($18.75 \times 0.8 = 15.0$). To set the meter at the 0.2-depth position, raise the weight and meter until the hand on the indicator is pointing to 3.75 feet.

The Weathermeasure Digital Flow Meter is the same device used in the rod method. The unit can be substituted for the Price meter when using the bridge-board equipment. The advantages of this device are:

- a. Less equipment must be set up
- b. Velocity measurements are read directly.

The same procedures as described for the Price meter with regard to number of partial cross-sections, measurement of depths, and operation and maintenance apply to the digital meter also.

All data are to be recorded in the same manner as described for the rod-type water current measurements.

5. Time-of-Travel

Time-of-travel refers to the movement of water or waterborne materials from point to point in a stream for steady or gradually varied flow conditions. In recent years, greater accuracy in the determination of time travel has been made possible by the production of stable fluorescent dyes and the devising of modern dye-tracing procedures.

Dye tracing simply means that a dye is slug injected at some location along the stream and the resulting response, or dye cloud, is measured at other locations downstream. When a fluorescent dye is used as a tracer material, the degree of fluorescence can be determined

with a fluorometer. The concentration of dye in the sample is directly proportional to its fluorescence. A plot of concentration against time defines the passage of the dye cloud at each sampling site. Time-of-travel is measured by observing the time required for movement of the dye cloud between sampling sites. Equally as important, the dispersion characteristics of the stream can also be determined.

Dyes injected into a stream behave in the same manner as the water particles themselves. A measure of the movement of the tracer will in effect be a measure of the motion of the stream and its dispersion characteristics.

The dispersion of the tracer in the receiving stream takes place in all three dimensions of the channel. Vertical dispersion is normally completed first, lateral later, depending upon the width of the stream and velocity variations. Longitudinal dispersion, having no boundaries, continues indefinitely and is the dispersion component of primary interest.

The movement of a dye cloud past any point downstream from an instantaneous dye injection can be represented by a time-concentration curve. The time-concentration curve, defined by the analysis of water samples taken at selected time intervals during the dye-cloud passage is the basis for determining time-of-travel and dispersion characteristics of streams.

Fluorometers measure the luminescence of a fluorescent substance when the substance is subjected to a light source of a given wave length. The higher the concentration of the fluorescent substance, the more emitted light the fluorometer will detect.

Several dyes are available that can be used as tracers in time-of-travel measurements. The most commonly used by the Division is rhodamine WT. The basic advantages of this particular dye are:

- a. It is non-toxic;
- b. Highly soluble;
- c. Easily detectable;
- d. Low loss rate;
- e. Easily handled;
- f. Low absorbability (will not readily adhere to aquatic plants, substrates, glassware, or plastic).

Dye studies in stream are usually conducted for two reasons:

- a. To determine time-of-travel for use in water quality models and
- b. To predict the time of arrival, passage time, and peak concentration of a pollutant(s) released or spilled upstream.

More detailed information on the methodology of low surveys can be found in the following references:

Handbook for Sampling and Sample Preservation of Water and Wastewater.
Environmental Monitoring and Support Laboratory, Office of
Research and Development, United States Environmental Protection
Agency. Cincinnati, Ohio. EPA-600/4-82-029. April 1982.
p 57, sec. 3.3

National Handbook of Recommended Methods for Water Data Acquisition.
Office of Water Data Coordination, United States Geological Survey.
Reston, Virginia. January 1982.
sec. 1-B-2, p 1-8; pp 1.8-1.91; sec. 1-B-2-d, p 1-39

A Practical Guide to Water Quality Studies of Streams. F.W. Kittrell,
United States Department of the Interior, Federal Water Pollution
Control Administration. Cincinnati, Ohio. 1969.
pp 53-54

Water Measurement Manual. United States Department of the Interior,
Bureau of Reclamation. Denver, Colorado. 1975.
pp 108, 126, 157

"Techniques of Water Resources Investigations of the United States
Geological Survey - Measurement of Time of Travel and Dispersion
in Streams by Dye Tracing" Book #3, Chapter A-9 United States
Department of the Interior, Geological Survey. Washington, D.C. 1982.
p 1, p 23

U.S.G.S. Techniques of Water Resource Investigations. Volume I.
Municipal Environmental Research Laboratory, Office of Research
and Development, United States Environmental Protection Agency.
Cincinnati, Ohio. EPA-600/9-76-014. July 1976.
Chapter A9

U.S.G.S. Techniques of Water Resource Investigations. Volume I.
Municipal Environmental Research Laboratory, Office of Research
and Development, United States Environmental Protection Agency.
Cincinnati, Ohio. EPA-600/9-76-014. July 1976.
Chapter A6, pp 6-10, 120-21; Chapter A8, pp 1-64

Methods for Chemical Analysis of Water and Wastes. Environmental
Monitoring and Support Laboratory, United States Environmental
Protection Agency. Cincinnati, Ohio. EPA-600/4-79-019. March 1979.
pp 107-109, 126

c. Calculations -

There are two (2) methods approved by the USGS for computing discharges from measurements made by current meters: 1) the midsection method and 2) Simpson's parabolic rule. Both are based on the summation of discharges of elementary areas. The midsection method is employed by the Division in calculating stream flows.

In the midsection method the depth and mean velocity are measured for each of a number of verticals along the cross-section as described previously in this section. The depth at each vertical is applied to a sectional width which extends halfway to the preceding vertical and halfway to the following vertical to develop a cross-sectional area. The product of the measured mean velocity at a vertical and the corresponding cross-sectional area gives the discharge for the elementary area. The summation of all the elementary discharges gives the total discharge. When using the two-point method of determining velocities, the formula for computing the discharge of an elementary area by the midsection method is:

$$q = \frac{V_1 + V_2}{2} \frac{(L_2 + (L_1) + (L_3 + L_2))}{2} d_2$$

Where:

L_1, L_2 and L_3 = distances in feet from the initial point, for any three consecutive verticals

V_1 and V_2 = velocities in feet per second (fps) at 0.2 and 0.8 of the water depth, respectively, at vertical L_2

d_2 = water depth in feet at vertical L_2

q = discharge in second-feet through section of average depth d_2 .

The total discharge for the cross-section is the sum of all the elementary discharges or:

$$Q = \sum q_i = (\bar{V}_i \times L_i \times d_i)$$

The above equations have been incorporated into a computer program that simplifies the flow calculation procedure thus saving much time. The Wang desk-top calculator can be used with tape program #529 by simply entering the mean velocity, width, and depth of each elementary area as recorded in the field for each flow station. The output will provide the flow in cubic-feet per second (cfs), the average depth (d), the average velocity (fps), and the total cross-sectional area.

Additional references can be found in:

Water Measurement Manual. United States Department of the Interior, Bureau of Reclamation. Denver, Colorado. 1975.
p 127

"Hydraulic Simulation in Instream Flow Studies: Theory and Techniques." Cooperative Instream Flow Service Group, Instream Flow Information Paper: No. 5, FWS/OB5-78/33. June 1978.
pp 99, 101

"Techniques of Water Resources Investigations of the United States Geological Survey - Measurement of Time of Travel and Dispersion

in Streams by Dye Tracing" Book #3, Chapter A-9 United States
Department of the Interior, Geological Survey. Washington, D.C. 1982
pp 22, 24, 32

III. GROUND WATER SAMPLING

A. Water Quality

1. General Introduction

Ground water is an important source of water, particularly in regions of scarce surface water supplies and polluted surface waters. Nearly all elements may be present in ground water and its mineral content varies from aquifer to aquifer and from place to place within the aquifer. The quality of ground water can be altered by various events, such as intrusion of sea water, seepage from wastewater lagoons, leachate movement from landfills, and subsurface wastewater disposal systems. Increased dependence on ground waters for drinking, industrial, and other purposes necessitates monitoring the quality of ground water.

Ground water data are collected and analyzed for either of two primary purposes. In the first case, a study may be conducted to evaluate the design and/or the operation of a facility at a particular site. In the second case, data may be collected and analyzed to provide factual information on ground water that will permit efficient development and intelligent management of ground water resources throughout a large region.

a. Objectives -

Methods of collecting a representative ground water sample are much more difficult and expensive in the subsurface environment. The subsurface is an extremely complex system subject to extensive physical, chemical and biological changes within small vertical and horizontal distances. The importance of proper sampling of wells cannot be overemphasized. Even though the well being sampled may be correctly located and constructed, special precautions must be taken to ensure that the sample taken from that well is representative of the ground water at that location and that the sample is neither altered nor contaminated by the sampling and handling procedure. Specific discussions concerning the objectives of groundwater sampling can be found in the following:

Handbook for Sampling and Sample Preservation of Water and Wastewater.
Environmental Monitoring and Support Laboratory, Office of Research
and Development, United States Environmental Protection Agency.
Cincinnati, Ohio. EPA-600/4-82-029. April 1982.
p 218, sec. 9.2

National Handbook of Recommended Methods for Water Data Acquisition.
Office of Water Data Coordination, United States Geological Survey.
Reston, Virginia. January 1982.
sec. 2, p 2-88

Ground Water Manual. United States Department of the Interior, Water
and Power Resources Service. Denver, Colorado. 1981.
Chap. 4-1, p 65

b. Survey Logistics -

The area of consideration, the time available for monitoring, and the potential concentration levels of pollutants all influence the sampling procedures selected. A regional or large area monitoring program may permit the use of existing wells, springs or even the baseflow of streams if these systems are compatible with the parameters of interest. If time is critical, existing sampling locations may be the only alternative. However, if the possible pollution source is relatively small, such as with organics, special monitoring wells will almost surely be necessary. The number and location of additional wells needed depends on the purpose of monitoring, aquifer characteristics, and mobility of pollutants in the aquifer. The concepts involved in developing survey logistics are found in:

Handbook for Sampling and Sample Preservation of Water and Wastewater.
Environmental Monitoring and Support Laboratory, Office of Research and Development, United States Environmental Agency. Cincinnati, Ohio. EPA-600/4-82-029. April 1982.
p 219, sec. 9.3

National Handbook of Recommended Methods for Water Data Acquisition.
Office of Water Data Coordination, United States Geological Survey. Reston, Virginia. January 1982.
sec. 2-6, p 2-90; sec. 5, p 5-16b

Ground Water Pollution and Hydrology. Robert B. Cleary, Princeton Associates. Princeton, New Jersey. 1982.
sec. 3, 4

Ground Water Manual. United States Department of the Interior, Water and Power Resources Service. Denver, Colorado. 1981.
Chap. 4, p 65

2. Frequency of Sampling

The factors that should determine the frequency of water level measurements are the types of fluctuation to be observed, the nature of the studies contemplated, and the available personnel. The principal factors that produce fluctuations in water table wells are recharge, withdrawal of water from wells, transpiration, and other natural discharges. In wells that extend to confined water bearing beds, the fluctuations in the water levels or pressure heads are relatively large and rapid and are produced by discharge of other wells or by other pressure effects, such as changes in atmospheric pressure and the effects of tides. In some localities, there are seasonal fluctuations produced by recharge and discharge. The frequency of ground water sampling must be tailored to the purposes for collecting the desired data within the constraints of time, available funds, and personnel.

