DIAGNOSTIC / FEASIBILITY STUDY FOR THE MANAGEMENT OF BUTTONWOOD POND NEW BEDFORD, MASSACHUSETTS

BAYSTATE
ENVIRONMENTAL
CONSULTANTS
INC.

DIAGNOSTIC/FEASIBILITY STUDY
FOR THE MANAGEMENT OF
BUTTONWOOD POND,
NEW BEDFORD, MASSACHUSETTS

PREPARED FOR
THE
CITY OF NEW BEDFORD
AND THE
MASSACHUSETTS DIVISION OF WATER POLLUTION CONTROL

UNDER
MGL CHAP. 628
MASSACHUSETTS CLEAN LAKES PROGRAM

BY
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FINAL REPORT

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PROJECT SUMMARY

Buttonwood Pond and its watershed were investigated and evaluated in 1986 and 1987 by Baystate Environmental Consultants, Inc., on behalf of the City of New Bedford. The study was made possible by funding through the Massachusetts Clean Lakes Program of the Department of Environmental Quality Engineering and the Olmsted Parks Restoration Program of the Department of Environmental Management. The physical, chemical and biological features of the pond were assessed and management recommendations have been prepared.

The results of the study indicate that Buttonwood Pond is receiving excessive loads of water, sediment and nutrients associated with storm water runoff generated in the urban watershed. Past sedimentation has filled in approximately one third of the pond, and current nutrient levels support algal blooms and dense growths of macrophytes. Flooding of park lands occurs in response to periods of intense precipitation; the inlet channel to the pond can handle only about 85 cu.m/min (50 cfs) of flow before overtopping, and the storage capacity of Buttonwood Pond is limited by very slight shoreline slopes. Approximately 62% of the phosphorus load to the pond is attributed to a single storm drainage system serving less than 18% of the watershed area. An upstream detention basin has an outlet structure which prevents detention of water during all but the highest possible flows. The Buttonwood Brook system has not been engineered for downstream water quality or flood control.

Review of available management options has eliminated many techniques from consideration. Evaluation of the remaining alternatives in light of technical and economic considerations has yielded a recommended management plan incorporating detention, diversion, dredging, and environmental education. The storm water drainage system contributing the majority of the phosphorus load to the pond is to be routed to the southwest corner of the park, along with four minor drainage systems which can be easily tied into the diversion pipe. The upstream detention basin is to be modified to detain water during low flows while passing enough flow during major storms to prevent overtopping and localized flooding. Soft sediment, silt laden sand, and accumulated debris are to be removed from Buttonwood Pond, dried and used within the park. The pond shoreline is to be steepened and stabilized in conjunction with the dredging program. An educational slide show and brochure are to be prepared and presented to watershed residents.

The proposed management plan is expected to yield substantial reductions in the loads of phosphorus (68 to 89%) and nitrogen (45 to 74%) to Buttonwood Pond. Considerable in-lake decreases in turbidity (40 to 95%) and plant density (60 to 80%)

FIGURES

PART I

DIAGNOSTIC EVALUATION

are also expected. The probability of flooding will be reduced (30 to 50%) as well. The physical features and appearance of Buttonwood Pond will be altered to provide a more hydrologically functional and aesthetically appealing water body. Habitat quality is expected to increase appreciably for most forms of aquatic life, and pond condition will be more appropriate to its desired uses. The proposed project is consistent with the Buttonwood Park Master Plan, which is in the implementation phase.

The total anticipated cost of the proposed management plan is $1,455,350, which includes the basic elements described above and a monitoring program for assessment of results and adjustment of management actions. A four-year implementation schedule has been outlined, with detention and diversion options implemented prior to any dredging. Monitoring and education should take place throughout the period. Additional management actions may be desirable (e.g., additional detention capacity provided upstream of Buttonwood Pond), but the proposed project should yield conditions acceptable for the desired uses of Buttonwood Pond and the surrounding park land.

INTRODUCTION

The establishment of the Massachusetts Clean Lakes Program under Chapter 628 of the Acts of 1981 enabled many municipalities and lake associations to acquire funding for study and restoration of their lakes. As an environmentally aware and concerned community, the City of New Bedford applied for a grant for a Phase I diagnostic/feasibility study of Buttonwood Pond, a highly visible element of Buttonwood Park. After being awarded the grant, the City contracted Baystate Environmental Consultants, Inc. to conduct the study.

Concern over the present and future status of Buttonwood Pond and its impact on the impending restoration of Buttonwood Park prompted the request for a study. The water quality impacts of human activities in the Buttonwood Pond watershed were largely unquantified, although it was apparent that the routing of storm water through the Buttonwood Brook system (including Buttonwood Pond) was largely responsible for deteriorating water quality and frequent flooding in the park and adjacent neighborhoods. Mitigation of any current negative influences on the pond and prevention of future degradation of this water resource were desired.

Under the Olmsted Parks Restoration Program, administered by the Massachusetts Department of Environmental Management (MDEM), major improvements are to be made in Buttonwood Park. These improvements are intended to provide increased recreational utility in a more aesthetic setting consistent with the park design principles of Frederick Law Olmsted, whose firm was involved with the establishment of Buttonwood Park. A master plan for the park has been developed by the Walker-Kluesing Design Group in conjunction with the MDEM and the City of New Bedford. Restoration work has already begun, and is likely to continue in a phased fashion for over a decade, as existing park features are brought into line with the master plan. Included in the plan are improvements to Buttonwood Pond, conceived and developed with the input of BEC.

DATA COLLECTION METHODS

Previous studies of Buttonwood Pond were reviewed, and historic conditions were discussed with City officials and other consultants involved in the park restoration effort. Maps and reports prepared by the United States Geological Survey (USGS) and Soil Conservation Services (SCS) were used to initially assess watershed characteristics. Of particular use were the USGS (1979) New Bedford North Quadrangle Sheet from the 7.5 minute series, the USGS-Massachusetts Department of Public Works Bedrock Geologic Map (Zen, 1983), the Southern Bristol County soil survey report prepared by SCS (1981), and aerial infrared photographs obtained from the National Cartographic Information Center (1985). Areal measurements were made with a Planix Electronic Planimeter. Determinations made from maps were verified by field inspection by staff engineers, biologists, and a geo-hydrologist.

Historical lake and land use were investigated through conversations with watershed residents, newspaper and technical articles, previous reports and maps, state agency correspondence, and field inspection. Of particular value was the historic research performed by Ms. Joy Kestenbaum for the Olmsted Parks Restoration Program. Mr. Dana Souza of the New Bedford Office of Neighborhoods also provided useful background material. Mr. Peter Jackson of MDEM was very helpful in securing documents pertaining to the pond study.

A bathymetric map was generated by plumb-lining along cross-lake transects and through visual inspection by a SCUBA diver. Soft sediment depth was assessed by driving a probe to first refusal; these measurements were also performed by a diver in conjunction with the bathymetric check. The subsurface structure of the outlet was examined by diver as well.

A comprehensive monitoring and investigative research program was implemented to assess the physical, chemical, and biological characteristics of Buttonwood Pond. Sampling stations were selected from topographic maps and field inspection. These stations are described in Table 1 and shown in Figures 1 and 2. The in-lake station was sampled with a Van Dorn bottle at the surface and bottom. All stations were sampled approximately biweekly between April and October and monthly thereafter until the following spring.

Fifteen parameters were routinely assessed at regular sampling locations (non-storm stations). Temperature and dissolved oxygen levels were measured with a YS1 model 57 meter, with vertical profiles obtained at the in-lake stations (0.3 to 1.0 m intervals). The pH was measured on-site with a Hach colorimetric kit and verified with a Sargent-Welch pH meter on

TABLE 1

BUTTONWOOD POND DIAGNOSTIC/FEASIBILITY STUDY

SAMPLING STATIONS

Station No.	Location
BU-1	Inlet off Brownell Ave., at old bridge abutments.
BU-2s	In-lake station, north of island, at surface.
BU-2b	In-lake station, north of island, at bottom.
BU-3	Outlet at Fuller Parkway.
BU-4	36 inch storm drain 50 m upstream of inlet.
BU-5	12 inch storm drain, just upstream of walking bridge near Kempton St.
BU-6	8 inch storm drain, entering pond directly in northwest corner.
BU-7	"Tile drainage" pipe near inlet.
BU-8	10 inch storm drain (channel) at Kempton Street.
BU-9	Buttonwood Brook at Kempton Street.
BU-10	Buttonwood Brook at Rt. 140 underpass, west branch.
BU-11	Buttonwood Brook at Rt. 140 underpass, east branch.
BU-12	Buttonwood Brook at Detention Pond, west branch.
BU-13	Buttonwood Brook on east side of Rt. 140, just south of drainage ditch confluence with channel under Rt. 140.
BU-14	Storm drain pipeline at Huntington-Brownell Ave. intersection.
BU-15	Storm drain pipeline at Gaywood-Brownell Ave. intersection.

FIGURE 1

SAMPLING STATION LAYOUT IN THE BUTTONWOOD POND WATERSHED

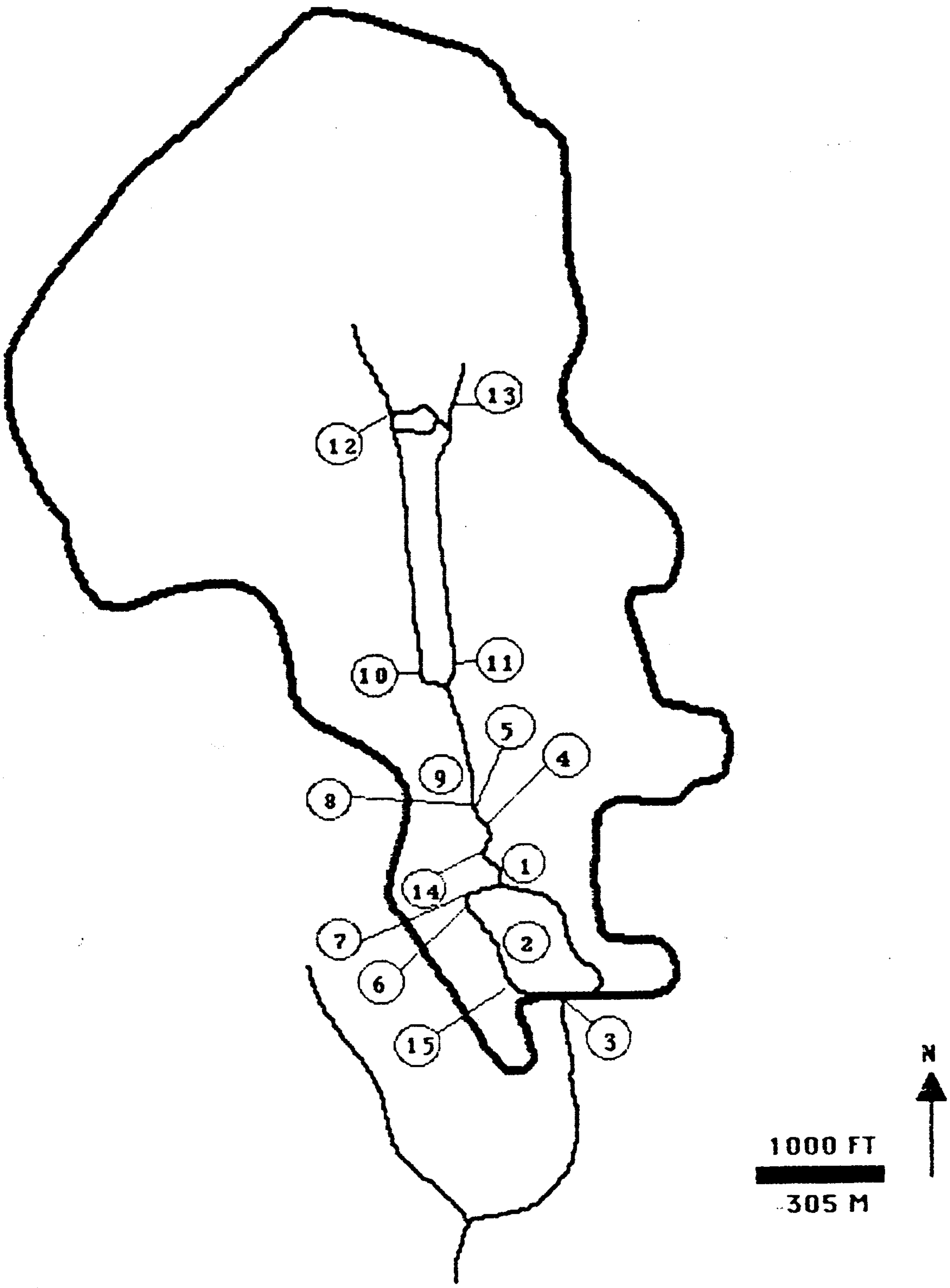
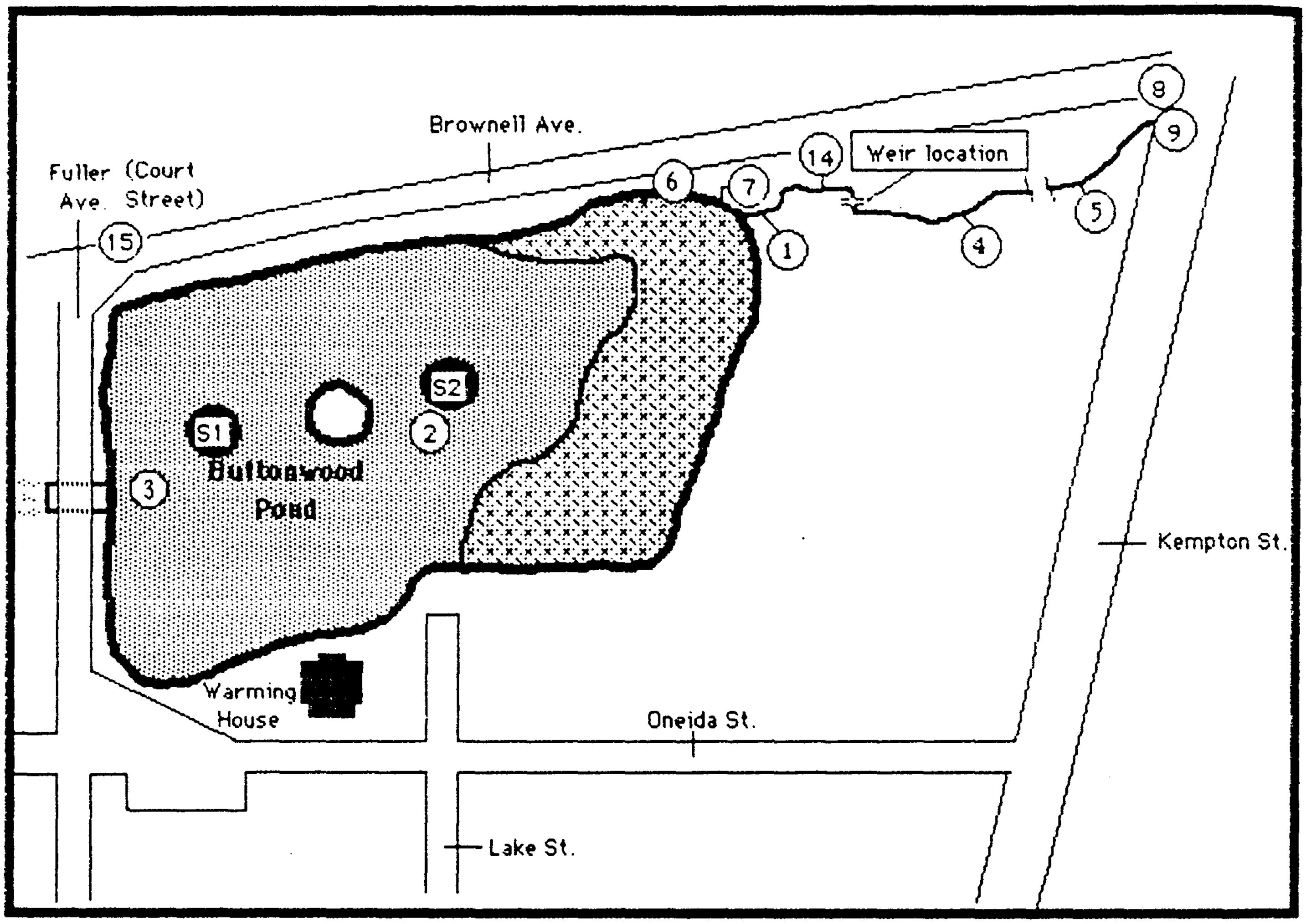


FIGURE 2

BUTTONWOOD POND SAMPLING STATION LOCATIONS



Buttonwood Pond, New Bedford

Location of the Sampling Stations

(1) = Water sampling site

(S1) = Sediment sampling site

= Emergent wetland on silt

= Open water

Note that stations 10 - 13 are upstream on Buttonwood Brook, out of the area shown here.

several occasions. Conductivity was assessed with a Horizon model 1484-10 meter. A four liter water sample was taken at each sampling location and transported to Arnold Greene Testing Laboratories in Natick, MA for analysis of suspended solids, dissolved solids, total alkalinity, chlorides, total Kjeldahl nitrogen, nitrate nitrogen, ammonia nitrogen, total phosphorus, and orthophosphorus by accepted standard methods (e.g., Kopp and McKee 1979, APHA et al. 1985). Separate bacteria samples were collected for analysis of fecal coliform and fecal streptococci, also performed by Arnold Greene Testing Laboratories by standard methods (membrane filter technique). Missing data are a consequence of site inaccessiblity or laboratory error.