Sampling should be frequent enough to describe all important water quality changes. First, important parameters and the smallest water quality change of interest must be identified. Changes in pumping rate, chemical composition of recharge, and inflow from surrounding areas may influence ground water quality. Changes in chemical and physical characteristics of ground water are generally slow, and often are adequately described by monthly, seasonal, or annual sampling schedules.

Particular reference to sampling frequency can be found in:

Handbook for Sampling and Sample Preservation of Water and Wastewater.
Environmental Monitoring and Support Laboratory, Office of Research
and Development, United States Environmental Protection Agency.
Cincinnati, Ohio. EPA-600/4-82-029. April 1982.
p 218, sec. 9.2

National Handbook of Recommended Methods for Water Data Acquisition.
Office of Water Data Coordination, United States Geological Survey.
Reston, Virginia. January 1982.
sec. 2-A-9, p 2-13

3. Methodology of Sampling

The type of sampling system used is a function of the type and size of well construction, pumping level, type of pollutant, analytical procedures and presence or absence of permanent pumping fixtures. Ideally, sample withdrawal mechanisms should be completely inert; economical to manufacture; easily cleaned, sterilized and reused; able to operate at remote sites in the absence of external power sources; and capable of delivering continuous but variable flow rates for well flushing and sample collection.

The advantage to collecting water samples from monitoring wells without in-place pumps is in the flexibility of selecting equipment and procedures. The principal disadvantage is the possibility of a non-representative sample either through collecting stagnant water that is in the well bore or introducing contamination from the surface by the sampling equipment or procedures.

General considerations concerning the methodology of groundwater sampling can be found in:

Handbook for Sampling and Sample Preservation of Water and Wastewater.
Environmental Monitoring and Support Laboratory, Office of
Research and Development, United States Environmental Protection
Agency. Cincinnati, Ohio. EPA-600/4-82-029. April 1982.
p 234, sec. 9.6

National Handbook of Recommended Methods for Water Data Acquisition.
Office of Water Data Coordination, United States Geological Survey.
Reston, Virginia. January 1982.
sec. 2-G-1, p 2-88

Ground Water Pollution and Hydrology. Robert B. Cleary, Princeton
New Jersey. 1982.
sec. 9

Field Methods in Contaminant Hydrology. University of Waterloo,
Waterloo, Ontario, Canada. April 1982.
Chap. 2

a. Sample Site Location -

The heterogeneous nature of subsurface environments makes the location of sampling points a complicated and unpredictable science when trying to intercept a pollutant plume. Hydrogeologic conditions are site specific and it is impossible to prescribe standard locations for sampling points that would be applicable to all sites.

Prior to initiating any field work, all existing geologic and hydrologic data should be collected, compiled and interpreted. There are several types of data that may be available including: geologic maps, cross-sections, aerial photographs, and an array of water well data including location, date drilled, depth, name of driller, water level and date, well completion methods, use of well, electron or radioactivity logs, or other geophysical data, formation samples, pumping test(s) and water quality data. After compiling and properly reviewing the collected data, the investigator can properly plan the type of investigation needed, including the necessary sampling locations.

Specific references to assist in the determination of sample site location are:

Handbook for Sampling and Sample Preservation of Water and Wastewater.
Environmental Monitoring and Support Laboratory, Office of Research and Development, United States Environmental Protection Agency.
Cincinnati, Ohio. EPA-600/4-82-029. April 1982.
p 220, sec. 9.4

National Handbook of Recommended Methods for Water Data Acquisition.
Office of Water Data Coordination, United States Geological Survey.
Reston, Virginia. January 1982.
sec. 2-6-1, pp 2-88, 2-112

b. Methods of Sample Collection -

The collection of representative water samples from monitoring wells is not a straightforward or easily accomplished task. Each monitoring well has its own individual hydrologic and chemical character that must be considered when planning a sampling protocol. The selection of the type of sampling device and sampling procedure must be tailored to the size and accessibility of the individual well, its hydrological and chemical character, the chemical constituents of interest, the time of year and purpose for monitoring.

The recommended minimum information to accompany ground water samples includes: point and method of collection, exact location of well or source, depth and diameter of well, casing record, screened intervals and type of screens, water-bearing formation(s), water level, rate of discharge and duration of pumping prior to sampling, water temperature and other field measurements, data and time of collection, appearance and any other relevant observations, such as use of the water, that may assist in interpreting water quality data.

Methods currently being used are found in the following:

Handbook for Sampling and Sample Preservation of Water and Wastewater.
Environmental Monitoring and Support Laboratory, Office of Research

and Development, United States Environmental Protection Agency.
Cincinnati, Ohio. EPA-600/4-82-029. April 1982.
p 234, sec. 9.6

National Handbook of Recommended Methods for Water Data Acquisition.
Office of Water Data Coordination, United States Geological Survey.
Reston, Virginia. January 1982.
sec. 2-G-1, pp 2-89

Field Methods in Contaminant Hydrology. University of Waterloo,
Waterloo, Ontario, Canada. April 1982.
Chap. 2

c. Types of Samples -

The types of samples to be obtained during any ground water monitoring program will depend wholly on the objects of the sampling program and the constituents of interest. Samples for analyses of conventional water quality parameters and parameters requiring specific handling and/or preservation should be collected in the appropriate manner described in the following references.

Assistance concerning the specific type of sample necessary can be found in:

Handbook for Sampling and Sample Preservation of Water and Wastewater.
Environmental Monitoring and Support Laboratory, Office of Research
Development, United States Environmental Protection Agency.
Cincinnati, Ohio. EPA-600/4-82-029. April 1982.
p 234, sec. 9.6

National Handbook of Recommended Methods for Water Data Acquisition.
Office of Water Data Coordination, United States Geological Survey.
Reston, Virginia. January 1982
sec. 2-G-2, pp 2-89

Field Methods in Contaminant Hydrology. University of Waterloo,
Waterloo, Ontario, Canada. April 1982.
Chap. 1

4. Container Type

A variety of factors affect the choice of containers and cap material. These include resistance to breakage, size, weight, interference with constituents, cost and availability. There are also various procedures for cleaning and preparing bottles depending upon the analyses to be performed on the sample. The specific situation will determine the use of glass or plastic. However, use glass containers for pesticides, oil and grease, and other organics.

Container type references are found in:

Handbook for Sampling and Sample Preservation of Water and Wastewater.
Environmental Monitoring and Support Laboratory, Office of Research
and Development, United States Environmental Protection Agency.

Cincinnati, Ohio. EPA-600/4-82-029. April 1982.
p 234, sec. 9.6; p 203, sec. 8.9

National Handbook of Recommended Methods for Water Data Acquisition.
Office of Water Data Coordination, United States Geological Survey.
Reston, Virginia. January 1982.
sec. 2-6, p 2-89; sec. 5-B-6, p 5-16

5. Preservation and Handling

Complete preservation of samples, either domestic sewage, industrial wastes, or natural waters, is a practical impossibility. Regardless of the nature of the sample, complete stability for every constituent can never be achieved. At best, preservation techniques can only retard the chemical and biological changes that take place in a sample after the sample is removed from the parent source. To maintain the integrity of the sample, appropriate selection of containers, pretreatment of containers if necessary and the holding times form the integral part of the sample preservation program.

Methods of preservation are relatively limited and are intended generally to: 1) retard biological action; 2) retard hydrolysis of chemical compounds and complexes; and 3) reduce volatility of constituents.

Preservation methods are generally limited to chemical addition, pH control, refrigeration, and freezing. Combinations of these methods are often used for the preservation of the sample. These methods are referenced in:

Handbook for Sampling and Sample Preservation of Water and Wastewater.
Environmental Monitoring and Support Laboratory, Office of
Research and Development, United States Environmental Protection
Agency. Cincinnati, Ohio. EPA-600/4-82-029. April 1982.
p 251, sec. 9.8

National Handbook of Recommended Methods for Water Data Acquisition.
Office of Water Data Coordination, United States Geological Survey.
Reston, Virginia. January 1982.
sec. 2-6, p 2-90; sec. 5-B-6, p 5-16

Field Methods in Contaminant Hydrology. University of Waterloo,
Waterloo, Ontario, Canada. April 1982.
sec. 5

Methods for Chemical Analysis of Water and Wastes. Environmental
Monitoring and Support Laboratory, United States Environmental
Protection Agency. Cincinnati, Ohio. EPA-600/4-79-019. March 1979.
pp XV-XIX

Standard Methods for the Examination of Water and Wastewater.
15th Edition. APHA-AWWA-WPCF. Washington, D.C. 1980.
pp 42-45

6. Analyses

Determinations for pH, specific conductance, and temperature should be made directly in the field. Other parameters of interest should be collected and

preserved in the field where appropriate and transported to laboratory for analysis as soon after collection as possible. Standard analysis techniques are found in:

Handbook for Sampling and Sample Preservation of Water and Wastewater.
Environmental Monitoring and Support Laboratory, Office of Research
and Development, United States Environmental Protection Agency.
Cincinnati, Ohio. EPA-600/4-82-029. April 1982.
p 251, sec. 9.8

Procedures for Handling and Chemical Analysis of Sediment and Water
Samples. Russell H. Plumb, Jr., Environmental Laboratory, United
States Army Engineer Waterways Experiment Station. Vicksburg,
Mississippi, Technical Report. EPA/CE-81-1. May 1981.
pp 3.1-3.399

Ground Water Pollution and Hydrology. Robert B. Cleary, Princeton
Associates. Princeton, New Jersey. 1982.
sec. 3; sec. 8

B. Flow

1. General Introduction

Natural movement of ground water is always from a high to low gradient. There can be stagnant areas where water can rest undisturbed for great lengths of time--e.g., hundreds of years. Ground water movement may be induced by sampling, production wells, or injection wells. Movement may also be subject to interaction with surface water and may reverse direction, depending on climatological conditions.

Ground water velocity is the average linear pore water velocity, or the velocity expected if the linear distance between two points is known. The average linear velocity, or simply the ground water velocity, is related to the specific discharge (u) described by the Darcy equation.

$$V = \frac{u}{ne}$$

Methods for determining the velocity in ground water flow systems can be grouped into three main categories: (1) artificial tracers, (2) environmental isotopes, (3) the Darcy equation (with the Dupuit-Forchheimer assumption).

a. Objectives -

Water level measurements are important basic preliminary data often used in selecting ground water sampling sites, equipment, and procedures. The direction of ground water flow can be determined using water level contours drawn from static levels in wells penetrating the same aquifer. These measurements must be carefully made to ensure an accurate determination of the direction of ground water flow. Therefore, flow direction is essential in the interpretation of ground water monitoring data.

General considerations concerning the objectives of groundwater flow measurement can be found in:

National Handbook of Recommended Methods for Water Data Acquisition.
Office of Water Data Coordination, United States Geological Survey.
Reston, Virginia. January 1982.
sec. 2-H, pp 2-115

b. Personnel Requirements -

These requirements are generally dictated by specific field conditions.. Guidelines concerning personnel requirements can be found in the following:

Microbiological Methods for Monitoring the Environment. United States Environmental Protection Agency. Washington, D.C.
EPA-600/8-78-017. 1978.
Part V, sec. C-3.5.2, p 265

c. Survey Logistics

The important facets of groundwater flow survey logistics are located in:

Handbook for Sampling and Sample Preservation of Water and Wastewater. Environmental Monitoring and Support Laboratory, Office of Research and Development, United States Environmental Protection Agency. Cincinnati, Ohio. EPA-600/4-82-029. April 1982.
p 219, sec. 9.4; p 220, sec. 9.5

National Handbook of Recommended Methods for Water Data Acquisition. Office of Water Data Coordination, United States Geological Survey. Reston, Virginia. January 1982.
sec. 2-H, p 2-117

Ground Water Pollution and Hydrology. Robert B. Cleary, Princeton Associates. Princeton, New Jersey. 1982.
sec. 2; sec. 7

2. Frequency of Measurement

Due to the wide range of flow velocities encountered between different aquifers, the frequency of static water level measurement is a site specific determination based largely on the geology of the study area. Therefore, a detailed geologic evaluation of the aquifer is essential before deciding on the intervals which samples will be collected. The parameters being monitored can also play a role in determining the sampling frequency. If sampling for organics of low molecular weight in a sand and gravel aquifer, weekly or monthly sampling may be warranted; whereas phosphorus monitoring in predominantly till aquifer may require only quarterly or annual sampling.

More specific information concerning the frequency of groundwater flow measurements can be found in:

National Handbook of Recommended Methods for Water Data Acquisition. Office of Water Data Coordination, United States Geological Survey. Reston, Virginia. January 1982.
sec. 2-H, p 2-116

3. Methodology of Measurement

The accuracy of static water level measurements is the most important part of a ground water study. Many devices ranging from chalked lines to ground penetrating radar can be employed, but whichever method is used careful field recording is essential. A basic reference for groundwater flow methodology is:

Field Methods in Contaminant Hydrology. University of Waterloo,
Waterloo, Ontario, Canada. April 1982.
sec. 2, sec. 3

a. Sample Site Location -

The considerations involved in determining groundwater flow sample site location can be found in:

National Handbook of Recommended Methods for Water Data Acquisition.
Office of Water Data Coordination, United States Geological Survey.
Reston, Virginia. January 1982.
sec. 2-H-5, p 2-117

b. Methods of Measurement -

Discussion of the specific methods utilized in the measurement of groundwater flow can be reviewed in:

National Handbook of Recommended Methods for Water Data Acquisition.
Office of Water Data Coordination, United States Geological Survey.
Reston, Virginia. January 1982.
sec. 2-H, p 2-117

Ground Water Pollution and Hydrology. Robert B. Cleary, Princeton
Associates. Princeton, New Jersey. 1982.
Chap. 6 and sec. 3

Field Methods in Contaminant Hydrology. University of Waterloo,
Waterloo, Ontario, Canada. April 1982.
sec. 2, sec. 3, sec. 4, sec. 5, sec. 6

IV. BIOLOGICAL (MACROINVERTEBRATE) SAMPLING

A. General Introduction

The role of aquatic biology in the water pollution control program of the MDWPC includes field and laboratory studies to establish water quality criteria for all surface waters of the Commonwealth and to monitor water quality.

Field studies are employed to measure the toxicity of specific pollutants or effluents to individual species or communities of aquatic organisms under natural conditions; detect violations of water quality standards; evaluate the trophic status of waters; and determine long term trends in water quality.

1. Objectives

Biological sampling is conducted to satisfy the following objectives:

- a. Classification Studies - to determine potential water uses, establish baseline biological and hydrologic information and to determine demarcation of major habitat types.
- b. Intensive Surveys - quantitative sampling above and below discharges to determine permit limits.
- c. Trend Monitoring - fixed station sampling to report the present condition as well as the long term trend in water quality.
- d. Toxicity Assessment - the detection and analysis of toxic substances including organics heavy metals, chlorine and ammonia. These may include sampling biota, toxicity testing or bioassays, and tissue analysis for bioconcentration.
- e. Eutrophication Monitoring - sampling primary producers to determine the trophic condition of lentic environments or the treatment requirements of lotic environments. Testing may include algal assays.
- f. Specific discussions concerning the objectives of biological sampling can be found in the following:

Handbook for Sampling and Sample Preservation of Water and Wastewater.
Environmental Monitoring and Support Laboratory, Office of Research and Development, United States Environmental Protection Agency. Cincinnati, Ohio. EPA-600/4-82-029. April 1982.
p 195, sec. 8.2

U.S.G.S. Techniques of Water Resource Investigations. Volume I.
Municipal Environmental Research Laboratory, Office of Research and Development, United States Environmental Protection Agency. Cincinnati, Ohio. EPA-600/9-76-014. July 1976.
Chapter A4, pp 1-2

Model State Water Monitoring Program. U.S. Environmental Protection Agency, Office of Water and Hazardous Materials, Monitoring and Data Support Division, EPA 440/9-74-002. September 1974.

Basic Water Monitoring Program. U.S. Environmental Protection Agency,
Standing Workgroup on Water Monitoring, EPA 440/9-76-025. September 1974.

2. Personnel Requirements

- a. Staffing requires the following critical areas of expertise:
 - i. Aquatic Botanists - for phytoplankton, periphyton and microphyton analyses.
 - ii. Microinvertebrate Specialists - both freshwater and marine specialists.
 - iii. Fisheries Biologists - for sampling, identification and tissue analysis.
- b. Desirable areas of expertise include:
 - i. Aquatic Microinvertebrate Zoologists - for zooplankton counts and identification.
 - ii. Fish Histopathologists - for fish kills and bioassays.
 - iii. Plant Physiologists - for benthic respiration and production studies.
- c. Guidelines concerning staffing requirements are found in the following:

Model State Water Monitoring Program. U.S. Environmental Protection Agency, Office of Water and Hazardous Materials, Monitoring and Data Support Division, EPA 440/9-74-002. September 1974.

Microbiological Methods for Monitoring the Environment. United States Environmental Protection Agency. Washington, D.C. EPA-600/8-78-017. 1978.
Part V, sec. C-3.5.2, p 265

Basic Water Monitoring Program. U.S. Environmental Protection Agency, Standing Workgroup on Water monitoring, EPA 440/0-76-025. September 1974.

Classification of Wetlands and Deepwater Habitats of the United States, U.S. Dept. of the Interior, Fish and Wildlife Service, Biological Services Program, FWS/OBS-79/31. December 1979.

A Guide to Stream Habitat Analysis Using the Instream Flow Incremental Methodology, U.S. Fish and Wildlife Service, Cooperative Instream Flow Service Group, Instream Flow Information Paper: No. 12 FWS/OBS 82/26. June 1982.

3. Survey Logistics

- a. Survey logistics depend on the objectives of the particular survey. Surveys may last from one day to one week, may involve from 2 to 8 biologists and may cover river segments from 1 to 20 miles long.

- b. The concepts involved in developing survey logistics are found in:

A Practical Guide to Water Quality Studies of Streams. F.W. Kittrell, United States Department of the Interior, Federal Water Pollution Control Administration. Cincinnati, Ohio. 1969
p 35

Biological Field and Laboratory Methods for Measuring the Quality of Surface Waters and Effluents. National Environmental Research Center, Office of Research and Development, United States Environmental Protection Agency. Cincinnati, Ohio. EPA-670/4-73-001. July 1973.
p 2

Model State Water Monitoring Program. U.S. Environmental Protection Agency, Office of Water and Hazardous Materials, Monitoring and Data Support Division, EPA 440/9-74-002. September 1974.

Classification of Wetlands and Deepwater Habitats of the United States, U.S. Dept. of the Interior, Fish and Wildlife Service, Biological Services Program, FWS-OBS-79/31. December 1979.

A Guide to Stream Habitat Analysis Using the Instream Flow Incremental Methodology, U.S. Fish and Wildlife Service, Cooperative Instream Flow Service Group, Instream Flow Information Paper: No. 12 FWS/OBS 82/26. June 1982.

4. Safety Considerations

Standard laboratory and field safety precautions are used. The general safety concepts are discussed in:

Model State Water Monitoring Program. U.S. Environmental Protection Agency, Office of Water and Hazardous Materials, Monitoring and Data Support Division, EPA 440/9-74-002.

Biological Field and Laboratory Methods for Measuring the Quality of Surface Waters and Effluents. National Environmental Research Center, Office of Research and Development, United States Environmental Protection Agency. Cincinnati, Ohio. EPA-670/4-73-001. July 1973.
p IX

Microbiological Methods for Monitoring the Environment. United States Environmental Protection Agency, Washington, D.C. EPA-600/8-78-017. 1978.
Part V, sec. C-3.5, p 265

B. Frequency of Sampling

1. Frequency of sampling depends on the particular objectives of the survey. In general, this dependency is related to the growing cycles of the biota. Sampling at a particular station may occur from 1 to 6 times during a year in order to obtain the proper information.