Storm sampling was conducted on five dates, with some variation in procedures and sampling stations on each date. A total of 12 storm stations were sampled in addition to the three routine sampling stations, although not all on any one date. As only two small drains enter the pond directly, while a major drain and numerous minor drains discharge into Buttonwood Brook, some modification of the normal approach to storm water assessment was warranted. In addition to most of the parameters routinely surveyed, samples were analyzed on two dates for oil and grease, turbidity, and eight heavy metals. BEC also assessed runoff from the spring thaw, not an actual storm event. On one date, samples from two stations were taken five times during the storm, and samples from three stations were size fractionated prior to analysis. Size fraction limits were set at 250 um, 100 um, 53 um, 10 um, and 0.45 um. A total sample was also assessed. Fractionation was carried out by gravity filtration of composite samples through nylon mesh of the appropriate size, except for the 0.45 um fraction, which was obtained by suction filtration through a glass fiber filter.

Flow was assessed at all stream stations, using either the float method, a Gurley Standard flow meter, or a pipe/weir equation (SCS 1975a), where appropriate. Additional to the BEC measurements, City personnel kept a record of flows at a weir installed by BEC near the Buttonwood Brook inlet to the pond. This flow monitoring program ran for about three months before frequent vandalism and finally a channel deepening procedure carried out by the Bristol County Mosquito Commission forced its termination.

A 20 cm Secchi disk was lowered on the shady side of the boat to evaluate water transparency at the in-lake station. Analyses of chlorophyll concentration and features of the phytoplankton and zooplankton communities were made for that location as well. Phytoplankton samples were obtained from a depth integrated composite sample, while zooplankton samples were collected by oblique tow of an 80 micron mesh net. Phytoplankton samples were preserved with Lugol's solution and zooplankton samples were preserved with a formalin solution. Plankton samples were analyzed microscopically for species composition, relative abundance and biomass. The size distribution of the zooplankton was also assessed, and all data were recorded and tallied using a microcomputer routine developed by BEC and Cornell University personnel.

Sediment samples were obtained from two in-lake stations (Figure 2) with a manual coring device (5 cm diameter lucite tube) operated by a SCUBA diver, providing a cross section of bottom sediment strata. Samples were analyzed by Arnold Greene Testing Laboratories for total Kjeldahl and nitrate nitrogen, total phosphorus, organic/inorganic fraction, heavy metals (As, Cd, Cr, Cu, Fe, Hg, Mn, Ni, Pb, V, Zn), PCB's, and oil and grease. Settling rate, bulking factor, and residual turbidity were determined by BEC personnel for the two in-lake samples and a composite sample obtained from the emergent wetland area.

Macrophyte species composition and areal extent of cover were assessed by visual inspection from a boat and by a SCUBA diver. The distribution of summer bottom cover was mapped, listing dominant species in each area. Qualitative notes were made on the subsurface density, composition, and distribution of macrophyte stands by the diver. A conductivity survey was conducted at the same time to locate any major input points for dissolved substances. The probe for the conductivity meter was trailed behind a slow-moving boat, or positioned by the diver, with readings made approximately every 50 meters.

As there was little data available for the Buttonwood Pond fishery, BEC conducted a fish survey in August of 1986. A 122 m seine with 1 cm mesh was laid out from shore in a semi-circle and hauled in to collect fish. Captured fish were placed in holding tanks until they could be measured and scale-sampled, after which they were returned to the pond. Collected scales were assessed in the laboratory with an overhead projector microscope to facilitate age and growth determinations.

LAKE AND WATERSHED DESCRIPTION AND HISTORY

Lake Description

Buttonwood Pond is located in the City of New Bedford, Bristol County, Massachusetts. It lies at latitude 41°38′00" and longitude 71°57′15", encompassing an open water area of 2.4 ha (5.9 ac) (Table 2). If the emergent wetland that is steadily encroaching upon the open water area of the pond is included in the pond area, Buttonwood Pond should be listed at 3.6 ha (8.9 ac). The entire possible area of Buttonwood Pond has a deformed rhomboid shape (Figures 2 and 3) with depth contours forming a single depression. The mean depth is 0.9 m (3 ft) and the maximum depth is 1.3 m (4.3 ft), with the deepest point near the south side (outlet area) of the pond. The hypsograph for Buttonwood Pond (Figure 4), based only on the open water portion of the pond, indicates the gently sloping nature of the pond bottom. A small drop in water level can expose a substantial portion of the pond bottom.

When the pond is full, a total volume of 21,600 cu.m of water is impounded, but current use of the pond as a flood control device results in high variability of the observed volume. The detention time for water in Buttonwood Pond ranges from less than 0.001 to 0.08 yr (2 hr to 30 days), with a predicted long-term mean of 0.02 yr (8 days). The high variability of the detention time is largely a function of the influence of storm water runoff. Flushing rate is simply the inverse of detention time; for Buttonwood Pond, a mean flushing rate of 50 times per year is calculated. The quality of water in Buttonwood Pond is therefore likely to be a function of recent inputs to the system.

The easternmost branch of Buttonwood Brook, along with the numerous storm water drainage pipes which discharge into it, is the primary source of water for Buttonwood Pond. Direct precipitation, direct runoff, and ground water seepage provide only slight inputs to the pond. Background flows through the pond are slight, but storm-induced flows can be quite substantial, leading to erosion and sediment deposition within the pond. The northern end of the pond, representing about a third of the original pond area, has been filled in this manner. The eastern and western shorelines, which are subject to substantial fluctuations in water level, are eroded and unstable. Even the granite block wall along the southern edge of the pond is crumbling in places as a consequence of natural forces associated with fluctuating water levels. The size and shape of the open water area of Buttonwood Pond has changed appreciably over the last three decades, judging from aerial photographs and maps viewed by BEC personnel at City Hall.

TABLE 2

CHARACTERISTICS OF BUTTONWOOD POND AND ITS WATERSHED

Lake Measures

Location: Bristol County, City of New Bedford 41°38'00" lat. 71°57'15" long.

Area:	2.4 ha	(5.9 acres)
Depth: Mean	0.9 m	(3.0 ft.)
Maximum	1.3 m	(4.3 ft)
Volume:	21,600 m^3	(17.7 acre-ft.)
Detention Time: Mean	0.02 yr	(8.0 days)
Range	<0.001-0.08 yr	(<0.1-30 days)
Longest Fetch	0.3 km	(1016 ft)
Greatest Distance Perpendicular To Fetch	0.2 km	(650 ft)
Shoreline Length	0.82 km	(2690 ft)
Shoreline Development	1.17	

Watershed Measures

Area (Excluding Buttonwood Pond):	198 ha	(489.3 acres)

Watershed Area/Lake Area	82.5
Land Use: % High Density Residential	59.1
% Low Density Residential	4.5
% Commercial	2.2
% Highway Corridor	5.2
% Cemetery	5.7
% Open/Vacant	2.5
% Park/Recreation	4.3
% Forest	14.2
% Wetland	2.3

FIGURE 3

BATHYMETRIC MAP OF BUTTONWOOD POND
BUTTONWOOD PARK, NEW BEDFORD, MA

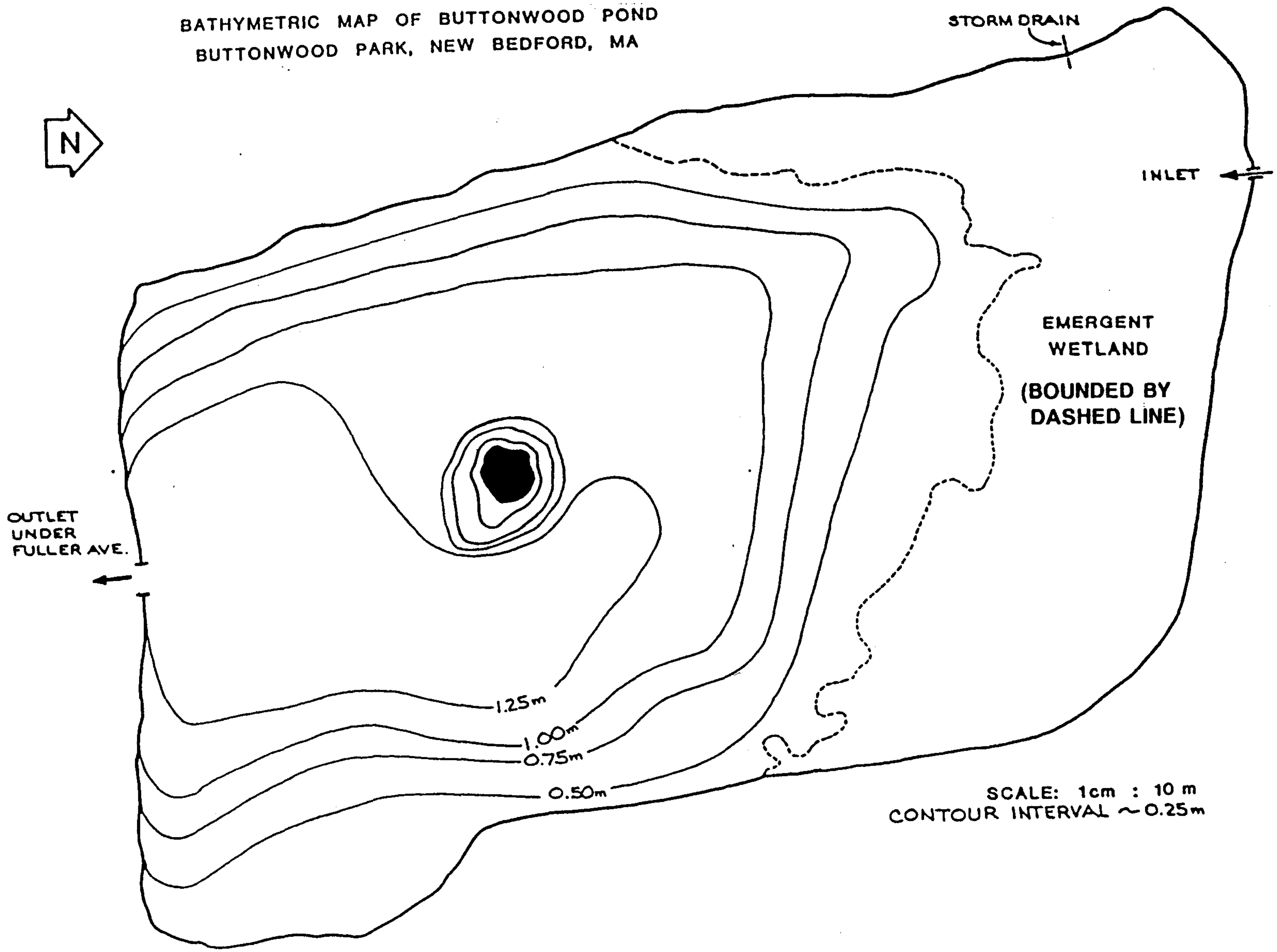
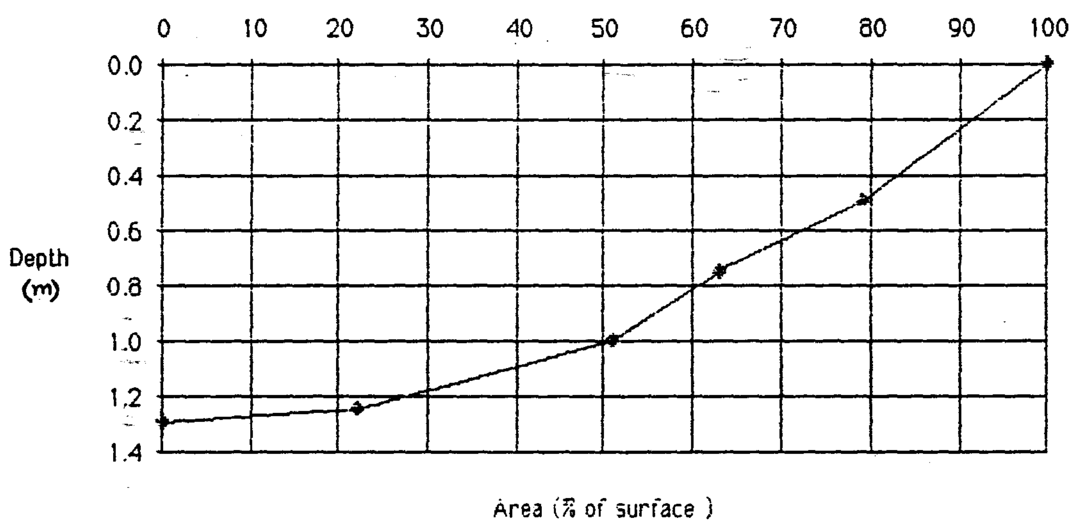


FIGURE 4

HYPSOGRAPHIC CURVE FOR BUTTONWOOD POND



Buttonwood Pond is a largely artificial impoundment of the easternmost branch of Buttonwood Brook. While the pond has existed for several hundred years, and may have been a marsh prior to that, it owes its current permanent status to the outlet structure on the south side of the pond. The outlet consists of a stone and masonry structure with a 2 m (6.5 ft) wide cement spillway and a 0.3 m (1 ft) diameter subsurface pond drain. The pond drain is controlled by a gate valve. The bottom of the pond drain is just several inches above the bottom of the pond, and could facilitate nearly complete draining of the pond under non-storm flows. The pond drain is inadequate to pass flows greater than 25 cu.m/min (<15 cfs), however.

The bottom meter of the outlet structure appears intact, but the top 0.3 m (subject to alternating exposure and submergence) exhibits cracking and chipping. Although the general function of the structure does not seem to be impaired, missing cement causes water to run down only the western edge of the spillway during dry weather conditions. Some underflow through soils or foundation cracks also appears to be occurring. The condition of the outlet is therefore suspect, and an official inspection by the DEM Dam Safety Unit should be conducted. Water passing through the outlet runs under Fuller Avenue (also called Court Street) in an arched, brick culvert of 2.4 m (8 ft) width and 1.2 m (4 ft) maximum height, further limiting outlet flows. The brook resumes its semi-channelized course at this point, passing through the zoo, a wet wooded area, and into a set of three small (maximum diameter = 0.6 m) culverts at the southwestern corner of the park (Hawthorn and Brownell Streets).

Buttonwood Pond is small, with only slight shoreline development, but it is an important focal point for activities in Buttonwood Park. It also plays an important role in flood control, acting as the only controllable impoundment in the entire Buttonwood Brook system. Other sources of storage capacity have no adjustable flow control structure. Consequently, the pond has been used to minimize flooding in the park at the expense of aesthetic appearance, recreational opportunity, and habitat quality.

Much of the physical, chemical, and biological condition of the pond can be explained solely as a function of storm water influence on the system. Nutrient enrichment, turbidity, siltation, and flooding are the primary effects. Buttonwood Pond is not especially effective as a flood control impoundment, and its use as such is in direct conflict with its role in the park as an aesthetic feature, recreational facility, and viable aquatic habitat.

There are currently no developed beaches on Buttonwood Pond, although unauthorized swimming has been observed. The public is not permitted to launch boats in the pond, but there are numerous access points for light boats, and a paddle boat concession is operated from the southeast corner of the pond during summer. The "Warming House", now harboring the park office and a senior citizens center, is also located at the southeast corner of the pond. Easy access to the shoreline exists on the east and west sides of the pond, with more difficult access possible across the filled area on the north side. The south shoreline is fenced off, due to its proximity to the road and the currently unstable nature of the granite block wall which defines the southern boundary of Buttonwood Pond.

Watershed Description

The watershed of Buttonwood Pond covers 198 hectares (489 ac), excluding the open water area of the pond itself, in an urban/suburban setting (Table 2, Figure 5). While this is not large in an absolute sense, the resultant watershed to pond area ratio is a very high 82.5 to 1. In our aquatic survey work throughout Massachusetts and the Northeast U.S. in general, BEC, Inc. has found that ratios of more than 50 to 1 result in degraded water quality and related lake problems in the absence of major management programs. Even with an almost completely forested watershed, one would not expect pristine conditions in Buttonwood Pond. Given the urban/suburban nature of the Buttonwood Pond watershed, the potential for water quality degradation is quite high. There are no point sources of pollution (registered discharges) in the watershed of Buttonwood Pond (SRPEDD 1978), but non-point sources are numerous and extensive.

High density residential areas (e.g., <0.1 ha or 0.25 ac lots, multi-family dwellings) account for over 59% of the watershed area (excluding the pond), with low density residential and commercial land comprising another 6.7% (Table 2, Figure 6). Highway corridors (mainly Route 140) constitute over 5% of the watershed, and heavily used park area accounts for over 4%. Forests and wetlands make up only 16.5% of the watershed of Buttonwood Pond. The remaining land in the watershed is either open/vacant (and likely to be built upon) or cemetery (St. Mary's Cemetery, off Route 6 and along Route 140). The large amount of impervious surface associated with such an urbanized watershed increases the runoff generated by precipitation events and snowmelt. The routing of this runoff to minimize transportation hazards and property damage results in excessive flows in Buttonwood Brook.

FIGURE 5

BOUNDARY AND TOPOGRAPHY OF THE BUTTONWOOD POND WATERSHED

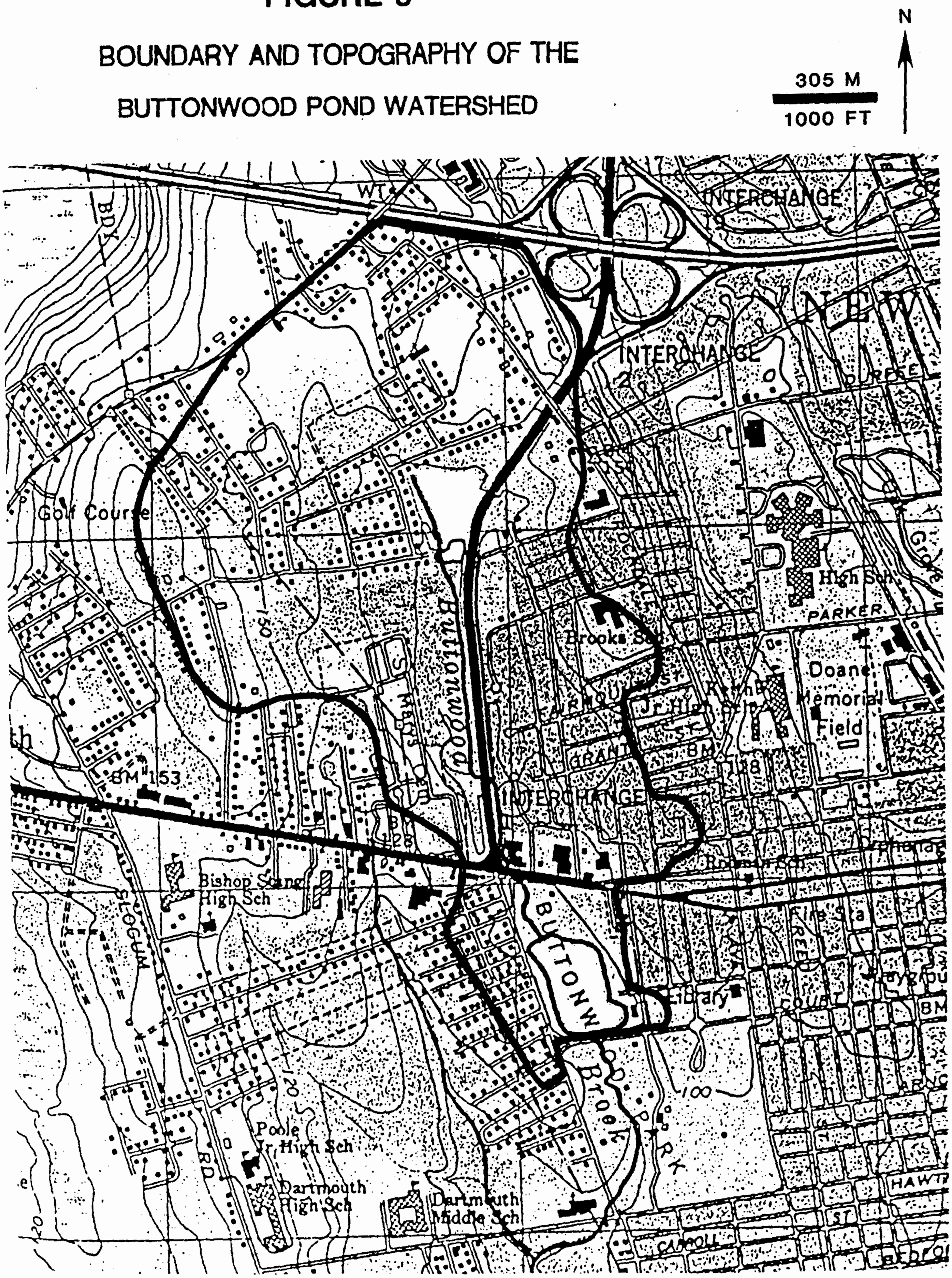
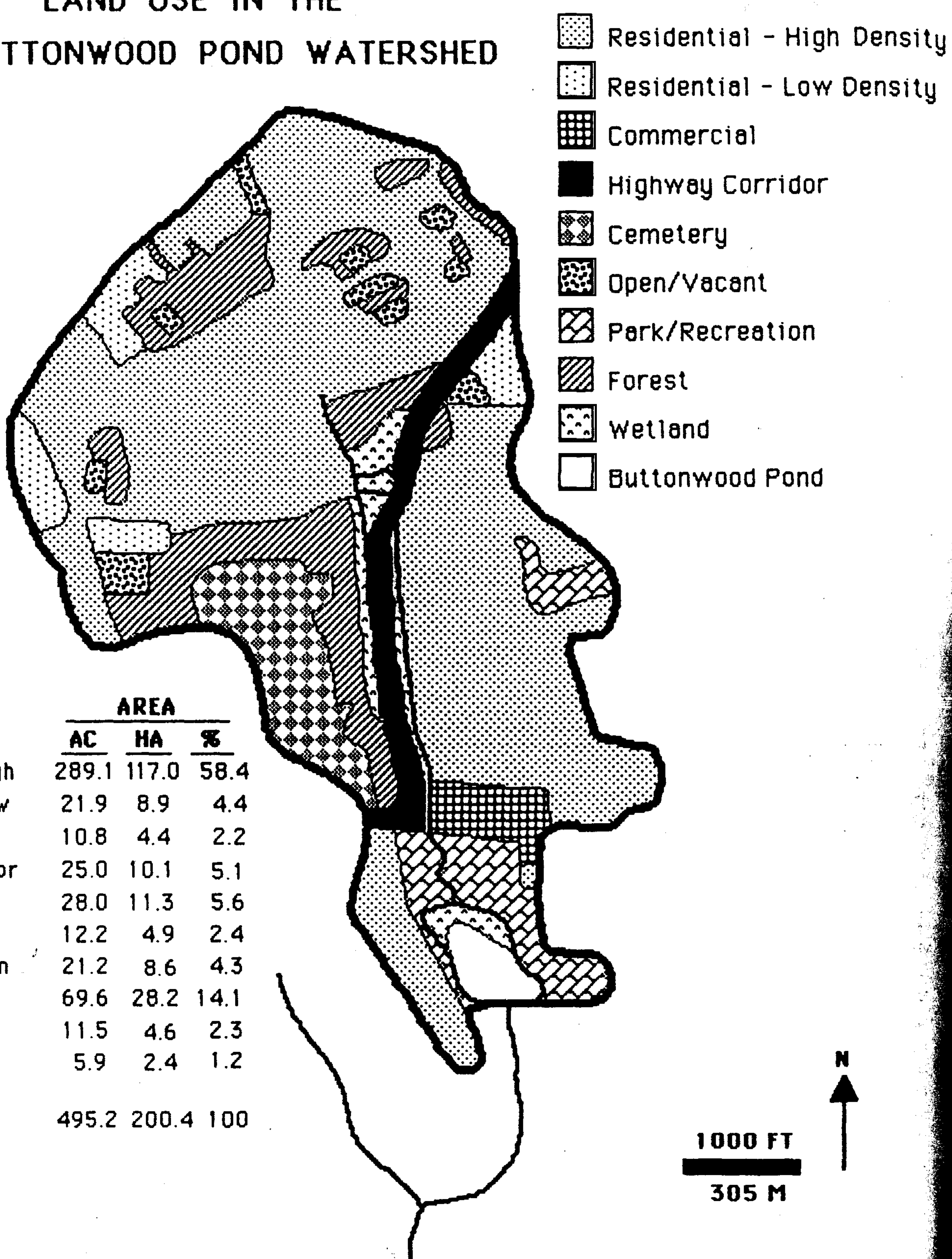


FIGURE 6

LAND USE IN THE BUTTONWOOD POND WATERSHED



LAND USE	AREA AC	AREA HA	AREA %
Residential - High	289.1	117.0	58.4
Residential - Low	21.9	8.9	4.4
Commercial	10.8	4.4	2.2
Highway Corridor	25.0	10.1	5.1
Cemetery	28.0	11.3	5.6
Open/Vacant	12.2	4.9	2.4
Park/Recreation	21.2	8.6	4.3
Forest	69.6	28.2	14.1
Wetland	11.5	4.6	2.3
Lake	5.9	2.4	1.2
TOTAL	495.2	200.4	100

The piping of storm drainage results in ten discernible sub-drainage basins for Buttonwood Pond (Figure 7). Approximately 47% of the watershed lies within Area 10, a predominantly dense residential area (Bayberry and Rockdale West developments) which includes the headwaters of Buttonwood Brook. Water generated in this area is piped or channelled to an existing detention basin adjacent to Route 140 in Area 8. However, the detention basin was apparently not designed or built to detain water at flows less than those associated with extremely large storms (e.g., 100 yr event), and there was no detention of storm water over the range of flows observed during this study.

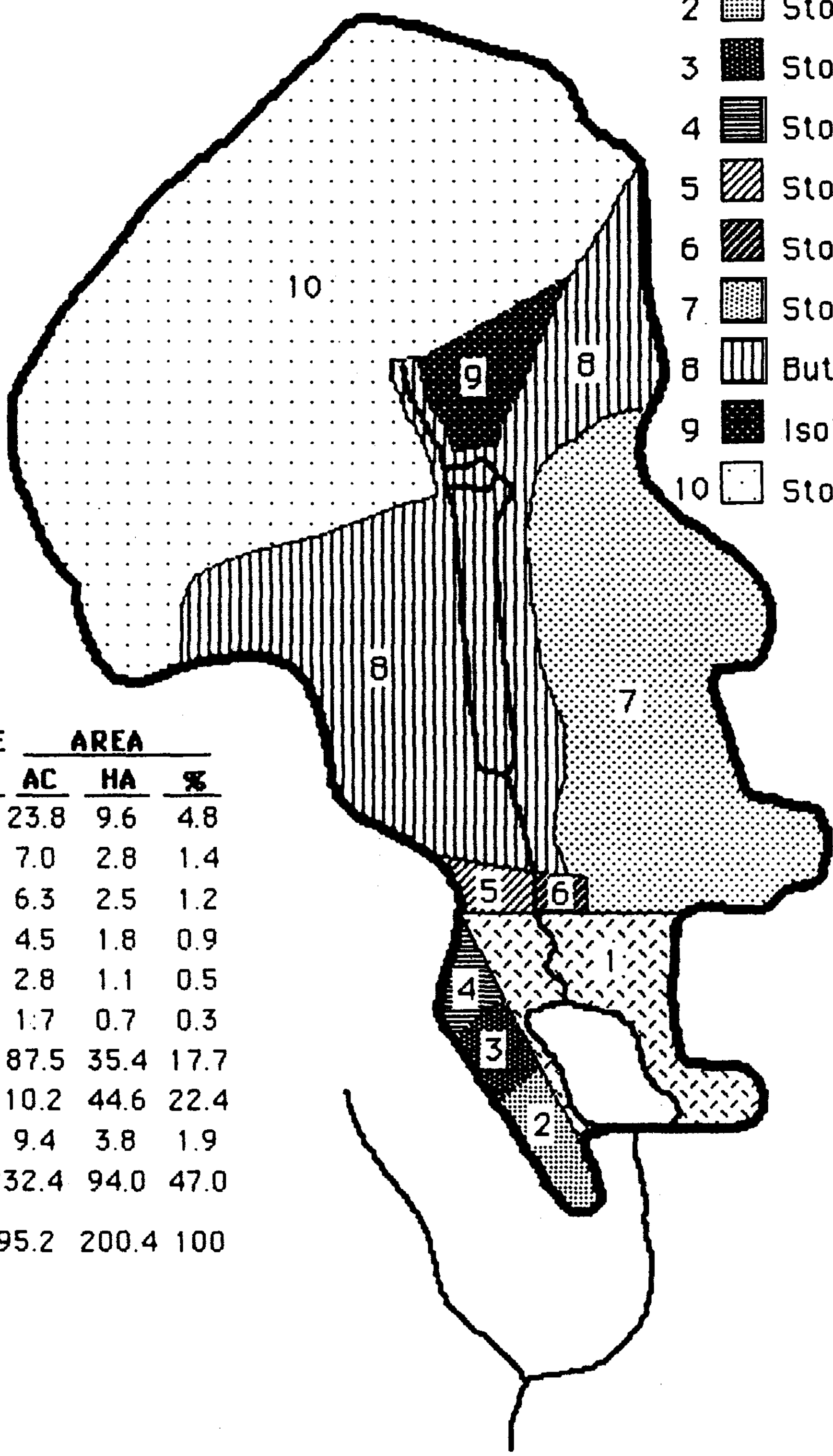
The next largest drainage area is Area 8, at slightly more than 22% of the total watershed area. This parcel contains residential and forested lands, the cemetery, and the Route 140 corridor. Drainage to the brook from nearly all lands but the highway in this area is without piping or clear channels. Route 140, however, has 12 drain pipes (0.3 m dia. each) and 16 concrete and stone sluice channels (each about 1 m wide) which route water off the road and into Buttonwood Brook within Area 8. Additionally, there are three drains routing water from parking areas on the east side of Route 140 (associated with the Rockdale East development) into Buttonwood Brook within Area 8. Buttonwood Brook flows on both sides of Route 140 through most of Area 8; the detention basin discussed above has two outlets, with the eastern one passing water under Route 140 via a 0.8 m (2.5 ft) diameter pipe. Flow on the eastern side of Route 140 is minimal, however, except during storms; most of the flow passing through the detention basin exits via the southern outlet and runs along the west side of Route 140.