Cincinnati, Ohio. EPA-600/9-76-014. July 1976.
Chap. A4, pp 3-5

Handbook for Analytical Quality Control in Water and Wastewater.
Laboratories, Environmental Monitoring and Support Laboratory
United States Environmental Protection Agency. Cincinnati, Ohio.
EPA-600/4-79-019. March 1979.
p 10.3

2. Methods of Sample Collection

- a. Sampling methods are highly specialized and in some cases highly experimental. Many are being developed in-house with the cooperation of the U.S. EPA and U.S. Fish and Wildlife Service. Techniques unique to this Division will be properly documented when fully developed.
- b. Methods currently under use are referenced in:

Handbook for Sampling and Sample Preservation of Water and Wastewater.
Environmental Monitoring and Support Laboratory, Office of
Research and Development, United States Environmental Protection
Agency. Cincinnati, Ohio. EPA-600/4-82-029. April 1982.
p 203, sec. 8.7, 8.8

Biological Field and Laboratory Methods for Measuring the Quality of
Surface Waters and Effluents. National Environmental Research
Center, Office of Research and Development, United States
Environmental Protection Agency. Cincinnati, Ohio. EPA-670/4-73-001.
July 1973.
Macroinvertebrates, pp 2,4,5,12

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Municipal Environmental Research Laboratory, Office of Research
and Development, United States Environmental Protection Agency.
Cincinnati, Ohio. EPA-600/9-76-014. July 1976.
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A practical Guide to Water Quality Studies of Streams. F.W. Kittrell,
United States Department of the Interior, Federal Water Pollution
Administration. Cincinnati, Ohio. 1969.

Using a Biotic Index to Evaluate Water Quality in Streams. Hilsenhoff,
William L., Technical Bulletin No. 132, Dept. of Natural Resources.
Madison, Wisconsin. 1982

National Handbook of Recommended Methods for Water Data Acquisition.
Office of Water Data Coordination, U.S. Geological Survey. Reston,
Virginia. January 1982.

Methods for Collection and Analysis of Aquatic Biological and Microbiolo-
gical Samples, U.S. Dept. of the Interior, Geological Survey. 1973.

Model State Water Monitoring Program. U.S. Environmental Protection
Agency, Office of Water and Hazardous Materials, Monitoring and Data
Support Division, EPA 440/9-74-002. September 1974.

National Handbook of Recommended Methods for Water Data Acquisition.
Office of Water Data Coordination, U.S. Geological Survey. Reston,
Virginia. January 1982.

3. Types of Samples

- a. Sample types include sampling of biota from major communities including: phytoplankton, periphyton, macroinvertebrates, macrophyton and fish. Water chemistry and sediment samples are also collected.
- b. Guidance in determining the specific type of sample necessary can be found in:

Using a Biotic Index to Evaluate Water Quality in Streams. Hilsenhoff, William L., Technical Bulletin No. 132, Dept. of Natural Resources. Madison, Wisconsin. 1982.

National Handbook of Recommended Methods for Water Data Acquisition.
Office of Water Data Coordination, U.S. Geological Survey. Reston,
Virginia. January 1982.

Handbook for Sampling and Sample Preservation of Water and Wastewater.
Environmental Monitoring and Support Laboratory, Office of Research
and Development, United States Environmental Protection Agency.
Cincinnati, Ohio. EPA-600/4-82-029. April 1982.
p 203, sec. 8.8; p 200, sec. 8.5; p 205

Biological Field and Laboratory Methods for Measuring the Quality
of Surface Waters and Effluents. National Environmental Research
Center, Office of Research and Development, United States
Environmental Protection Agency. Cincinnati, Ohio. EPA-670/4-73-001.
July 1973.
Macroinvertebrates, p 5

Model State Water Monitoring Program. U.S. Environmental Protection
Agency, Office of Water and Hazardous Materials, Monitoring and
Data Support Division, EPA 440/9-74-002. September 1974.

Basic Water Monitoring Program. U.S. Environmental Protection Agency,
Standing Workgroup on Water Monitoring, EPA 440/9-76-025. September,
1974.

Classification of Wetlands and Deepwater Habitats of the United States.
U.S. Dept. of the Interior, Fish and Wildlife Service, Biological Services
Program, FWS/OBS-79/31. December 1979.

A Guide to Stream Habitat Analysis Using the Instream Flow Incremental
Methodology. U.S. Fish and Wildlife Service, Cooperative Instream Flow
Service Group, Instream Flow Information Paper: No. 12 FWS/OES 82/26.
June 1982.

D. Container Types

1. Glass bottles, plastic bags, plastic bottles, plastic buckets, and paper presses are all used as containers depending on the particular type of sample.

2. References relevant to the choice of container type are listed below:

Handbook for Sampling and Sample Preservation of Water and Wastewater.
Environmental Monitoring and Support Laboratory, Office of
Research and Development, United States Environmental Protection
Agency. Cincinnati, Ohio. EPA-600/4-82-029. April 1982.
p 203, sec. 8.9

Biological Field and Laboratory Methods for Measuring the Quality
of Surface Waters and Effluents. National Environmental Research
Center, Office of Research and Development, United States
Environmental Protection Agency. Cincinnati, Ohio. EPA-670/4-73-001.
July 1973.
Macroinvertebrates, p 12

E. Preservation and Handling

1. Samples are preserved and handled by standard biological techniques noted in the following documents:

Handbook for Sampling and Sample Preservation of Water and Wastewater.
Environmental Monitoring and Support Laboratory, Office of
Research and Development, United States Environmental Protection
Agency. Cincinnati, Ohio. EPA-600/4-82-029. April 1982.
p 217, sec. 8.10

Biological Field and Laboratory Methods for Measuring the Quality of
Surface Waters and Effluents. National Environmental Research Center,
Office of Research and Development, United States Environmental
Protection Agency. Cincinnati, Ohio. EPA-670/4-73-001. July 1973.
Macroinvertebrates, p 12

F. Analyses

Standard biological examinations and analyses are conducted using methodologies found in the following references:

Handbook for Sampling and Sample Preservation of Water and Wastewater.
Environmental Monitoring and Support Laboratory, Office of Research
and Development, United States Environmental Protection Agency.
Cincinnati, Ohio. EPA-600/4-82-029. April 1982.
p 195, sec. 8.3

Biological Field and Laboratory Methods for Measuring the Quality of
Surface Waters and Effluents. National Environmental Research Center,
Office of Research and Development, United States Environmental
Protection Agency, Cincinnati, Ohio. EPA-670/4-73-001. July 1973.
Macroinvertebrates, pp 14, 15, 33

V. LAKE SAMPLING - INTRODUCTION

Lake systems are sampled for three main reasons:

1. To determine the symptoms or cause of an immediate problem, 2. to determine the baseline water quality and instantaneous trophic status, and 3. to determine the long term water quality trend and the causes for these trends in both the lake and its watershed.

A. Water Quality

1. General Introduction

As in previous sections, the importance of a water quality sampling program is never overstated. Proper care must be taken to adequately develop and implement the field procedures to properly fulfill the intent of the sampling program. A proper field sampling survey lies in proper planning, collection of representative samples, proper handling and preservation of samples, and proper analysis of the samples.

2. Frequency of Sampling

- a. The frequency of sampling for a lake survey is directly related to the goals of the survey. Baseline water quality data is generally sampled at only one point in time, when flows are low and biological productivity is elevated. Determining causative factors in the trophic status of a lake or pond, however, may require periodic sampling throughout one complete cycle of the lentic system.
- b. Guidance for determining the frequency of sampling can be found in:

Handbook for Sampling and Sample Preservation of Water and Wastewater.
Environmental Monitoring and Support Laboratory, Office of
Research and Development, United States Environmental Protection
Agency. Cincinnati, Ohio. EPA-600/4-82-029. April 1982.
pp 339-340

National Handbook of Recommended Methods for Water Data Acquisition.
Office of Water Data Coordination, United States Geological Survey.
Reston, Virginia. January 1982.
p 5.11

3. Methodology of Sampling

a. Sample Site Location

- i. Many factors are involved in the location of a sample site. These generally include:

Accessibility
Depth of water
Rate of flow
Temperature of water

- ii. General principals governing the choice of sample site location are found in:

Handbook for Sampling and Sample Preservation of Water and Wastewater.
Environmental Monitoring and Support Laboratory, Office of Research and Development, United States Environmental Protection Agency. Cincinnati, Ohio. EPA-600/4-82-029. April 1982.
pp 195-199; 327-332.