Area 7 (Figure 7) occupies just under 18% of the watershed, but is one of the most critical parcels from the perspectives of pollutant loadings and management needs. Area 7 is almost entirely dense residential land, and the runoff from this area is delivered to Buttonwood Brook by a single 0.9 m (3 ft) diameter pipe which discharges into the brook about 50 m upstream of the inlet to Buttonwood Brook.

Area 9 is a self-contained woodland/wetland parcel which overflows into Area 8. Area 1 consists of Buttonwood Park land which drains into the pond or brook via overland runoff alone. The remaining drainage areas (Areas 2-6) are comprised of residential/commercial lands and roadways which are served by storm sewers which discharge directly into the brook (Areas 4, 5 and 6) or pond (Areas 2 and 3). During dry periods most of the background flow through the pond can be traced to a small wetland on the northwest edge of Area 10. Very small dry weather additions to that flow are sometimes made by Areas 8 and 9. There is virtually no dry weather flow contribution from the other sub-watersheds noted.

FIGURE 7

SUB-DRAINAGE BASINS IN THE BUTTONWOOD POND WATERSHED



DRAINAGE AREA #	AREA AC	HA	%
1	23.8	9.6	4.8
2	7.0	2.8	1.4
3	6.3	2.5	1.2
4	4.5	1.8	0.9
5	2.8	1.1	0.5
6	1.7	0.7	0.3
7	87.5	35.4	17.7
8	110.2	44.6	22.4
9	9.4	3.8	1.9
10	232.4	94.0	47.0
TOTAL	495.2	200.4	100

Watershed Geology and Soils

The entire New Bedford region is underlain by Alaskites, which are gneissic granites of Proterozoic age (Zen 1983). Some hornblendes and schists are found, and muscovite is a common component of the gneiss encountered. Bedrock color ranges from light gray through pinkish gray to tan. There has been some metamorphosis of the bedrock components, with the area described as including feldspathic gneiss and amphibolite with few indicators of metamorphic grade. The bedrock morphology has been modified somewhat by glacial activity, with accumulations of sand and silt (glacial outwash) resulting. Given the low permeability of the overlying strata in most areas, the bedrock geology does not appear to play an important role in the water chemistry of the Buttonwood Pond system.

The soils of the Buttonwood Pond watershed (Figure 8) are nearly all fine sandy loams, with the Paxton, Ridgebury, Whitman and Woodbridge series represented. Considerable portions of the watershed are also characterized by the SCS (1981) as urban complexes, which means that soil properties have been appreciably altered by development. The watershed area is fairly evenly divided between slopes of 0 to 3% and 3 to 8%, with just one parcel (northwest corner) having a slope of 8 to 15%.

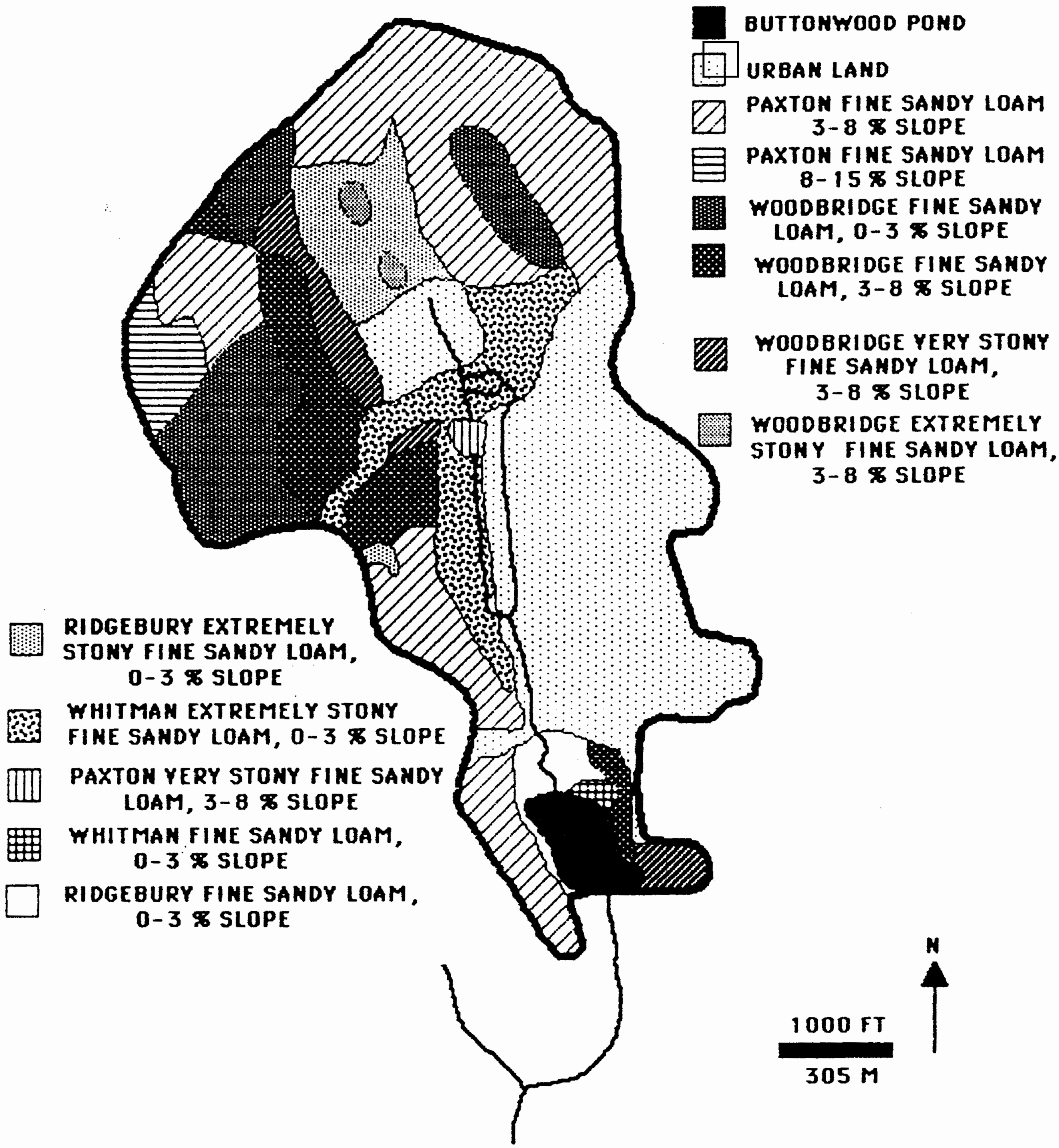
Fine sandy loams have permeabilities which range from 0.5 to 15.2 cm/hr (0.2 to 6.0 in/hr) (SCS 1981), suggesting poor to moderate drainage characteristics. Given the high frequency of silts in the New Bedford subsoil and the relatively thin nature of the topsoil, a relatively slow percolation rate would be expected for precipitation falling on the soils in the Buttonwood Pond watershed. Coupled with extensive coverage by impervious surfaces, this suggests great potential for the generation of runoff. The large flows generated by storm events are therefore not surprising.

Historical Lake and Land Use

All of New Bedford was a seaboard lowland with open tundra characteristics at the close of the last ice age. A spruce - fir forest subsequently covered the area, giving way to a deciduous forest. In terms of settlement, nearby coastal areas were more attractive to Native Americans and European settlers alike. Nevertheless, as the City of New Bedford grew, this area became a source of lumber, and there were few trees remaining in the area after initial settlement by Europeans. The Buttonwood area was purchased from the Native Americans by the Russell family, founders of New Bedford, then passed into the ownership of the Giffords. Eventually the tract was broken into 16 lots which were used as pasture or stood idle until about 1870 (Kestenbaum 1987). The first buildings in the immediate area of the current park were built in the 1870's, and by 1892 there were several boarding houses at the perimeter of what is now Buttonwood Park.

FIGURE 8

SOIL TYPES IN THE
BUTTONWOOD POND WATERSHED



Whether Buttonwood Pond was a pond, emergent wetland, or stream channel prior to settlement of the area by Europeans is unknown, but during the 1800's it was used as an ice pond, and maintained its pond status from that time on. An archaeological study conducted by the Public Archaeology Laboratory, Inc. revealed evidence of considerable human influence prior to park establishment, primarily by fill introduction and solid waste disposal. No potentially valuable finds were recorded, however, and no further investigation was recommended; a finding of no significant archaeological resources was issued.

The relevant history of the pond and its watershed really begins with the establishment of Buttonwood Park in the late 1800's. The events leading to park establishment and the modifications which have taken place over nearly a century since that time have been chronicled by Ms. Joy Kestenbaum, landscape historian for Buttonwood Park, as part of the Olmsted Historic Landscape Preservation Program of the Massachusetts Department of Environmental Management. A summary of her findings is included in Appendix A.

Buttonwood Park was established on undeveloped land under the direction of Stephen Brownell, Chairman of the Park Commission and a subsequent mayor, just before the start of the twentieth century. The firm of Olmsted, Olmsted and Eliot was retained to advise the City on key features and layout, but much of the original plan was not carried out. The park, as originally envisioned, would have encompassed about 60 ha centered around a lake of substantial size, and would have included the great meadow, peripheral transportation arteries, and vegetative screening from bordering developed areas which typifies the classic Olmstedian landscape designs of the mid- to late 1800's. Instead, a flat, lightly vegetated park of about 24 ha with a 2.4 ha pond and an expansive lawn was created, largely as a consequence of the economic and political climate in New Bedford at that time. The existing pond was dredged at that time and the dredged material was used to grade the surrounding land.

Additional land parcels were added as they became available and as funds permitted, and a former Olmsted associate, Warren Manning, prepared a plan for bringing the park more in line with Olmsted's principles for landscape design. Manning's recommendations were not closely followed, however, and the park continued to develop in a somewhat haphazard way. A zoo was gradually incorporated into the park, Court Street was constructed through it, the current outlet structure was built, and the pond was enlarged somewhat. Recreational features such as ballfields, playgrounds, and a bandshell were added.

Buttonwood Park became the largest and most frequented park in New Bedford, but the lack of a cohesive design has prevented the park from realizing its full potential as a haven from the negative aspects of city life.

Of particular importance to Buttonwood Pond and Brook was the analysis and design work of one Mr. William F. Williams, a City engineer who undertook the restructuring of the waterway through the park after floods destroyed the existing outlet structure and channels in 1902. Mr. Williams noted increasing variability in flows as development around the park and upstream on Buttonwood Brook proceeded, and feared that the water supply might be inadequate to maintain the pond during prolonged dry spells. A canal downstream of the pond with steep slopes and riprap reinforcement was proposed, and the section of the brook downstream of the pond within the park was extensively modified. A new outlet structure and overpassing roadway (Court Street, or Fuller Ave.) were also constructed at that time, but no upstream improvements were made. Many of the hydrologic problems facing the park then, as perceived by Williams, still persist and have been magnified by extensive development of the watershed.

Public works projects beginning during the Great Depression and continuing through the 1960's resulted in the addition of such structures as the warming house and Buttonwood Library, along with a host of monuments spread throughout the park. Many wetlands of the Buttonwood Pond watershed were converted to residential areas during this period. By the late 1970's, few developable parcels remained. The extension of City water and sewer lines to all reaches of the watershed (SRPEDD 1978) has facilitated almost complete development, with only a few wetland areas likely to be preserved.

Land use in the Buttonwood Pond watershed in 1971 was already dominated by residential uses at 45% of the total area, according to the McConnell Map Down Series, New Bedford North Quadrangle (1971). Route 140 and St. Mary's Cemetery are shown in their present forms, and wetland area is about the same as today. There has been a slight decrease in open and recreational space, but the most striking difference is the decline in agricultural lands from 33% in 1971 to about 14% in 1986 (Figure 6). Concurrent with the decline in agriculture has been an increase in residential and commercial usage from 45% in 1971 to about 66% in 1986. Appreciable future changes are not anticipated.

As flooding problems were noted early in this century, runoff from agricultural and even wetlands must have been substantial during major storm events, probably owing to the nature of the soils. Agricultural pollutants undoubtedly entered Buttonwood Pond, although the more extensive wetlands north of the pond probably provided more storage capacity and treatment then. With the advent of dense housing developments and associated storm drainage, however, the delivery of runoff to the brook and pond has substantially increased. Flood events expected to have an occurrence frequency of once every ten years based on hydrologic data for 1930 through 1950 now occur about once every two years, according to City officials and park personnel. The pollutants associated with storm runoff are causing physical, chemical, and biological impairment of the pond, and have reduced recreational utility and habitat quality for most forms of aquatic life.

Several studies performed in the 1970's (Tibbetts Engineering Corp. 1970, SCS 1976, GHR Engineering Corp. 1980) have assessed the flooding problems and recommended possible solutions. These recommendations include the modification of the pond and brook within the park and alteration of the culvert under Hawthorn and Brownell Streets, which carries water out of the park and downstream to the confluence with the other branches of Buttonwood Brook. No modifications have yet been made in these areas. The use of upstream detention basins have been recommended and in one case carried out in association with major development projects. It is interesting to note that the existing upstream detention basin and entry channel associated with the Bayberry and Rockdale West developments have been cited by the SCS (1975b) as good examples of storm water management techniques. We at BEC concur in principle, but the actual design and operation of this facility provides no perceptible benefit to Buttonwood Pond.

The recreational history of Buttonwood Pond is diverse, and has been largely dictated by the changing physical and chemical nature of the pond. From its "original" use as an ice pond, Buttonwood Pond was transformed into the recreational focal point of the park by the early 1900's. Early in the park's history, Buttonwood Pond was a popular site for swimming and boating (Souza 1986). Elaborate swan boats cruised the pond on pleasant weekend afternoons, and later Red Cross lifesaving courses were taught there. Toy sailboats were set adrift on windy days. Properly attired ladies and gentlemen strolled or rode along the carriage path which ran near the pond shore. The cherry blossoms on the trees between the pond and Brownell Street attracted large crowds and provided an ideal setting for pond-side picnics.

In the winter, ice skating was popular at Buttonwood Pond. Partly in response to the popularity of the sport, the warming house was built on the eastern shore. This building also served as a boat storage and launching facility. The small island at the center of the pond provided lighting for nightime activities, particularly skating. A foot trail ringed the pond beginning in the 1930's, with an elaborate wood and concrete bridge over the inlet at the north end. Fishing was popular at the pond with adults and children alike, and both public and private stocking of the pond took place. Fishing derbies were popular spring activities. Buttonwood Pond was a true all-purpose aquatic facility, and served the public well until about the 1960's.

Fluctuating water levels, shoreline erosion, sedimentation, and deteriorating water quality became chronic problems during the 1960's. Swimming was banned for health and safety reasons. Sedimentation and fluctuating water levels minimized the utility of the pond for ice skating; appropriate ice conditions are now relatively rare. Boating in the shallow, silty waters became much less popular than in previous decades; the use of private craft in the pond was banned, and boat concessions ceased operation. Yet recently a paddleboat concession was granted to Mr. George Moniz, who has rented paddleboats at the pond for the last two summers. Shallow depths and nuisance plant growths have hampered this enterprise, however.

Fishing has continued as a popular pond use, but participation is mainly by smaller children. Stocking of the pond and competitive fishing derbies have ceased. Picnicking along the pond shore has become less common, although the cherry trees still blossom and there is ample access. Sunbathers are common at lunch hour on sunny days when the ground around the pond is dry enough to lay on. Feeding the large assemblage of waterfowl and other birds is now popular, although these pidgeons, gulls, ducks, and geese are partly responsible for deteriorating pond conditions. Many people walk or jog around the pond every day, although the condition of the trail along the northeastern shoreline and the lack of a bridge at the inlet act as deterents. The public clearly wishes to utilize Buttonwood Pond and its immediate surroundings, but the pond and its shoreline are not in a particularly usable state.

Current recreational and wildlife usage goals for the pond include paddleboating, quality fishing, skating, peripheral walking and jogging, other peripheral uses (e.g., picnicking), aesthetic appeal, and a diverse bird community (on and near the water) (NBMAC 1987). These uses are consistent with the original design and intent of the park, as outlined by Olmsted, Olmsted and Eliot in the 1890's. There is no plan to bring back swimming, as conditions are not likely to be suitable for primary contact recreation on a continuous basis. These goals are admirable and achievable, and a Master Plan for reaching them is now in place.

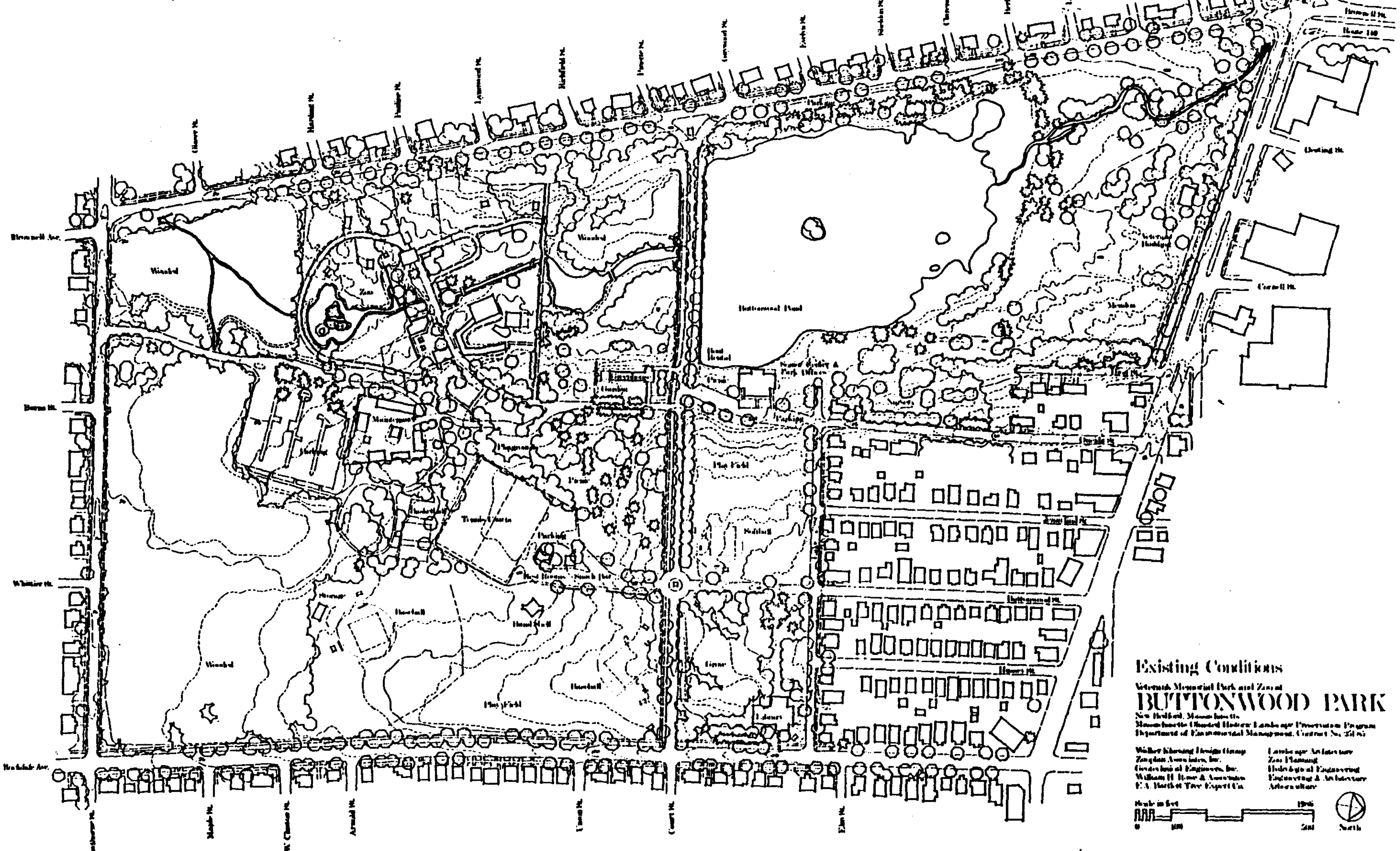
In 1985 the New Bedford Municipal Advisory Committee was formed to guide the proposed restoration/alteration of Buttonwood Park. Funds were expected to become available through the Olmsted Historic Landscape Preservation Program of the

Massachusetts Department of Environmental Management (MDEM). Such monies did become available, and this committee has met monthly to help hired consultants devise a workable park plan and priorities for implementation. The Walker-Kluesing Design Group from Boston has acted as the lead consultant, preparing the Master Plan with input from other consultants with relevant specialties. A current list of committee members, including Dr. Wagner of BEC, is included with the historic summary in Appendix A.

The existing conditions in Buttonwood Park as of 1986 are shown in Figure 9, while an illustrative version of the approved Master Plan is presented in Figure 10. Relocation of the tennis courts has been accomplished already, and money has been allocated for certain parking improvements, tree maintenance, and additional plantings. None of the original grant monies have been allocated for pond improvements, as the exact nature of those improvements will not be known until the Clean Lakes Program Phase I Project Report (this document) is completed and approved. The Master Plan does call for morphometric alteration of the pond, although the precise shape and island configuration is not definite at this time. Eventual enlargement of the pond is desired, but this is dependent on the removal of Court Street an indefinite number of years from now. The intent is to produce a more linear, streamlined system which incorporates the best features of the current pond and associated wetland while improving recreational opportunity, aesthetic appeal, and habitat quality.

FIGURE 9

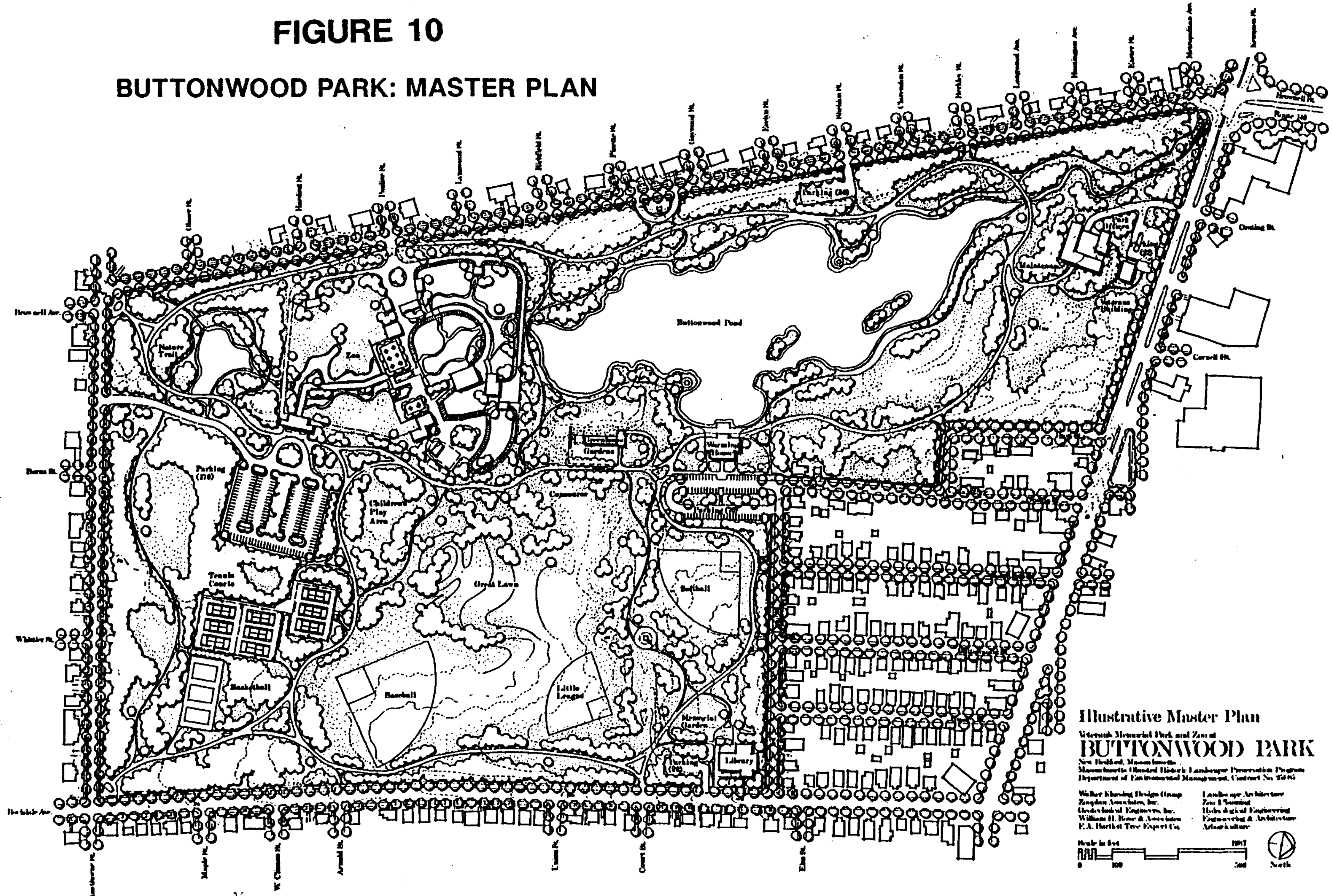
BUTTONWOOD PARK: EXISTING CONDITIONS



MAP PREPARED BY WALKER-KLUESING DESIGN GROUP

FIGURE 10

BUTTONWOOD PARK: MASTER PLAN



MAP PREPARED BY WALKER-KLUESING DESIGN GROUP

LIMNOLOGICAL DATA BASE

Limnological data were collected for one year in an effort to assess pond condition and evaluate temporal and spatial variability in physical, chemical, and biological features. Through this data collection effort we attempt to learn how the system functions and which factors are important to its well-being. Considerable information is generated, and one must sort out the critical items from those of general interest or minimal utility in the management of the system. Therefore, in the interest of brevity, most raw data have been incorporated into a technical appendix (Appendix B) which serves as a support document to this report. Calculation sheets which detail the derivation of useful values and other information of secondary importance have also been included in an appendix (Appendix C).

Flows and Water Chemistry

The chemical nature of Buttonwood Pond influences biological characteristics, and is itself greatly influenced by the rate of transfer of substances into and out of the water column. Flow characteristics are therefore of major importance in the system. Inflow from the one tributary, Buttonwood Brook, is erratic, with flows ranging from about 0.5 to 49 cu.m/min (0.3 to 28.8 cfs) (Table 3, Appendix B). The arithmetic mean of the flows measured by BEC personnel was just over 6.5 cu.m/min (3.8 cfs), but a simple arithmetic mean of less than 20 values may be inappropriate for a system with such high variability.

There are two levels of flow in the Buttonwood Brook system: background, or dry weather flows, and storm, or wet weather flows. Dry weather flows are slight, usually less than 3 cu.m/min (1.8 cfs), while storm flows can exceed 170 cu.m/min (100 cfs). Storm flows tend to peak rapidly in this system, then decline to pre-storm levels about four days after a major precipitation event. Since the flow data acquired by BEC personnel represent a random sampling of the actual flow regime, they are assumed to be representative of the typical range of conditions in the brook. However, extreme events may have been missed, and the inclusion of one or two near peak storm flows could greatly skew the mean upward. The median flow for Station 1, the inlet to Buttonwood Pond, was only 2 cu.m/min (1.2 cfs), based on the BEC data.

To better characterize the flow regime of Buttonwood Brook upstream of Buttonwood Pond, BEC instituted a lay monitoring program for flow. A V-notch weir was established about 30 m upstream of the inlet in the brook channel, and measurements were recorded by park personnel on 40 out of a possible 70 days between May 14 and July 23, 1986. Vandalism and rechannelization by the Bristol County Mosquito Commission forced the termination

TABLE 3

VALUES OF MONITORED PARAMETERS IN THE BUTTONWOOD POND SYSTEM

PARAMETER	UNITS	VALUE TYPE	BU-1	BU-2S	BU-2B	BU-3	BU-7
FLOW	CU.M/MIN	MEAN	6.51			1.24	.14
		MAXIMUM	48.96			5.10	.17
		MINIMUM	.49			.07	.05
TOTAL PHOSPHORUS	UG/L	MEAN	88	98	91	85	45
		MAXIMUM	300	264	180	230	150
		MINIMUM	10	20	20	36	10
ORTHOPHOSPHORUS	UG/L	MEAN	52	32	31	29	26
		MAXIMUM	200	146	79	62	71
		MINIMUM	10	10	10	10	10
AMMONIA NITROGEN	MG/L	MEAN	.27	.04	.03	.05	.08
		MAXIMUM	2.10	.26	.16	.21	.50
		MINIMUM	.01	.01	.01	.01	.01
NITRATE NITROGEN	MG/L	MEAN	.82	.14	.06	.20	.53
		MAXIMUM	1.90	1.20	.37	1.20	.84
		MINIMUM	.10	.01	.01	.01	.08
TOTAL KJELDAHL NITROGEN	MG/L	MEAN	.89	.80	.80	.83	.42
		MAXIMUM	3.60	1.70	1.50	2.20	.57
		MINIMUM	.21	.29	.31	.31	.29
NITROGEN:PHOSPHORUS RATIO	NONE	MEAN	98.5	25.1	26.1	32.6	
		MAXIMUM	282.4	61.7	88.0	90.9	
		MINIMUM	6.6	9.8	12.2	8.4	
TEMPERATURE	CELSIUS	MAXIMUM	19.0	24.5	24.5	23.5	17.0
		MINIMUM	-.5	-.5	2.1	-.2	7.0
DISSOLVED OXYGEN	MG/L	MEAN	9.3	10.4	8.5	7.8	7.4
		MAXIMUM	14.4	14.2	14.1	15.2	9.3
		MINIMUM	6.6	6.6	4.7	2.3	2.3
D.O. SATURATION	%	MEAN	86	105	88	77	
		MAXIMUM	111	156	144	126	
		MINIMUM	71	65	53	35	
TOTAL SUSPENDED SOLIDS	MG/L	MEAN	18.5	5.0	8.2	4.8	13.9
		MAXIMUM	179.0	13.0	20.0	18.0	32.0
		MINIMUM	.2	1.2	.4	.8	7.6
TOTAL DISSOLVED SOLIDS	MG/L	MEAN	152	107	99	118	153
		MAXIMUM	257	181	153	280	188
		MINIMUM	56	53	53	61	64
CONDUCTIVITY	UMHOS/CM	MEAN	246	221	212	198	210
		MAXIMUM	400	400	360	440	440
		MINIMUM	78	98	102	103	103

TABLE 3 (CONTINUED)

LUES OF MONITORED PARAMETERS IN THE BUTTONWOOD POND SYSTEM

RAMETER	UNITS	VALUE TYPE	BU-1	BU-2S	BU-2B	BU-3	BU-7
	S.U.	MAXIMUM	7.2	7.8	8.4	7.6	7.0
		MINIMUM	5.7	6.4	6.5	6.3	5.7
TAL ALKALINITY	MG/L	MEAN	25	19	19	20	27
		MAXIMUM	35	26	26	28	33
		MINIMUM	5	13	13	13	6
LORIDE	MG/L	MEAN	53	41	37	46	42
		MAXIMUM	136	96	70	155	55
		MINIMUM	16	23	24	25	23
CAL COLIFORM	N/100ML	MEAN*	82	33		56	18
		MAXIMUM	5900	600		1300	420
		MINIMUM	0	0		0	0
CAL STREPTOCOCCI	N/100ML	MEAN*	644	75		132	1197
		MAXIMUM	100000	7000		57000	50000
		MINIMUM	0	0		0	48
:FS RATIO	NONE	MEAN	2.6	2.5		2.1	
		MAXIMUM	17.5	9.1		8.4	
		MINIMUM	.1	.1		.1	
LOROPHYLL A	UG/L	MEAN		33.4			
		MAXIMUM		91.0			
		MINIMUM		3.8			
CCHI DISK TRANSPARENCY	METERS	MEAN		1.0			
		MAXIMUM		1.3			
		MINIMUM		.5			

* GEOMETRIC MEAN APPLIED INSTEAD OF ARITHMETIC MEAN.

of this program. This data base produced a mean flow of 3.2 cu.m/min (1.9 cfs), an estimated background flow of 0.5 cu.m/min (0.3 cfs), and a maximum flow of over 50 cu.m/min (30 cfs). Measurements were made during two major storm events, one of which caused extensive flooding in the park.