Procedures for Handling and Chemical Analysis of Sediment and Water Samples. Russell H. Plumb, Jr., Environmental Laboratory, United States Army Engineer Waterways Experiment Station. Vicksburg, Mississippi. Technical Report EPA/CE-81-1. May 1981.
pp 2.4, 2.11

Handbook for Analytical Quality Control in Water and Wastewater.
Laboratories, Environmental Monitoring and Support Laboratory United States Environmental Protection Agency. Cincinnati, Ohio. EPA-600/4-79-019. March 1979.
p 10.3

National Handbook of Recommended Methods for Water Data Acquisition.
Office of Water Data Coordination, United States Geological Survey. Reston, Virginia. January 1982.
pp 3.40-3.41; 5.13-5.14

Procedures for Handling and Chemical Analysis of Sediment and Water Samples. Russell H. Plumb, Jr., Environmental Laboratory, United States Army Engineer Waterways Experiment Station. Vicksburg, Mississippi. Technical Report EPA/CE-81-1. May 1981.
pp 2.3-2.4, 2.11

United States Environmental Protection Agency. Cincinnati, Ohio. EPA-600/4-79-019. March 1979.
p 10.3

b. Types of Samples

- i. The methods of sampling shall be either grab or composite.
ii. The methodologies for sample collection are found in:

Handbook for Sampling and Sample Preservation of Water and Wastewater.
Environmental Monitoring and Support Laboratory, Office of Research and Development, United States Environmental Protection Agency. Cincinnati, Ohio. EPA-600/4-82-029. April 1982.
p 196

Standard Methods for the Examination of Water and Wastewater.
15th Edition. APHA-AWWA-WPCF. Washington, D.C. 1980.
pp 36-38

4. Container Type

- a. The type of container chosen is dependent on many factors. The most important of these include:

- Type of analyses to be conducted
- Volume
- Preservation method
- Holding time
- Type of transport
- Collection method

- b. Discussion and guidance in choosing the container type are found in:

Handbook for Sampling and Sample Preservation of Water and Wastewater.
Environmental Monitoring and Support Laboratory, Office of Research and Development, United States Environmental Protection Agency. Cincinnati, Ohio. EPA-600/4-82-029. April 1982.
pp 205, pp 326-327

Procedures for Handling and Chemical Analysis of Sediment and Water Samples. Russell H. Plumb, Jr., Environmental Laboratory, United States Army Engineer Waterways Experiment Station. Vicksburg, Mississippi. Technical Report EPA/CE-81-1. May 1981.
pp 2.2-2.3

5. Collection Methods

- a. The method of collection for individual samples is also dependent on several factors including the following:

- Type of analyses to be conducted
- Volume
- Container type
- Depth of water
- Rate of flow
- Type of sample

- b. Specific methods of collection are described:

Handbook for Sampling and Sample Preservation of Water and Wastewater.
Environmental Monitoring and Support Laboratory, Office of Research and Development, United States Environmental Protection Agency. Cincinnati, Ohio. EPA-600/4-82-029. April 1982.
pp 206-207

Standard Methods for the Examination of Water and Wastewater.
15th Edition. APHA-AWWA-WPCF. Washington, D.C. 1980.
pp 35-36

6. Preservation and Handling

- a. The methods for the preservation and handling of individual samples is almost entirely dependent upon:

- Type of analyses to be conducted
- Holding time

- b. Specific information concerning the methods of preservation and handling can be found in:

Handbook for Sampling and Sample Preservation of Water and Wastewater.
Environmental Monitoring and Support Laboratory, Office of Research
and Development, United States Environmental Protection Agency.
Cincinnati, Ohio. EPA-600/4-82-029. April 1982.
pp 343, 368-397

National Handbook of Recommended Methods for Water Data Acquisition.
Office of Water Data Coordination, United States Geological Survey.
Reston, Virginia. January 1982.
pp 3.45-3.48

Procedures for Handling and Chemical Analysis of Sediment and Water
Samples. Russell H. Plumb, Jr., Environmental Laboratory, United
States Army Engineer Waterways Experiment Station. Vicksburg,
Mississippi. Technical Report EPA/CE-81-1. May 1981.
pp 2.11-2.20

Methods for Chemical Analysis of Water and Wastes. Environmental
Monitoring and Support Laboratory, United States Environmental
Protection Agency. Cincinnati, Ohio. EPA-600/4-79-019. March 1979.
pp XV-XIX

Standard Methods for the Examination of Water and Wastewater.
15th Edition. APHA-AWWA-WPCF. Washington, D.C. 1980.
pp 38-39

7. Analyses

- a. Several volatile and/or unpreservable parameters are determined on site or directly upon return from the field. These parameters currently include:

pH
Dissolved oxygen
Specific conductivity
Temperature
Phytoplankton
Chlorophyll a

- b. Specific methodologies for these analyses can be found in the following:

National Handbook of Recommended Methods for Water Data Acquisition.
Office of Water Data Coordination, United States Geological Survey.
Reston, Virginia. January 1982.
pp 3.49-3.55

Procedures for Handling and Chemical Analysis of Sediment and Water
Samples. Russell H. Plumb, Jr., Environmental Laboratory, United
States Army Engineer Waterways Experiment Station. Vicksburg,
Mississippi. Technical Report EPA/CE-81-1. May 1981.

U.S.G.S. Techniques of Water Resource Investigations. Volume I.
Municipal Environmental Research Laboratory, Office of Research

and Development, United States Environmental Protection Agency.
Cincinnati, Ohio. EPA-600/9-76-014. July 1976.
Chapter C1, pp 1-56

Methods for Chemical Analysis of Water and Wastes. Environmental
Monitoring and Support Laboratory, United States Environmental
Protection Agency. Cincinnati, Ohio. EPA-600/4-79-019. March 1979.

Standard Methods for the Examination of Water and Wastewater.
15th Edition. APHA-AWWA-WPCF. Washington, D.C. 1980.

VI. INDUSTRIAL AND MUNICIPAL WASTEWATER SAMPLING

A. Introduction

Wastewater Treatment Facility discharges are sampled for seven primary reasons:

1. To provide input data to lake and stream water quality models;
2. To provide a data base for assessing a discharge's effect on aquatic communities;
3. To provide baseline and status quo data for determining the level of treatment required of specific discharges to obtain or maintain a desired level of water quality;
4. To provide a data base for the assessment of operational deficiencies at existing treatment facilities so as to facilitate a rational program aimed at alleviating those deficiencies;
5. To verify the accuracy of monthly reports submitted by each discharger under the Commonwealth's Compliance Monitoring Program;
6. To provide data for legal enforcement actions against violations of the Clean Water Act and other environmental protection laws;
7. To verify the applicability of various treatment methodologies to the treatment of specific types of wastes.

B. Frequency of Sampling

Surveys of wastewater discharges can be divided into two categories: general purpose, which include reasons for sampling 1, 2, 3, and 5 above; and special purpose which include 4, 6, and 7 above.

1. General Purpose Surveys

Surveys are scheduled to provide three consecutive days of sampling starting on Monday and terminating on Thursday when composite sampling techniques are used. For grab samples either three or four days of samples will be obtained, starting on Monday for four days or Tuesday for three days and terminating on Thursday. The frequency, however, will be adjusted to match the needs of those requesting the survey.

2. Special Purpose Surveys

No standard frequency can be established as each survey (even repetitive surveys on a single discharge) has its own unique character and requirements. Sampling frequency will be established by conference with the party(ies) requesting the survey.

C. Methods of Sampling

1. Municipal Discharges

- a. Sampling will be via 24 hour time base composite techniques for all constituents for which an appropriate preservation method is available or not required, and for which composite techniques can be applied without inducing unacceptable errors.
- b. For constituents not suitable to composite techniques (e.g., chlorine residual, coliform bacteria, dissolved oxygen, oil & grease, etc.), grab samples will be taken. Grab samples will also be taken when equipment failure prevents composite samples from being obtained, when the sample is taken as a scan for use in future planning, or when the requirements of the party(ies) requesting the survey or the discharger's permit require grab samples.
- c. When facilities permit or when special conditions require, composite samples will be composited on a flow proportioned basis.

2. Industrial Discharges

- a. Sampling will be via time based composite techniques for all constituents for which an appropriate preservation method is available or not required, and for which composite technique can be applied without inducing unacceptable errors. The duration over which such a composite sample is collected will be varied so as to match the production schedule or, where the treatment plant processes wastes for a time span significantly different from the production schedule, to match the time frame over which the discharge can be expected.
- b. For constituents not applicable to composite sampling samples will be collected as per VI.C.I.b. and c. above.

3. Special Purpose Surveys

All samples will be collected as per the requirements of the party(ies) requesting the survey.

4. Location of Sample Point

All samples will be collected at a point which:

- a. provides adequate mixing to ensure a representative sample;
- b. is located sufficiently upstream of all treatment process side stream return and chemical addition points as to prevent any unwanted or unknown contamination of the sample as may be avoided consistent with the purpose for which the sample is taken; and
- c. is located as close to the operator's normal sampling point as is consistent with the equipment to be used, the proposed use of the data and the prevailing waste stream characteristics.

D. Sample Preservation

1. All samples except for nutrients (i.e., COD, NH₃-N, NO₃-N, total phosphorus) will be preserved as per the preservation guidelines presented

in USEPA Technology Transfer: Methods For Chemical Analysis of Water and Wastes for all samples taken.

2. For Special Purpose Surveys, when requested by the party(ies) requesting the survey, when unusual delays can be expected in transporting the samples to the laboratory or whenever time and manpower considerations allow, all samples will be preserved including those for nutrients, unless the requesting party(ies) specify otherwise.
3. All grab samples will be preserved at time of collection and type of preservative will be noted.
4. Except when collected as part of a Special Purpose Survey, composite samples for nutrients and metals will be split from a thoroughly mixed unpreserved composite sample and will be preserved at the time of splitting.
5. Composite samples for all other constituents will be preserved in the sampler at the time of collection unless special considerations allow otherwise.
6. For Special Purpose Surveys all composite samples will be preserved in the sampler at the time of collection unless requested otherwise.

E. Equipment

1. For general surveys composite samples will be collected utilizing the automatic sampling equipment normally used by the operator of the discharge.
2. When no automatic sampler is available or when such equipment is too small to provide the needed volume or is improperly located, ISCO model 1680 samplers or equivalent will be used as may be available from DEQE stores.
3. When constituents not applicable to sampling by a standard ISCO model 1680 sampler are to be sampled the ISCO sampler will be appropriately modified or an alternative sampler will be procured from the USEPA or alternative source.
 - a. Any deficiencies from this requirement will be noted in the field report.
4. All sample containers will be in compliance with the guidelines presented in USEPA Technology Transfer: Methods For Chemical Analysis of Water and Wastes, or will be noted in the field report.
5. For Special Purpose Surveys when the requirements of this section cannot be complied with due to equipment limitations, blank samples will be procured to quantify or otherwise minimize induced errors.

NPDES Compliance Monitoring Inspector Training-Sampling Procedures,
Enforcement Division, Office of Water Enforcement and Permits, Compliance
Branch, United States Environmental Protection Agency, Washington, D.C.
June 1980. pp 18-22.

F. Standard Analyses

1. Municipal Wastewater Treatment Facilities

- a. Influent: pH, 5 day Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Suspended Solids (SS), Total Solids (TS), Total Kjeldahl Nitrogen (TKN), Ammonia Nitrogen (NH₃-N), Nitrate Nitrogen (NO₃-N), Total Phosphorus (TP), Total Alkalinity (Alk.)
- b. Intermediate Stage Effluents (e.g., Primary Effluent):
Same as influent, a. above
- c. Final Effluent, Surface Water Discharge:
All analyses for influent (a. above) plus Settleable Solids and Chloride (Cl⁻), Total Chlorine Residual, Total and Fecal Coliform Bacteria (if disinfecting)
- d. Final Effluent, Groundwater Discharge:
All analyses for surface discharge effluent plus Sulfate (SO₄⁼) and Trihalomethanes (THM) (if disinfecting)
- e. Aeration tank mixed liquor or return/waste activated sludge:
pH, Suspended Solids (SS), Volatile Suspended Solids (VSS), Total Solids (TS), Total Volatile Solids (TVS), Total Alkalinity (Alk.), Total Kjeldahl Nitrogen (TKN), Nitrate Nitrogen (NO₃-N), Total Phosphorus (TP)
- f. Metals, all points:
Silver (Ag), Aluminum (Al), Cadmium (Cd), Chromium (Cr), Copper (Cu), Iron (Fe), Mercury (Hg), Manganese (Ma), Nickel (Ni), Lead (Pb), Tin (Sn), Zinc (Zn)
- g. Metals groundwater discharge:
All metals listed above (f.) plus Sodium (Na)

2. Industrial Wastewater Treatment Facilities

- a. Biological treatment - same as for municipal treatment facilities
- b. Physical/chemical treatment - as required by discharge permit

3. Receiving Waters

- a. pH, 5 day Biological Oxygen Demand (BOD), Suspended Solids (SS), Total Solids (TS), Total Kjeldahl Nitrogen (TKN), Ammonia Nitrogen (NH₃-N), Nitrate Nitrogen (NO₃-N), Total Phosphorus (TP), Total Alkalinity (Alk.), Chloride (Cl⁻), Color, Turbidity

G. Chain of Custody

1. Objectives

Accurate written records that follow the possession of a sample through all phases of a sample program must be maintained in order to be able to use sampling data in litigation.

2. Procedures can be found in:

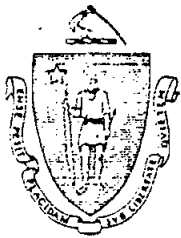
NPDES Compliance Monitoring Inspector Training-Sampling Procedures,
Enforcement Division, Office of Water Enforcement and Permits, Compliance
Branch, United States Environmental Protection Agency, Washington, D.C.
June 1980. pp 27-30, Handouts 6-7

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2. National Handbook of Recommended Methods for Water Data Acquisition. Office of Water Data Coordination, United States Geological Survey. Reston, Virginia. January 1982.
3. Procedures for Handling and Chemical Analysis of Sediment and Water Samples. Russell H. Plumb, Jr., Environmental Laboratory, United States Army Engineer Waterways Experiment Station. Vicksburg, Mississippi. Technical Report EPA/CE-81-1. May 1981.
4. A Practical Guide to Water Quality Studies of Streams. F.W. Kittrell, United States Department of the Interior, Federal Water Pollution Administration. Cincinnati, Ohio. 1969.
5. Water Measurement Manual. United States Department of the Interior, Bureau of Reclamation. Denver, Colorado. 1975.
6. Biological Field and Laboratory Methods for Measuring the Quality of Surface Waters and Effluents. National Environmental Research Center, Office of Research and Development, United States Environmental Protection Agency. Cincinnati, Ohio. EPA-670/4-73-001. July 1973.
7. Ground Water Pollution and Hydrology. Robert B. Cleary, Princeton Associates. Princeton, New Jersey. 1982.
8. Field Methods in Contaminant Hydrology. University of Waterloo, Waterloo, Ontario, Canada. April 1982.
9. "Hydraulic Simulation in Instream Flow Studies: Theory and Techniques." Cooperative Instream Flow Service Group, Instream Flow Information Paper: No. 5, FWS/OB5-78/33. June 1978.
10. Ground Water Manual. United States Department of the Interior, Water and Power Resources Service. Denver, Colorado. 1981.
11. "Microbiological Manual" United States Environmental Protection Agency. Washington, D.C. 1978.
12. "Techniques of Water Resources Investigations of the United States Geological Survey - Measurement of Time of Travel and Dispersion in Streams by Dye Tracing" Book #3, Chapter A-9 United States Department of the Interior, Geological Survey. Washington, D.C. 1982.

13. U.S.G.S. Techniques of Water Resource Investigations. Volume I. Municipal Environmental Research Laboratory, Office of Research and Development, United States Environmental Protection Agency., Cincinnati, Ohio. EPA-600/9-76-014. July 1976.
14. U.S.G.S. Techniques of Water Resource Investigations. Volume II. Municipal Environmental Research Laboratory, Office of Research and Development, United States Environmental Protection Agency. Cincinnati, Ohio. EPA-600/9-76-014. July 1976.
15. Methods for Chemical Analysis of Water and Wastes. Environmental Monitoring and Support Laboratory, United States Environmental Protection Agency. Cincinnati, Ohio. EPA-600/4-79-019. March 1979.
16. Handbook for Analytical Quality Control in Water and Wastewater Laboratories. Environmental Monitoring and Support Laboratory United States Environmental Protection Agency. Cincinnati, Ohio. EPA-600/4-79-019. March 1979.
17. Standard Methods for the Examination of Water and Wastewater. 15th Edition. APHA-AWWA-WPCF. Washington, D.C. 1980.
18. Microbiological Methods for Monitoring the Environment. United States Environmental Protection Agency. Washington, D.C. EPA-600/8-78-017. 1978.
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25. NPDES Compliance Monitoring Inspector Training-Sampling Procedures. Enforcement Division, Office of Water Enforcement and Permits, Compliance Branch, United States Environmental Protection Agency. Washington, D.C. June 1980.

STANDARD OPERATING PROCEDURES
Inorganic Chemistry Laboratory
Lawrence Experiment Station
1984



The Commonwealth of Massachusetts
Department Of Environmental Quality Engineering

Lawrence Experiment Station

37 Shattuck Street, Lawrence, Massachusetts 01843

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I. Receipt of Samples:

Samples for inorganic chemistry analysis are delivered to the Lawrence Experiment Station by any of the following methods.

1. United Parcel Service Delivered to the shipping room
2. U.S. Postal Service. Samples are picked up at the Post Office by the L.E.S. shippers.
3. City or Town employees hand carry to the laboratory.
4. D.E.Q.E. personnel hand-carry samples to the laboratory..

After the samples arrive at the station they are delivered to the chemistry laboratory where they are logged-in by the laboratory personnel.

II. Logging-in Procedure:

Samples are logged as follows: The identification tag is checked for complete information (collector, collection date, town, source, types of analysis requested). If the information is incomplete or ambiguous, it is given to the Chief of Lab for clarification. If the information is complete the sample is assigned a laboratory identification number and then logged into a bound log book.

III. Sample Preparation:

Samples are prepared for analysis in accordance with references given for each parameter.

IV. Analysis:

Samples usually fall into one of five main categories.

1. Routine chemical
2. Safe Drinking Water Inorganics
3. Water Pollution
4. Hazardous Waste
5. Sediments and Shellfish

The following is an outline of the methods used for each analysis.

A. Routine Chemical Analysis:

- a. Turbidity: Nephelometry, EPA "Methods for Chemical Analysis of Water and Wastes", 1983, method 180. 1. "Standards Methods for the Examination of Water and Wastewater", 15th Edition, part 214A 1980.
- b. Sediment and Odor: Neither of these parameters is quantitative. Sediment is a visual inspection of the settled solids on the bottom of the container. The scale is from 0 to 5 (zero being when the bottom of the container has no sediment; and, five being when the bottom is completely covered. Odor is based on a scale from 0 to 5. Zero meaning, no odor detectable; and five meaning odor of such intensity that the water is absolutely unfit to drink. This method is referenced in "Standard Methods for the Examination of Water and Wastewater", 11th Edition, 1960.
- c. Color: Colorimetric - Platinum - Cobalt, EPA Methods for Chemical Analysis of Water and Wastes", method 110. 2. 1983. "Standard Methods for the Examination of Water and Wastewater", 15th Edition,

- d. pH: Electrometric, EPA "Methods for Chemical Analysis of Water and Wastes". 1983 Method 150. 1. "Standard Methods for the Examination of Water and Wastewater", 15th Edition, part 423, 1980.
- e. Alkalinity-Total (CaCO₃): Titrimetric (pH 4.5), EPA "Methods for Chemical Analysis of Water and Wastes", 1983, Method 310. 1. "Standard Methods for the Examination of Water and Wastewater", 15th Edition, part 403, 1980.
- f. Hardness: By calculation, Standard Methods for the Examination of Water and Wastewater", 15th Edition, part 314A 1980.
- g. Calcium: Atomic Absorption Spectroscopy, Flame A.A. EPA "Methods for Chemical Analysis of Water and Wastes", 1983, Method 215. 1. "Standard Methods for the Examination of Water and Wastewater", 15th Edition, part 311A 1980.
- h. Magnesium: Atomic Absorption Spectroscopy, Flame EPA "Methods for Chemical Analysis of Water and Wastes", 1983, Method 242. 1. "Standard Methods for the Examination of Water and Wastewater", 15th Edition, part 318A. 1980.
- i. Potassium: Atomic Absorption Spectroscopy, Flame, EPA "Methods for Chemical Analysis of Water and Wastes", 1983 Method 258. 1. "Standard Methods for the Examination of Water and Wastewater", 15th Edition, part 322A. 1980.
- j. Sodium: Atomic Absorption Spectroscopy, Flame, EPA "Methods for Chemical Analysis of Water and Wastes", 1983, Method 273. 1. "Standard Methods for the Examination of Water and Wastewater", 15th Edition, part 325A. 1980.
- k. Iron: Atomic Absorption Spectroscopy, Flame, EPA "Methods for the Chemical Analysis of Water and Wastes", 1983, Method 23. 1. "Standard Methods for the Examination of Water and Wastewater", 15th Edition, part 315A. 1980.
- l. Manganese: Atomic Absorption Spectroscopy, Flame, EPA "Methods for Chemical Analysis of Water and Wastes", 1983, Method 243. 1. "Standard Methods for the Examination of Water and Wastewater", 15th Edition, part 319A, 1980.
- m. Sulfate: Turbidimetric Nephelometry, EPA "Methods for Chemical Analysis of Water and Wastes", 1983, Method 375. 4. "Standard Methods for the Examination of Water and Wastewater", 15th Edition part 426C. 1980.
- n. Chloride: Titrimetric, Silver Nitrate, EPA "Methods for Chemical Analysis of Water and Wastes", 1983, Method 325. 3. "Standard Methods for the Examination of Water and Wastewater", 15th Edition part 407B. 1980.
- o. Specific Conductance: (u mhos/cm). EPA "Methods for Chemical Analysis of Water and Wastes", 1983, Method 120. 1. "Standard Methods for the Examination of Water and Wastewater", 15th Edition, part 205, 1980.
- p. Nitrogen (Ammonia): Colorimetric, Automated Phenate, EPA "Methods for Chemical Analysis of Water and Wastes", 1983 Method 350. 1. "Standard Methods for the Examination of Water and Wastewater", 15th Edition, part 417F. 1980.
- q. Nitrogen (Nitrate): Colorimetric, Automated Hydrazine, EPA "Methods for Chemical Analysis of Water and Wastes" 1983, Method 353. 1.
- r. Nitrogen (Nitrite): Spectrophotometric, EPA "Methods for Chemical Analysis of Water and Wastes", 1983, Method 354. 1. "Standard Methods for the Examination of Water", 15th Edition part 419. 1980.
- s. Copper: Atomic Absorption Spectroscopy. Flame. EPA "Methods for Chemical

Analysis of Water and Wastes", 1983. Method 220. 1. "Standard Methods for the Examination of Water and Waste-water", 15th Edition, part 313A, 1980.