During flooding, the water in Buttonwood Brook overflows the banks of the stream at several points within the park, including the area just inside the park. An account of a substantial storm event (yet not one with a low frequency of occurrence) and its effect on the brook in this area is included in Appendix B. This stretch of stream was capable of containing flows of up to 50 cu.m/min until the Mosquito Commission dredged and channelized it in July of 1986. Now it will contain perhaps 80 to 100 cu.m/min, owing to a deepening of the channel, clearing of obstructions, and the cutting of a channel through the heavily sedimented inlet area. While this reduces flooding in the park, it increases sedimentation of the pond and necessitates its use as a flood control structure. Now, when storms of substantial magnitude are predicted, park personnel open the pond drain ahead of time and increase storage capacity by partially draining the pond.

Outlet flows do not agree closely with inlet values, largely as a result of the use of Buttonwood Pond as a storm water storage facility. Flows at the outlet may be considerably greater than at the inlet if the pond drain is open in preparation for a storm, and the outflow may be appreciably lower than the inflow when storage capacity is being utilized. Outflows do tend to be less variable than inflows as a consequence of this practice, but they hardly represent the actual flow regime of the system.

The flow values gathered at Station 7 are all rather low, reflecting the minor nature of this source. Flow was observed on only six dates, indicating the intermittant aspect of this source. Station 7 is a spring-like seep along the northwest shoreline of the pond which appears to represent storm water filtering through the sediment from a broken pipe. It was originally thought to possibly represent a natural spring, but discussion with park personnel revealed that this water originated from a broken storm pipe serving part of Brownell Avenue (Drainage Area 3). Flow was observed only during the spring, when ground water levels were sufficient to prevent complete incorporation of this flow prior to passage into the pond. Water not passing through the pipe discharging to the pond at Station 6 filtered through the sediment and entered at Station 7.

Direct entry storm drains, ground water, and direct precipitation contribute only slightly to observed flows, but their relative importance to the hydrologic budget of Buttonwood Pond will be discussed further in the Hydrologic Budget section of this report. What is important about these minor sources is their tendency to contribute in concert with other flows, magnifying the variability of flows and the hydrologic instability of the system.

Phosphorus is usually viewed as the key plant nutrient in aquatic (and often terrestrial) systems. It is most often the element in shortest supply in relation to the needs of plants, and is more easily controlled than most other essential plant nutrients. The level of phosphorus in a lake is therefore of critical importance to the condition of the system.

The measured concentration of total phosphorus ranged from a minimum of 10 ug/l to a maximum of 300 ug/l during this study (Table 3). Both the maximum and the minimum values were recorded at Station 1, the inlet of Buttonwood Brook to Buttonwood Pond. Value ranges at the other regularly monitored stations were slightly more narrow but similar. Mean concentrations were similar at the inlet, in-lake, and outlet stations, ranging from 88 to 98 ug/l. These values are not significantly different (Paired T-test, $P>0.05$, Sokal and Rohlf 1981), suggesting that there is little change in water quality with respect to phosphorus as water passes through the pond. Station 7, the seepage area derived from storm water, exhibited an average total phosphorus concentration of 45 ug/l. This value appears appreciably smaller than the others, but is also not significantly different in a statistical sense; the lesser number of samplings at that station is the cause of the apparent difference (Appendix B).

Orthophosphorus, or soluble reactive phosphorus, was also assessed during this study. This form of phosphorus is more readily available for uptake by algae and higher plants than the remaining portion of the total phosphorus concentration. Total phosphorus and orthophosphorus values therefore provide a range of phosphorus bioavailability, a parameter of some relevance where nuisance growths are of concern. Orthophosphorus concentrations were appreciably lower than the corresponding total phosphorus values, ranging from 10 to 200 ug/l and exhibiting mean values of 26 to 51 ug/l (Table 3). The relative temporal and spatial patterns for the two phosphorus forms were quite similar, however (i.e., when total phosphorus is high, orthophosphorus is also elevated).

From ecological and management viewpoints, both the total phosphorus and orthophosphorus means are rather high. Total phosphorus levels of more than 50 ug/l are often cause for concern, as they can fuel substantial algal blooms. However, bioavailability mediates the actual impact of phosphorus concentration, making evaluation of orthophosphorus levels desirable. If algal production is limited by phosphorus, a very small pool (around 10 ug/l or less) of orthophosphorus might be reasonably expected. Orthophosphorus levels in Buttonwood Pond are considerably greater than 10 ug/l on average, suggesting that excess phosphorus is available. If other factors are favorable, visible blooms of algae would be expected in Buttonwood Pond.

Although generalizations can be made from mean values, the rather wide range of observed concentrations of phosphorus and other measured constituents of Buttonwood Pond water warrant further discussion. If one compares the weather record with the recorded levels of phosphorus (or almost any other parameter), one finds that higher inlet (Station 1) values correspond to periods of precipitation, unless the sample was taken at the tail end of a major event, in which case a wash-out phenomenon is sometimes observed. Low values at the inlet correspond to prolonged dry spells, during which storm water inputs were negligible. Storm water inputs therefore appear to be the major source of pollutants to the pond, and control water quality when present. In the absence of storm water inputs, water quality at the inlet of Buttonwood Pond improves markedly.

In-lake water quality exhibits less of a correlation with precipitation. This is not too surprising, given the practice of detaining storm water in the pond as a flood control measure. Much of the water in the pond after a storm is storm water runoff, and the purification capacity of the pond is insufficient to permanently remove pollutants from the water column before the next storm. The association of many pollutants with very fine particles and colloidal material (a situation discussed in more detail in association with storm water assessments), along with wind action on this shallow system, acts to keep pollutants suspended in the water column. As the detention time for water in the pond in the absence of precipitation can be as much as 30 days, this condition can persist between most storms.

Nitrogen is another important plant nutrient, and occurs in three major forms in aquatic systems: ammonia, nitrate, and organic compounds. Ammonia and nitrate can be measured directly, while organic nitrogen is assessed as the difference between the total Kjeldahl nitrogen (a digestion-based test result) and ammonia nitrogen. Ammonia and nitrate are readily available for uptake by plants, and the former can be toxic to most animals, depending on the temperature, pH, and dissolved solids level. Nitrogen inputs to aquatic systems are very difficult to control as a consequence of the high nitrogen concentration in the atmosphere, nitrogen fixation by certain plants (including bluegreen algae) and the high mobility of nitrate in soil.

Ammonia nitrogen levels at the inlet are highly variable, but those of the pond and its outlet fluctuate only moderately (Table 3). A moderate mean concentration of 0.27 mg/l was obtained for the inlet, while the means for other stations were all below 0.1 mg/l. No ammonia toxicity hazard is presented. Ammonia nitrogen appears to be rapidly converted to nitrate nitrogen in this well aerated system.

Nitrate nitrogen values fluctuated noticeably at most stations (Table 3), but average concentrations were all below 1 mg/l. The mean values for the inlet and at Station 7 were greater than 0.5 mg/l, a level seldom achieved under natural conditions (Martin and Goff 1972), but the in-lake and outlet means were relatively low.

Total kjeldahl nitrogen (TKN) concentrations fluctuated appreciably at the inlet, in-lake, and outlet stations, but were more constant at Station 7. The filtering action of the soil through which water entering the pond at Station 7 passes is probably minimizing the particulate nitrogen concentration at that station. This water was always very clear. The mean TKN level at Stations 1, 2, and 3 was almost invariant, ranging from 0.80 to 0.89 mg/l. The similarity of these moderate values suggests that relatively little particulate nitrogen is retained by the system on a net basis. During major storms, most inputs pass quickly through the system, with only the later inputs being retained for more than a day. While those inputs may be subjected to form changes and recycling within the pond, they too are eventually flushed from the system; only a very small percentage of the particulate inputs are likely to be permanently retained.

The nitrogen:phosphorus ratio, calculated as [(TKN + nitrate nitrogen)/total phosphorus] x 2.21, indicated phosphorus to be in relatively shorter supply than nitrogen at all stations nearly all of the time. This is the typical situation in freshwater lakes (Goldman and Horne 1983), and suggests that phosphorus would be a more appropriate target for control than nitrogen. The ratio does not prove that phosphorus is the limiting factor for growth in the system, however, as influences such as light and other elements have not been considered. Yet in most cases it is easier to create a phosphorus limitation than to attempt to control the other possible influences. In the case of Buttonwood Pond, emphasis should probably be given to controlling phosphorus availabilty and flushing rate; along with light, these two factors appear to be the greatest influences on algal biomass in the pond.

The temperature of water at the sampled stations demonstrated a typical temperate zone seasonal pattern of variation. The surface of Buttonwood Pond freezes during the winter, but not to any great ice depth. The ice supported human weight only a small portion of the time it was present, and ice cover was lost and reformed several times during the winter of 1986-87. The bottom water rarely differs markedly from the surface water with respect to temperature. The greatest differences are associated with warm, calm, dry periods, during which the surface of the pond reaches a higher temperature than the bottom waters. There is no true thermal stratification in Buttonwood Pond.

Dissolved oxygen levels varied appreciably over time, but were never low enough to threaten the aquatic life of the pond. The lowest values were recorded at the outlet (Station 3) and the storm water - derived seep (Station 7), each at 2.3 mg/l. Low values at the outlet were encountered only when underflow (seepage) constituted the major portion of the water exiting the pond at the outlet. Lack of aeration of ground water at both of these stations may be responsible.

In-lake temperature and dissolved oxygen profiles at 0.5 m intervals are provided in Appendix B. There is relatively little vertical variation in either parameter, except when the pond was undisturbed for a prolonged period of time (more than a week). Oxygen tended to decline with depth, but the difference between surface and bottom values was rarely substantial. The pond is generally very well mixed by wind and flow. Although the oxygen demand of incoming storm waters is potentially large, the high aeration rate and low detention time for the pond appear to counteract any impact. Only when the water in the pond is not wind-mixed for a prolonged period can the sediment oxygen demand create a detectable vertical gradient of oxygen within the pond.

The amount of oxygen that will dissolve in water is dependent on temperature, dissolved substances, and atmospheric pressure. The relation of the actual oxygen level to the maximum possible concentration is termed the percent saturation, and reveals much about the processes at work in a given system. In Buttonwood Pond the percent saturation ranges from a low of 53% to a high of 156% (supersaturated). Low values are linked to sediment oxygen demand, while high values are probably a combined product of wind aeration and oxygen generation by plants during photosynthesis. Mean values at the inlet, in-lake, and outlet stations ranged from 77 to 105%, suggesting no great deviation from complete saturation. Except during prolonged periods of low flow and little wind, there is insufficient time for oxygen consuming substances to create an oxygen deficit in this system.

Total suspended solids (TSS) concentrations are sometimes quite high at the inlet (Station 1), but tend to be moderate in the pond itself (Station 2) (Table 3, Appendix B). Low values are associated with dry, calm periods, while higher levels are linked to storm events. TSS concentrations at the bottom of the pond are often higher than at the surface; incomplete settlement of introduced particles or resuspension by wind action are both plausible mechanisms in this system. Turbidity was not an assessed parameter in this study, but the observed range of visual clarity in Buttonwood Pond seems greater than that suggested by in-lake TSS values. Variation in particle size distributions among sampling dates may be responsible, as light is more scattered (and clarity more reduced) by a given weight of small particles than the same mass of larger particles.

In some instances it is possible to estimate sediment loading from a mass-flow analysis using TSS values, but this appears inappropriate at Buttonwood Pond. The sediment load to Buttonwood Pond is primarily tractive; that is, the sediment is delivered as a moving bed on the bottom of the inlet stream, not as a suspended load which later settles out. Sediments built up at the inlet prior to the channelization in July of 1986, fanning out in a classic deltaic pattern. Extreme flows occasionally blasted small channels through this delta, usually at an angle to the current channel path, causing lateral spreading of sediment. Eventually the delta became large enough and solid enough to substantially impede flow in Buttonwood Brook from its point of entry into the park. Sediments accumulated in the stream within the park, reducing channel capacity and increasing flood potential, and finally necessitating the dredging/channelization performed by the Bristol County Mosquito Commission in 1986. Now the stream has a deep channel through the delta, and a new delta is forming, further encroaching on the open water area of the pond.

Concentrations of total dissolved solids (TDS) (Table 3, Appendix B) varied appreciably over time, ranging from 53 to 280 mg/l at the regularly sampled stations. Lower values were recorded in summer, probably as a consequence of lower chloride inputs (no road salting). In-lake values varied less than inlet or outlet values, and were lower on average, probably as a function of in-lake dilution during dry weather. Note that the sampling location at the outlet is on the downstream side of Fuller Ave. (Court Street), thus subjecting it to salt and other inputs from a portion of that road. Overall, TDS concentrations were moderate to high throughout the system.

Conductivity values for the regularly sampled stations generally mirrored the TDS values (Table 3, Appendix B), although the correlation between these parameters was not as strong as in most other systems studied by BEC. Usually, TDS values in mg/l are about two thirds as large as conductivity values in umhos/cm (siemens). Except at Station 7, the intermittant seepage area derived from storm water, TDS values were only 50 to 60% of the corresponding conductivities, on average. The generation of higher conductivity per unit of dissolved solids may be caused by a preponderence of multivalent ions (e.g., calcium, sulfate), or the results could simply represent field or laboratory error. Mean conductivities ranged from 246 umhos/cm at the inlet to 198 umhos/cm at the outlet, all fairly high values and indicating potentially great fertility within the system.

A shoreline conductivity survey was conducted in August to detect any "hot spots" for pollutant input via ground water seepage. The path of the sanitary sewer pipe which passes under the pond was also traced with the conductivity probe. There was very little difference among values obtained by this approach; the range of recorded conductivity values was 280 to 290 umhos/cm. Evaluation of ground water seepage (see the Hydrologic Budget section of this report) further indicates minimal inputs via seepage.

Chloride concentrations followed the seasonal pattern observed for TDS and conductivity (Table 3, Appendix B), with the lowest values recorded during summer and the highest in winter. Road salting operations are probably responsible for the high values observed, but there are certainly other sources of chloride in the area. Most values are higher than typical background conditions observed in BEC studies of forested or lightly developed areas. Yet the observed values are not high enough to cause any detectable harm to the aquatic community of Buttonwood Pond or Brook (McKee and Wolf 1963); the observed chloride concentrations are an indication of adverse human influence on this system, but do not represent a major threat to the ecosystem.

The pH of the water at the regularly sampled stations varied by a factor of ten to almost twenty within stations, ranging from a low of 5.7 standard units at the inlet during a precipitation event to a high of 8.4 standard units at the bottom of the pond in the presence of a large benthic mat of filamentous green algae. The influence of both acid precipitation and photosynthesis on the pH in the pond is evident in these data. While fluctuations in pH over the observed range are not viewed as beneficial to aquatic life in the system, they do not represent an imminent hazard.

Mean total alkalinity at the regularly sampled stations in the Buttonwood Pond system ranged from 19 to 27 mg/l (Table 3, Appendix B), suggesting substantial but not extremely high buffering capacity with respect to acid inputs. Although acid precipitation will greatly depress the pH of storm water runoff, alkaline compounds in the accumulated street pollutant load and natural background alkalinity tend to offset this influence. When a large storm or several smaller storms in series are involved, some temporary depression of pH at the inlet is observed. When spring or summer flows are slight, algal production in the pond raises the pH detectably through the removal of carbon dioxide during photosynthesis. While no immediate threat is posed to most forms of aquatic life in the pond, these influences add to the instability of the system and increase the probability of ecological problems through additive influence.