B. Safe Drinking Water Inorganics:

a. Arsenic: Atomic Absorption Spectroscopy Furnace, EPA "Methods for Chemical Analysis of Water and Wastes, 1983 Method 206. 2. "Standard Methods for the Examination of Water and Wastewater, 15th Edition, part 304, 1980.

b. Barium: Atomic Absorption Spectroscopy, Furnace, EPA "Methods for Chemical Analysis of Water and Wastes", 1983, Method 208. 2. "Standard Methods for the Examination of Water and Waste-water:", 15th Edition, part 304. 1980.

c. Cadmium: Atomic Absorption Spectroscopy, Furnace, EPA "Methods for Chemical Analysis of Water and Wastes", 1983, Method 213. 2. "Standard Methods for the Examination of Water and Waste-water", 15th Edition, part 304, 1980.

d. Chromium: Atomic Absorption Spectroscopy, Furnace, EPA "Methods for Chemical Analysis of Water and Wastes", 1983, Method 218. 2. "Standard Methods for the Examination of Water and Waste-water", 15th Edition, part 304, 1980.

e. Lead: Atomic Absorption Spectroscopy, Furnace, EPA "Methods for Chemical Analysis of Water and Wastes", 1983, Method 239. 2. "Standard Methods for the Examination of Water and Waste-water", 15th Edition, part 304, 1980.

f. Mercury: Cold Vapor, Manual. EPA "Methods for Chemical Analysis of Water and Wastes", 1983. Method 245. 1. "Standard Methods for the Examination of Water and Waste-water". 15th Edition, part 320A, 1980.

g. Selenium: Atomic Absorption Spectroscopy, Furnace, EPA "Methods for Chemical Analysis of Water and Wastes", 1983, Method 270. 2. "Standard Methods for the Examination of Water and Wastewater, 15th Edition, part 304, 1980.

h. Silver Atomic absorption Spectroscopy, Furnace, EPA "Methods for Chemical Analysis of Water and Wastes", 1983, Method 272. 2. "Standard Methods for the Examination of Water and Waste-water", 15th Edition, part 304, 1980.

i. Fluoride: Potentiometric, Ion Selective Electrode, EPA "Methods for Chemical Analysis of Water and Wastes", 1983, Method 340. 2. "Standard Methods for the Examination of Water and Waste-water", 15th Edition part 413B, 1980.

j. Nitrogen (Nitrate): Colorimetric, Automated Hydrazine, EPA "Methods for Chemical Analysis of Water and Wastes", 1983, Method 353. 1.

C. Water Pollution Samples:

Water pollution samples are logged in the water pollution laboratory. If the requested analysis include any of the following parameters, the samples are sent to the inorganic chemistry lab: Metals, nitrogen (nitrate), nitrogen (ammonia), specific conductivity, calcium, magnesium, sodium, potassium, hardness (CaCO_3), sulfate and turbidity. For sample preparation and methods of analysis see sections III and IVA.

D. Hazardous Waste Samples:

Hazardous Waste samples are logged in the organic chemistry laboratory. These samples are handled as described in Section C.

E. Sediments, Fish and Shellfish:

Studies on bottom sediments, fish and shellfish usually include metal analysis. Samples of this type are usually logged in by the inorganic chemistry laboratory. For sample preparation and analysis see Section III and IVA.

V. Data Handling:

Each analyst records analytical data into bound work-books. The laboratory secretary transcribes and types the data onto report forms. The forms are checked for accuracy by the Chief of Lab. and if approved, copies are sent to our Boston and Regional offices. Finally the reports are filed, (according to City or Towns) in our office.

VI. Instrument Maintenance:

All routine maintenance is performed by the analyst. Records are kept in a book which has been assigned to each instrument. The Instrumentation Laboratory atomic absorption Spectrometer, model #951V, is the only instrument in the inorganic chemistry lab., presently under service contract.

VIII. Quality Assurance:

In addition to compliance with EPA's "Methods for Chemical Analysis of Water and Wastes" and "Standard Methods for the Examination of Water and Wastewater" (for analytical procedures and methodology), the following Quality Assurance plan will be in effect for the following parameters: calcium, magnesium, sodium potassium, all metals, ammonia, nitrate, chloride and fluoride. Section VII-B only of this plan will be in effect for the following parameters: turbidity, color, pH, alkalinity, sulfate, and specific conductivity.

A. Purpose:

To control the quality of all analytical data generated in and leaving the inorganic chemistry lab.

B. Precision:

In order to ensure precise analytical data, one out of every ten samples shall be selected and run in duplicate. It shall be analyzed immediately after the set of ten it was selected from and prior to the next set of ten. It shall be recorded in the work-book in the order in which it is run and not at the end of the analysis (an example is given in Section VII-D). The duplicate data is then used as follows:

- a. The difference between the original sample and the duplicate is determined.
- b. The Standard Deviation of the differences (at least 20 is determined).
- c. A Quality Control Chart is generated from this data using 1 and 2 standard deviations around zero. Two (2) standard deviations determines the upper and lower control limits. If a duplicate is out of control the analysis is stopped and the analyst checks for error. When the problem is solved, that set of ten (10) samples is re-analyzed.

A sample chart is shown in fig. 1.

C. Accuracy: In order to ensure accurate analytical data, the following two (2) methods shall be used.

- 1.) An EPA reference standard shall be run after every ten samples. These known concentrations indicate whether the working standards are good or bad, and whether the instrument settings have been properly set-up.
- 2.) To ensure the accuracy of actual field samples, one out of every ten samples (the duplicate sample) shall be spiked with a known amount of analyte. After analysis, the percent-recovery * of the spike shall be determined and used as follows:
 - a. The mean (of at least 20 samples) of the per-cent recoveries is determined.
 - b. The standard deviation of the percent-recoveries is determined.
 - c. A quality control chart is generated from this data, using 2 (two) and 3 (three) standard deviations around the mean percent-recovery; two (2) standard deviations determine the upper and lower warning limits; three (3) standard deviations determines the upper and lower control limits. If a spike is out of control, the analysis is stopped and the analyst checks for error. When the problem is solved, that set of ten (10) samples is reanalyzed. A sample chart is shown in fig. 2.

D. Order of Analysis: A typical run should include the following: Standard, blank, EPA Reference, ten (10) samples, blank, duplicate, spike, EPA Ref., etc. All of the Q.C. data generated should be recorded on the Q.C. Charts and in a separate Q.C. data book. Variance from this plan must be approved the Lab. Chief.

E. Performance Evaluation: Our quality Assurance program also includes participation in EPA's semiannual performance evaluation study, both for water pollution (WP series) and drinking water (WS series).

* Determine % recovery as follows:

$$\frac{\text{Sample} + \text{Spike} \text{ --- avg. } (\text{orig} + \text{dup})}{\text{Spike}} \times 100$$

(Copy - copy)
µg/l

Range: 1.0 To 10. µg/l

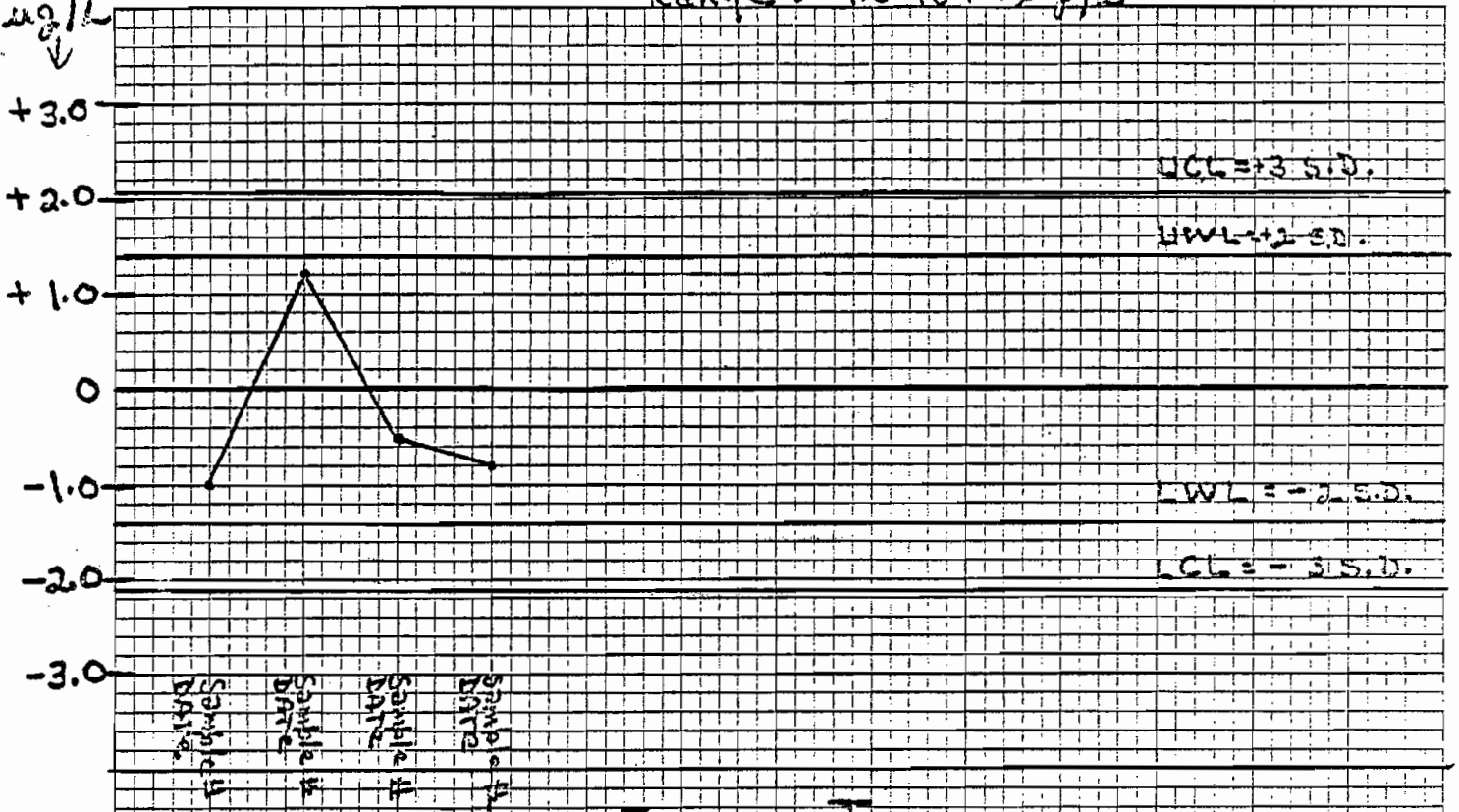


Figure I
Precision (duplicates)
P.C. Chart

Range: 1.0 To 10. µg/l

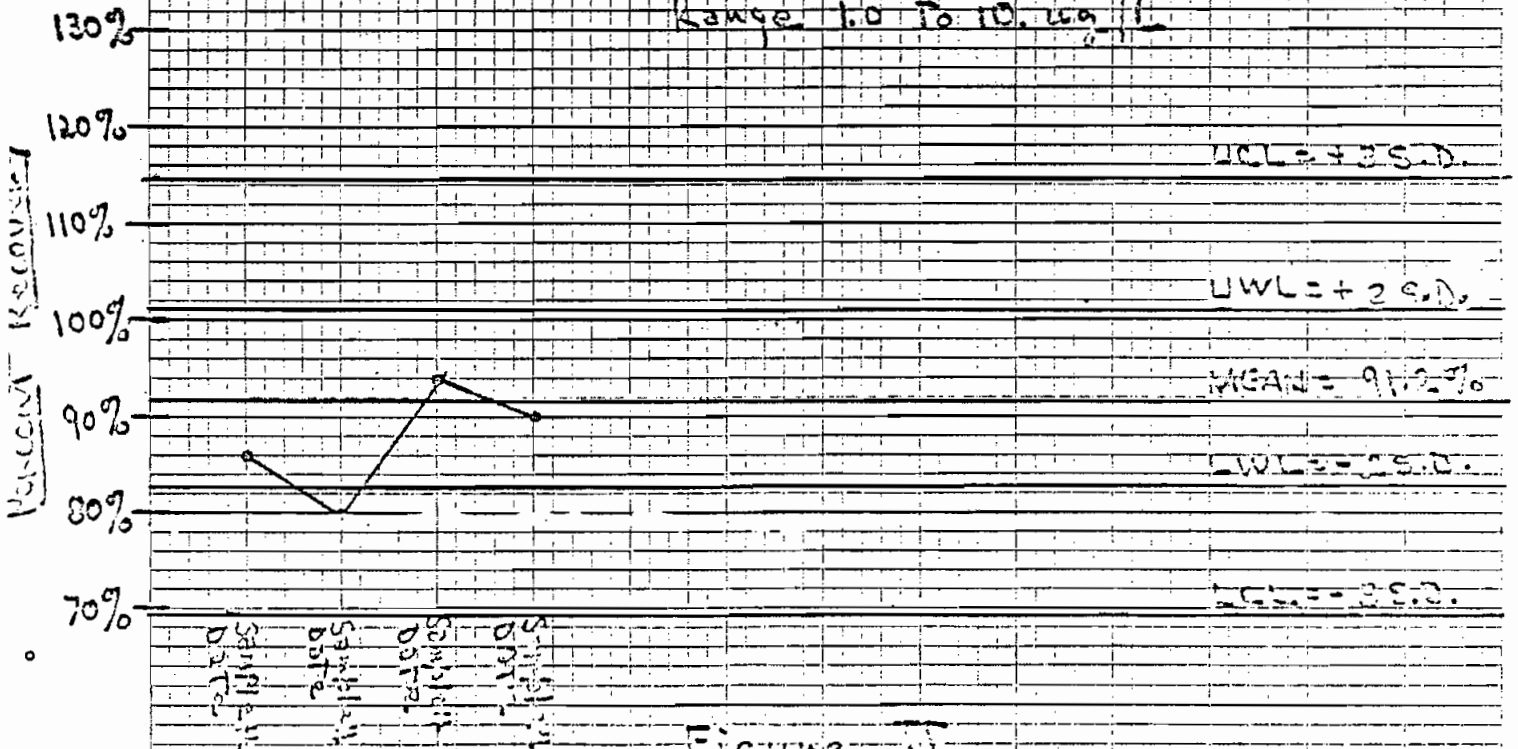


Figure II
Accuracy (SPRINT)

MASSACHUSETTS DEPARTMENT OF ENVIRONMENTAL QUALITY ENGINEERING

LAWRENCE EXPERIMENT STATION

METALS DETECTION LIMITS

FLAME ATOMIC ABSORPTION SPECTROSCOPY

<u>ELEMENT</u>	<u>mg/l</u>	<u>ug/l</u>
Aluminum	0.10	100
Cadmium	0.02	20
Chromium	0.02	20
Copper	0.02	20
Iron	0.04	40
Lead	0.04	40
Manganese	0.01	10
Nickel	0.03	30
Silver	0.02	20
Zinc	0.01	10

APPENDIX 5

MONITORED PARAMETERS AND ANALYTICAL TECHNIQUES

APPENDIX A-5
TEN MILE RIVER MONITORING PROGRAM
ANALYSIS - PRESERVATION - TECHNIQUE

<u>PARAMETER</u>	<u>UNIT</u>	<u>PRESERVATION</u>	<u>ANALYTICAL TECHNIQUE</u>
Dissolved Oxygen	mg/l	MnSO ₄ ; KI; no sunlight.	Modified Winkler.
Temperature	°F	none	In situ reading.
BOD ₅	mg/l	cool 4°C	5-day oxygen depletion at 20°C.
COD*	mg/l	cool 4°C	Dichromate reflux.
pH	standard unit	cool 4°C none	Electrometric glass indicator, silver chloride reference; in situ reading with meter.
Alkalinity	mg/l as CaCO ₃	cool 4°C	0.02N sulfuric acid potentiometric titration to pH 4.5.
Hardness	mg/l as CaCO ₃	cool 4°C	Atomic absorption spectrophotometry. Air-acetylene flame.
Specific Conductance	umhos/cm	cool 4°C	Wheatstone Bridge type meter.
Total Solids	mg/l	cool 4°C	Evaporation to dryness at 103-105°C. Gravimetric.
Suspended Solids	mg/l	cool 4°C	Filtration through .45 micron glass fiber filter paper.
Chloride	mg/l	cool 4°C	Argentometric; titration with silver nitrate.
Sulfate	mg/l	cool 4°C	Turbidimetric Nephelometry
Total Kjeldahl-Nitrogen	mg/l	H ₂ SO ₄ , pH ≤2.0, cool 4°C	Acid digestion; colorimetric analysis.
Ammonia-Nitrogen	mg/l	H ₂ SO ₄ , pH ≤2.0, cool 4°C	Phenate method, automated. Colorimetric analysis.
Nitrate-Nitrogen	mg/l	H ₂ SO ₄ , pH ≤2.0 cool 4°C	Hydra zinc reduction method automated. Colorimetric analysis.
Total Phosphorus	mg/l as P	H ₂ SO ₄ , pH ≤2.0 cool 4°C	Acid digestion; ascorbic acid reduction colorimetric method.
Ortho-Phosphorus	mg/l as P	H ₂ SO ₄ , pH ≤2.0 cool 4°C	

<u>PARAMETER</u>	<u>UNIT</u>	<u>PRESERVATION</u>	<u>ANALYTICAL TECHNIQUE</u>
Aluminum	mg/l	HNO ₃ , pH ≤2.0	Atomic absorption spectrophotometry; nitrous oxide-acetylene flame.
Cadmium	mg/l	HNO ₃ , pH ≤2.0	Atomic absorption spectrophotometry; air-acetylene flame.
Total Chromium	mg/l	HNO ₃ , pH ≤2.0	Atomic absorption spectrophotometry; air-acetylene flame.
Copper	mg/l	HNO ₃ , pH ≤2.0	Atomic absorption spectrophotometry; air-acetylene flame.
Gold	mg/l	HNO ₃ , pH ≤2.0	Atomic absorption spectrophotometry; air-acetylene flame.
Iron	mg/l	HNO ₃ , pH ≤2.0	Atomic absorption spectrophotometry; air-acetylene flame.
Lead	mg/l	HNO ₃ , pH ≤2.0	Atomic absorption spectrophotometry; air-acetylene flame.
Nickel	mg/l	HNO ₃ , pH ≤2.0	Atomic absorption spectrophotometry; air-acetylene flame.
Silver	mg/l	HNO ₃ , pH ≤2.0	Atomic absorption spectrophotometry; air-acetylene flame.
Zinc	mg/l	HNO ₃ , pH ≤2.0	Atomic absorption spectrophotometry; air-acetylene flame.
Total Coliform Bacteria	Coliform/ 100 ml	cool 4°C	Membrane filter.
Fecal Coliform Bacteria	Coliform/ 100 ml	cool 4°C	Membrane filter.
Volatile Organics*	ug/l	cool 4°C	Gas chromatograph - mass spectrometry; purge and trap.
Residual Chlorine*	mg/l	none	Hach field meter.

*Wastewater discharge samples only