Bacteria

Fecal coliform (FC) and fecal streptococci (FS) bacteria were assessed during this study (Table 3, Appendix B). These bacteria come from the digestive system of all warm-blooded animals, human and non-human, and do not in themselves represent a serious health threat. However, as they are often accompanied by pathogens, they are considered indicators of a potential health hazard if present in substantial quantities. The mean FC values obtained during this study were not in excess of the Massachusetts standard for contact recreation, which is 200/100ml for multiple sample geometric means. The single sample standard of 400/100ml, however, was contravened at least once at each station and over a third of the time at the inlet. As swimming is not permitted in Buttonwood Pond, this is not a point of serious concern at this time, however.

There are no bathing standards for FS, but values for this parameter were appreciably higher than those obtained for FC. In-lake values were substantially lower than those recorded at the other regularly sampled stations, but were as high as 7000/100 ml. The most visible source of fecal bacteria is the bird community, including both the waterfowl which frequent the pond and the upland/wetland species associated with the park and watershed as a whole. Other less obvious sources include pets and urban wildlife (e.g., squirrels, raccoons). As the watershed is completely sewered, human sources should be negligible, although pipe misconnections, leakage, or breakage could result in contamination of the brook.

FC:FS ratios may give some indication of the origin of observed bacteria, as ratios associated with human derived bacterial assemblages are considerably higher than those associated with non-human sources. The obtained FC:FS ratios spanned a wide range (Table 3, Appendix B), but consideration of only those ratios for which both FC and FS values were over 200/100 ml (proper approach according to Millipore Corp. 1972) strongly implicates non-human sources for observed fecal bacteria. Examination of storm water FC:FS ratios further supports a contention of non-human sources for fecal bacteria detected in the Buttonwood Pond system.

Storm Water Assessment

As storm water runoff is apparently a dominant influence on the Buttonwood Pond system, efforts have been made to adequately characterize the quantity and quality of storm water inputs to Buttonwood Pond. Without nearly constant monitoring of a storm water dominated system, however, it is not possible to precisely quantify pollutant loads induced by storm events. A certain amount of error must be accepted and dealt with in a management context. We have attempted to minimize this error by combining the required storm water assessment program with tributary investigation tasks and by emphasizing locations and parameters of apparent critical importance to the overall condition of the pond. The following account represents what we believe to be a reasonable approximation of storm water generation, handling, quantity, and quality in the watershed of Buttonwood Pond.

Storm water runoff in the Buttonwood Pond watershed is generated by precipitation falling on impervious or minimally permeable surfaces such as roads, roof tops, parking areas, and compacted soils. To avoid property damage and transportation hazards caused by flooding, this water is routed to Buttonwood Brook via pipes or overland channels. While the percentage of the precipitation in any given storm which becomes runoff varies with storm characteristics and antecedent weather conditions, it is reasonable to assume that 10 to 95% of the precipitation falling anywhere in the watershed will become runoff (based on typical runoff coefficients given by the WPCF 1970). For the overall Buttonwood Pond watershed, an average runoff coefficient of at least 0.5 (50%) is estimated. Given the relatively low slopes associated with watershed topography, this is a rather high runoff production rate, relative to the historic average for New England (Sopper and Lull 1970, Higgins and Colonell 1971). It is not a surprising rate for an urban area, however, which is precisely what the Buttonwood Pond watershed has become over the last few decades.

The routing system for storm water in the Buttonwood Pond watershed has been discussed to some extent in the Lake and Watershed Description section of this report. The sub-watersheds associated with delineated storm drainage systems are presented in Figure 7. As noted previously, Area 1 in Figure 7 includes no drainage pipes, while Areas 2 through 7 each have a single pipe outletting into Buttonwood Brook or Pond. Nearly every street within Areas 2 through 7 is served by a storm drainage system, and most side streets are served by a 0.25 m (10 inch) pipe. A few short side streets are served by 0.20 m (8 inch) pipes, and some of the drains in the side streets of the Rockdale West development have diameters of 0.30 to 0.38 m (12 to 15 inches). Major streets are served by pipes with diameters up to 0.9 m (36 inches) in diameter. The exit pipes for Areas 2 and 6 are 0.3 m (12 inches) in diameter, while the discharge pipes for Areas 3 and 4 have diameters of 0.46 m (18 inches). Area 5, which normally serves just a few drains on Route 6 (as does Area 6), has a discharge pipe diameter of 0.25 m (10 inches). Runoff generated in Area 7 enters Buttonwood Brook via a 0.9 m (36 inch) pipe, and Area 8 is served by the previously described system of pipes and sluice channels along Route 140. Area 9 has no known drainage pipes, while Area 10 drains into the detention basin in Area 8 through 0.9 m (36 inch) and 0.61 (24 inch) pipes (Figure 11).

In parts of Area 7 there are roof top drains linked directly to the system, and there are a few streets with pipes designed to allow infiltration by ground water. The storm drainage systems of the watershed are otherwise limited to street drains. No flow was ever observed in any drain during dry periods (after at least four days of no precipitation), and flows were minimal for several days following a storm event. There is considerable potential for some infiltration of ground water into almost any storm drainage system, and such infiltration is encouraged by the pipe features in parts of Area 7.

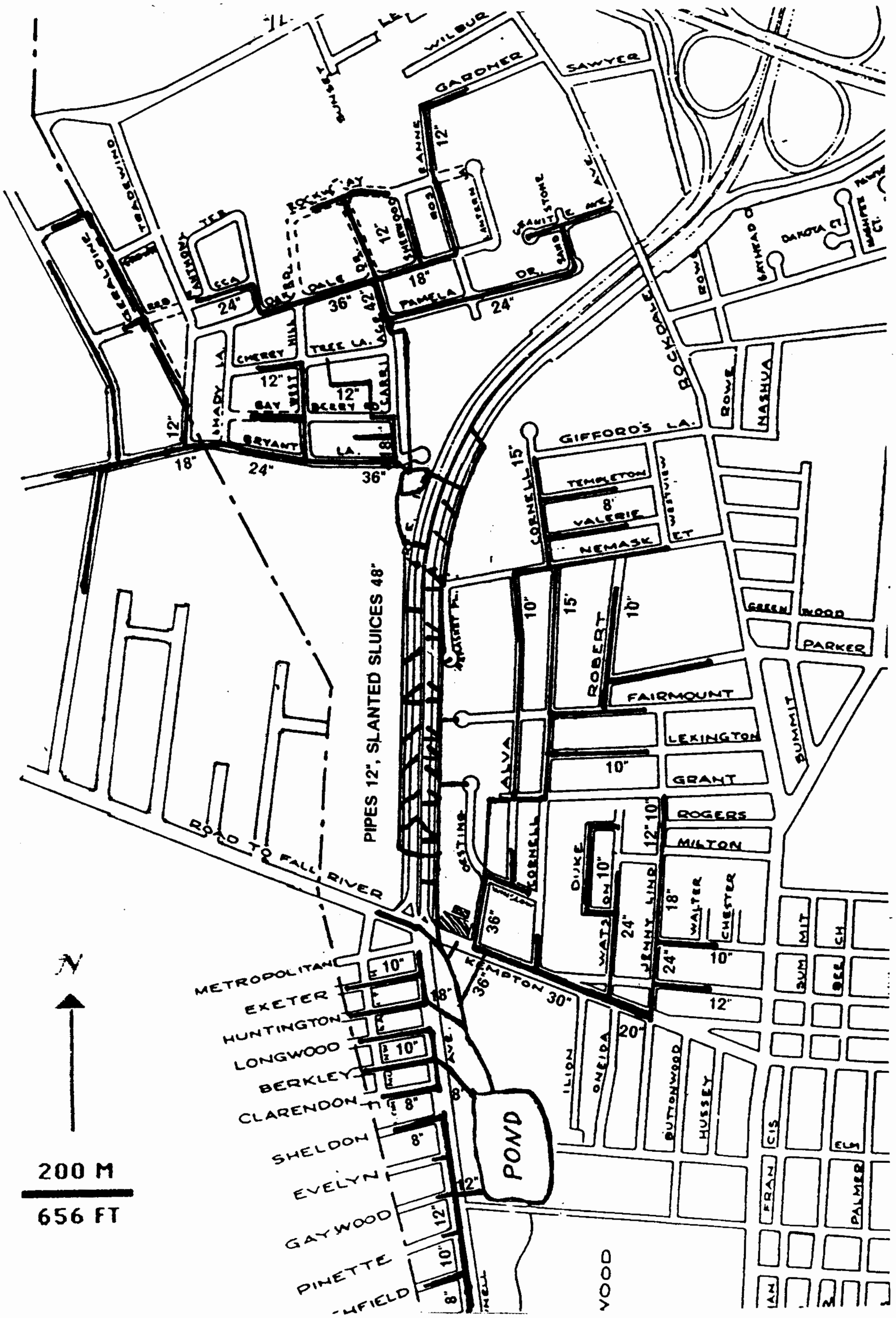
Given the potential for infiltration of storm water drainage pipes by ground water and the lack of basal flows during dry periods, there is no indication of illegal connections to the storm drainage system. Yet past problems with illegal hook-ups have been noted (Cambra 1979), and recent reports (Souza 1987) have been made regarding sewage pollution of the storm water drainage system serving Area 7. Improper use of storm drains as disposal facilites (e.g., for waste oil) has also occurred in the past, and may still be occurring from time to time.

The only broken pipe known to exist at this time is associated with Area 3, the discharge pipe for which was originally located at the inlet to the pond (at the site of the former bridge over the inlet). This pipe was apparently crushed by vehicular traffic on the lawn area, and was replaced by a PVC pipe entering the pond directly at its northwest corner. Access to the original, broken pipe was apparently not completely sealed off, resulting in the seepage area sampled as Station 7. It may be that much of the water passing through that pipe is infiltrated ground water, given the flow pattern at Station 7, but qualitative aspects of the seepage suggests some storm water influence.

Flows emanating from each delineated sub-watershed are roughly proportional to the area involved, with some adjustment for variations in runoff coefficients and piping arrangements. Delivery of runoff to the discharge point is rapid, with substantial flows observed within ten minutes of the start of a downpour. The storm hydrograph for each pipe is therefore highly dependent on the pattern of rainfall within each storm.

FIGURE 11

STORM WATER DRAINAGE SYSTEM OF THE BUTTONWOOD POND WATERSHED



Recorded storm flows (Appendix B) are highly variable, varying with the rainfall intensity and among stations. The greatest flow was routinely observed at the inlet (Station 1), as most of the runoff generated during storms passes into the pond at this point. Other points of specific interest are Stations 4 (storm drain discharge for Area 7), 9 (representing the flow from Areas 8, 9 and 10), and 12 (representing most of Area 10). During minor precipitation events the flow from Area 7 (Station 4) usually constitutes the bulk volume of the inlet flow. During major events the inlet flow includes major contributions from Areas 7, 8 and 10, with the breakdown among these major sources depending on the pattern of rainfall intensity and time of measurement during the storm. Each is capable of producing substantial flows, but the runoff from Area 7 is delivered sooner than that of Area 8, which in turn reaches the pond sooner than the runoff from Area 10, simply as a function of distance travelled.

Flows at other points within the system are either minor or are derived from the flows discussed above. Flows rarely exceed 1.0 cfs at the other storm drain stations (Stations 5, 6, 8, 14 and 15) or in any of the pipes along Route 140. On average, flow tends to increase in the downstream direction as expected, but point flows at Station 12 are sometimes larger than those at Stations 9 or 10, largely as a consequence of storage capacity in the wetland area and ditch downstream of the existing detention basin. Flows at Stations 9 and 10 tend to be less extreme than at the other stations, a desirable feature for flood control. Added to the flows from other stations, most notably that of Station 4 (the 0.9 m drain), they can still cause flooding within the park, however.

Severe flooding was not observed during any of the sampled storm events, although such flooding did occur twice during the duration of the monitoring program. The aftermath of the flooding was observed, however, and the inlet channel came very close to flooding on two occasions when BEC personnel were present. Now that the inlet channel has been deepened and cleared, and Buttonwood Pond is used as a runoff storage facility, flooding frequency should decline. However, calculations by Geotechnical Engineers, Inc. (Walker-Kluesing Design Group 1986) indicate that flooding is still likely on an annual basis, representing a hazard for park visitors and the animals in the zoo downstream of the pond. Storm water quantity will be given further consideration in the Hydrologic Budget section of this report.

The quality of storm water runoff entering the Buttonwood Pond system is highly variable over space and time, but is typically quite undesirable from the perspective of pond management (Table 4, Appendix B). Nitrogen concentrations are

TABLE 4

SELECTED PARAMETER RANGES FOR STORM WATERS AT STATIONS IN THE BUTTONWOOD POND SYSTEM

PARAMETER (UNITS)		STATION												
		BU-1	BU-3	BU-4	BU-5	BU-6	BU-8	BU-9	BU-10	BU-11	BU-12	BU-13	BU-14	BU-15
AMMONIA-N (MG/L)	MINIMUM	.06	.02	.11	.08	.07	.10	.01	.01	.03	.08	.09	.27	.19
	MAXIMUM	2.10	.21	5.50	.41	.44	.44	.35	.20	.50	.68	.30	.27	.19
NITRATE-N (MG/L)	MINIMUM	.02	.04	.08	.06	.04	1.09	1.17	.88	.32	1.13	.58	.61	.22
	MAXIMUM	1.21	.24	1.30	.69	.59	1.67	1.50	1.53	.93	3.20	.66	.61	.22
TKN (MG/L)	MINIMUM	.33	.59	.40	.37	.22	1.29	.26	.34	.30	.32	.45	.75	.25
	MAXIMUM	3.60	1.40	20.00	.88	1.60	2.90	2.17	2.66	2.00	1.42	1.17	.75	.25
ORTHO-P (UG/L)	MINIMUM	80	20	130	25	29	20	10	10	10	13	17	29	39
	MAXIMUM	155	62	2160	140	140	76	91	75	39	200	31	29	39
TOTAL-P (UG/L)	MINIMUM	150	91	235	98	51	100	15	41	46	17	77	129	110
	MAXIMUM	320	120	2500	130	180	155	253	232	173	463	174	129	110
TSS (MG/L)	MINIMUM	28	1	3	14	16	18	1	3	5	1	41	62	6
	MAXIMUM	179	18	180	112	90	34	52	84	124	80	47	62	6
COND. (UMHOS/CM)	MINIMUM	78	103	24	22	24	49	60	180	310	66	115	115	31
	MAXIMUM	220	200	375	120	135	590	138	186	600	210	655	115	31
CHLORIDE (MG/L)	MINIMUM	16.0	25.0	2.2	4.9	4.5	5.8	13.8	38.4	106.0	8.7	22.0	24.7	3.0
	MAXIMUM	53.0	45.9	92.0	31.3	272.0	198.0	138.0	42.0	228.0	42.0	247.0	24.7	3.0
PH (SU)	MINIMUM	6.3	6.3	5.6	5.5	5.5	6.1	6.1	6.5	6.6	6.3	6.3	6.5	6.5
	MAXIMUM	7.4	7.1	7.0	6.7	6.6	6.9	7.0	6.7	6.7	6.8	6.4	6.5	6.5
FC (#/100 ML)	MINIMUM	200	100	220	0	30	10	1	300	100	23	200	700	
	MAXIMUM	5900	1300	6000	1300	700	3000	18000	22000	15000	13000	8000	700	
FS (#/100 ML)	MINIMUM	3500	120	10000	610	40	50	97	141	98	37	840	900	1700
	MAXIMUM	100000	57000	100000	65000	4300	10000	107000	133000	126000	115000	113000	900	1700

most often moderate, while phosphorus levels are high most of the time at most stations. Values for total suspended solids, conductivity, and chlorides were quite variable within stations; these parameters are strongly influenced by season, antecedent weather conditions, and the intensity and duration of precipitation. The pH of samples composed primarily of storm water runoff was slightly acidic. Given the more acidic nature of rainfall in New England, substantial alkalinity is apparently imparted to the runoff by accumulated street pollutants.

Concentrations of fecal bacteria were excessive in most samples, although wash-out did occur during longer storms, resulting in some low values. The state standard for fecal coliforms in waters used for contact recreation was contravened by most samples, however. Fecal streptococci outnumbered fecal coliforms in most samples, indicating the sources of the bacteria to be non-human (Millipore Corp. 1972). Pets, birds, and urban wildlife are the likely sources in this watershed. However, there have been recorded incidents of human sewage contamination, most recently with respect to Station 4 (draining Area 7), so such contamination cannot be completely ruled out.

Levels of oil and grease and selected heavy metals were assessed during two storm events (09/16/86 and 04/28/87) (Appendix B). Oil and grease levels were low to moderate during the first storm and moderate during the second storm. These compounds most likely are derived from gasoline or motor oil spilled onto roadways or into drains, accidentally or otherwise. While visibly detectable spills have been reported in the past (Souza 1987), the observed values do not represent any serious hazard. Concentrations of heavy metals were generally low, although iron, manganese, and zinc were often present at levels distinctly higher than those of the other metals assessed. While these pollutants may accumulate in the sediments of the pond and eventually degrade environmental quality, the observed levels do not indicate substantial adverse impacts in the short run.

Several elements of the final storm sampling warrant special mention. Turbidity was added to the list of parameters to be assessed during the last storm event sampled, to provide some reference values for this useful parameter (which was not required for the monitoring program). Values were moderate to high overall, with the highest values associated with storm drainage discharge pipe stations (Stations 4, 5, 6, 8, 14 and 15). Values for water exiting the existing (and generally unused) detention basin were higher than those for water just beyond the downstream wetland and ditch along Route 140. Detectable removal of solids in this area is indicated. The turbidity of water leaving Buttonwood Pond (Station 3) was noticeably less than that of water at the inlet, suggesting that substantial quantities of solids were settling in the pond. Resuspension at a later date is considered highly probable.

Additionally, a sample was taken at the inlet immediately prior to the start of the final event sampled. Obvious increases in the concentrations of total suspended solids, turbidity, orthophosphorus, total phosphorus, total kjeldahl nitrogen, ammonia nitrogen, and flow were noted for this station during the storm (Appendix B). The pH also rose appreciably. Nitrate nitrogen and fecal coliform bacteria levels declined, while conductivity, chloride and fecal streptococci did not change appreciably from pre-storm conditions.

Another interesting aspect of the last storm event was the time series sampling performed at Stations 4 and 9. Waters passing these stations combine to provide nearly all of the flow through the inlet, and appear to carry the bulk of the pollutant load to the pond. The wash-out phenomenon was observed at Station 4 with respect to ammonia nitrogen, total kjeldahl nitrogen, orthophosphorus, total phosphorus, chloride, and conductivity (Appendix B), as values for these parameters all declined with time during the storm. The pH of the water at these stations also decreased over the duration of the storm; as the rain washed away the accumulated street load of alkaline substances, the acidic pH of the precipitation was less altered. Total suspended solids, turbidity, and flow varied with the intensity of precipitation, which exhibited several peaks during the storm.

At Station 9, representing storm water flows from Areas 8, 9 and 10, there was much less of a pattern associated with the time series samples. Only during the final heavy downpour of the storm event (associated with Sample 9E) was there any evidence of changing pollutant concentrations. Pollutant loading may be less intense in these areas, but some influence by the wetlands associated with the stream corridor is postulated. Flows at Station 9 were observed to be moderated in other sampled storm events, and it appears that the assessed parameters are similarly influenced. Water quality at Station 9 could not be construed as good, but it was considerably better than that of the water emanating from the large pipe at Station 4.

A third interesting aspect of the final storm water sampling is the data generated regarding the association of selected pollutants with various particle size fractions (Appendix B). Size fractionation of total suspended solids, nitrate nitrogen, total kjeldahl nitrogen, and total phosphorus was performed for composite samples obtained at Stations 4, 10 and 12. A substantial portion of the loads of these pollutants was associated with large particles at Station 4, the large storm drainage pipe serving Area 7. Even with the large particle (>250 um) size fraction removed, however, remaining loads were still quite high in an absolute sense. There was only a slight decrease in the concentrations of the assessed parameters over the range of size fractions analyzed for Stations 10 and 12. Much of the pollutant load passing these stations is associated with very small particles (<10 um) or is dissolved.

Sediment Analysis

Soft sediment depths do not exceed 0.5 m in the open water portion of the pond (Figure 12), but average about 1.0 m in the filled, or emergent wetland, area of Buttonwood Pond. Much of the pond area actually has soft sediments less than 0.3 m (1 ft) deep. The entire pond area is underlain by coarse sand, although the upper 0.3 m of underlayment (coarse substrate) includes detectable quantities of silt. While the absolute quantity of soft sediment in Buttonwood Pond is not great, the shallowness of the pond makes any accumulation of soft sediment appear substantial. Although the average depth of the sediments in the emergent wetland is only 1.0 m, this is enough to produce dry land in that area most of the time; only during flooding is this area submerged.

Soft sediments include topsoil, sand, and silt eroded from the watershed and organic matter produced primarily in the pond. In the filled area along the northern side of the pond, debris such as tires and plastic products have accumulated as well as eroded soils. The organic content of the soft sediments is not especially high, indicating that organic matter is not the primary component of the sediment; inputs from past erosion are the primary agents of infilling at Buttonwood Pond.

Soft sediments collected from two stations in Buttonwood Pond (Figures 2 and 12) were analyzed for selected metals, nutrients, oil and grease, and organic content (volatile solids) (Table 5). Comparison of recorded values with reference values obtained by the United States Geological Survey (USGS 1977) indicates that the sediments of Buttonwood Pond do not contain any of the assessed compounds at extremely high levels; all are less than the reference values representing the lower limits for samples in the upper 10 to 15% of USGS samples. This does not mean that sediment quality is acceptable, only that it is not extremely poor, relative to other sites evaluated by the USGS.

Comparison of sediment parameter values with the reference values established by the United States Environmental Protection Agency (USEPA 1977) for evaluating sediment quality in Great Lakes reveals that Buttonwood Pond would be considered heavily polluted with respect to arsenic, lead, zinc, oil and grease, total kjeldahl nitrogen, and volatile solids. The pond would be rated as moderately polluted with respect to copper, and

FIGURE 12

SOFT SEDIMENT DEPTH AND SEDIMENT SAMPLING LOCATIONS IN BUTTONWOOD POND, BUTTONWOOD PARK, NEW BEDFORD, MA

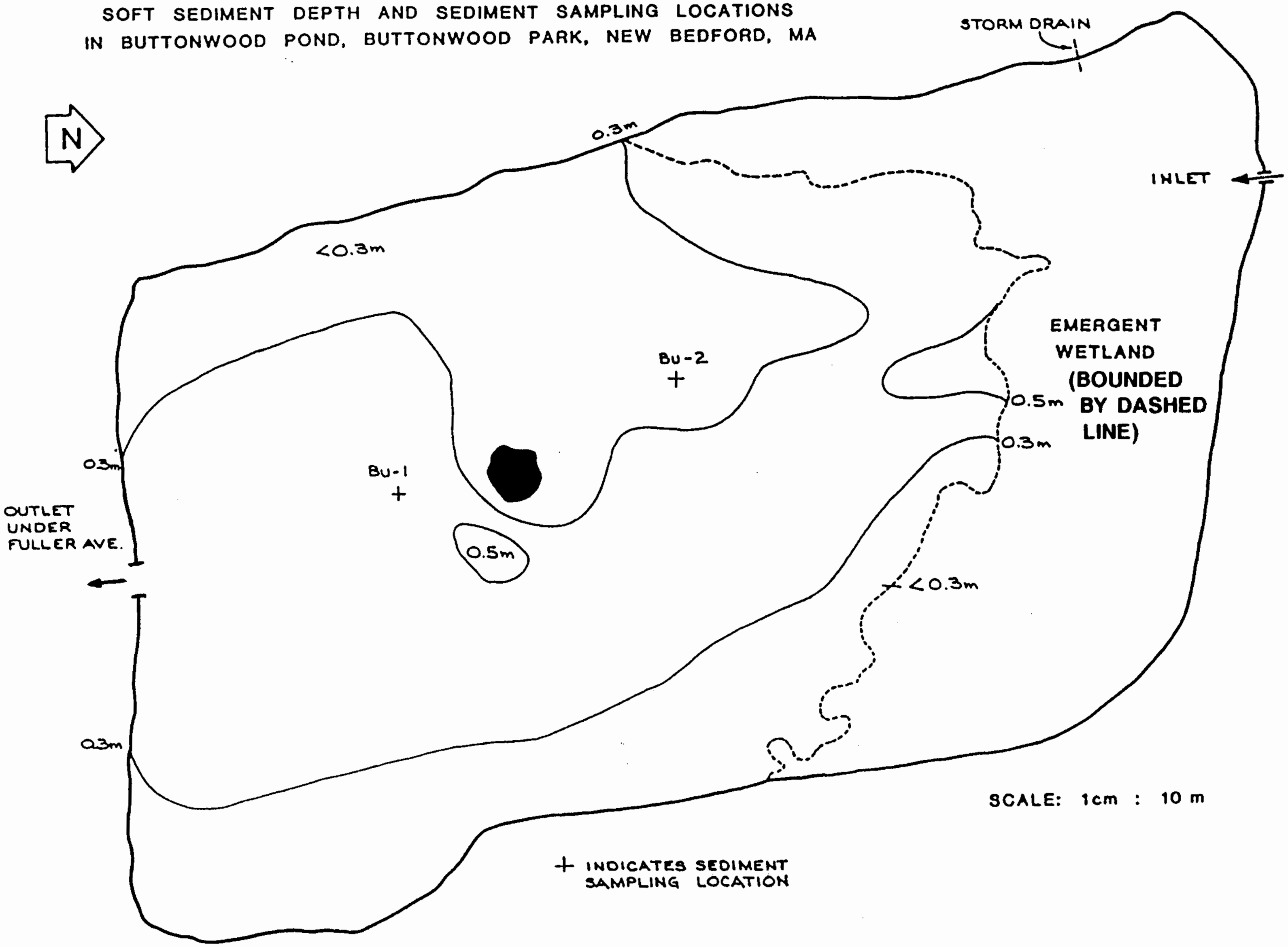


TABLE 5

CHEMICAL CHARACTERISTICS OF BUTTONWOOD POND SEDIMENTS
COLLECTED IN AUGUST, 1986

PARAMETER	CONCENTRATION (MG/KG) AT EACH STATION BU-S1	BU-S2
ARSENIC	10	5
CADMIUM	2.7	1.8
CHROMIUM	20	9
COPPER	61	30
IRON	12090	5170
LEAD	455	254
MANGANESE	163	190
MERCURY	.16	.06
NICKEL	22	11
VANADIUM	65	19
ZINC	334	154
VOLATILE SOLIDS (%)	12.9	8.0
OIL AND GREASE	2040	8600
NITRATE NITROGEN	26	8
TKN	4570	3170
TOTAL PHOSPHORUS	2.5	7.5

unpolluted with respect to chromium, manganese, nickel, and total phosphorus. The USEPA rating system is rather stringent; most urban lake sediments would be considered heavily polluted.

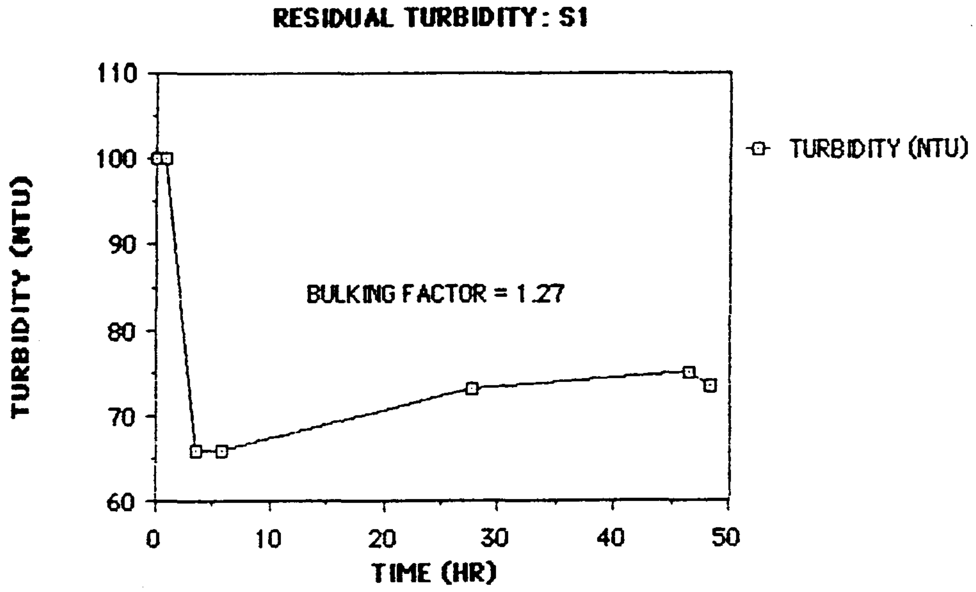
Based on the Massachusetts Division of Water Pollution Control standards for dredged material disposal (MDWPC 1979), the sediment in Buttonwood Pond is classified as Category I with respect to all appropriate parameters except zinc and lead, which yield classifications of Category II and III, respectively. Based on the established criteria for oil and grease and organic content, the sediments in Buttonwood Pond are classified as Type B. In terms of disposal, pond sediments can be characterized as moderately organic with above average concentrations of oil and grease, lead, and zinc. Upland disposal is possible without hazard, but effluent restrictions are likely to be applied to any dewatering area. The chemical nature of the sediments is indicative of the urban watershed and associated traffic by gas-powered vehicles.

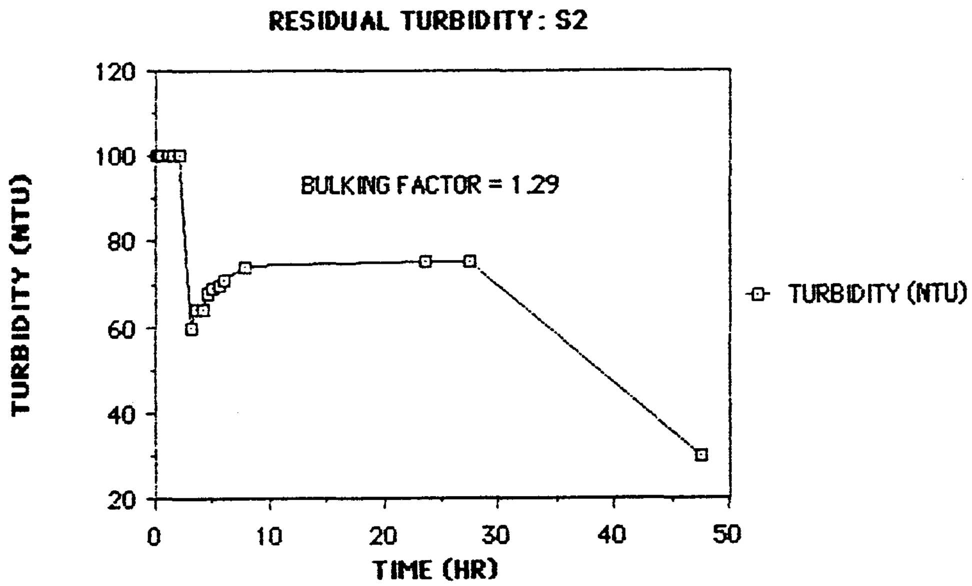
One notable aspect of sediment chemistry is the relatively low phosphorus concentration (Table 5). This may be a consequence of high inorganic content (organic soils retain phosphorus better) or low levels of phosphorus in the incoming sediment. As sediment passing through the watershed and into the pond is thoroughly washed and agitated on the way, all soluble phosphorus would be expected to be removed by the time the sediment settled to the bottom of the pond. The low phosphorus level support the contention that little phosphorus is retained by the pond.

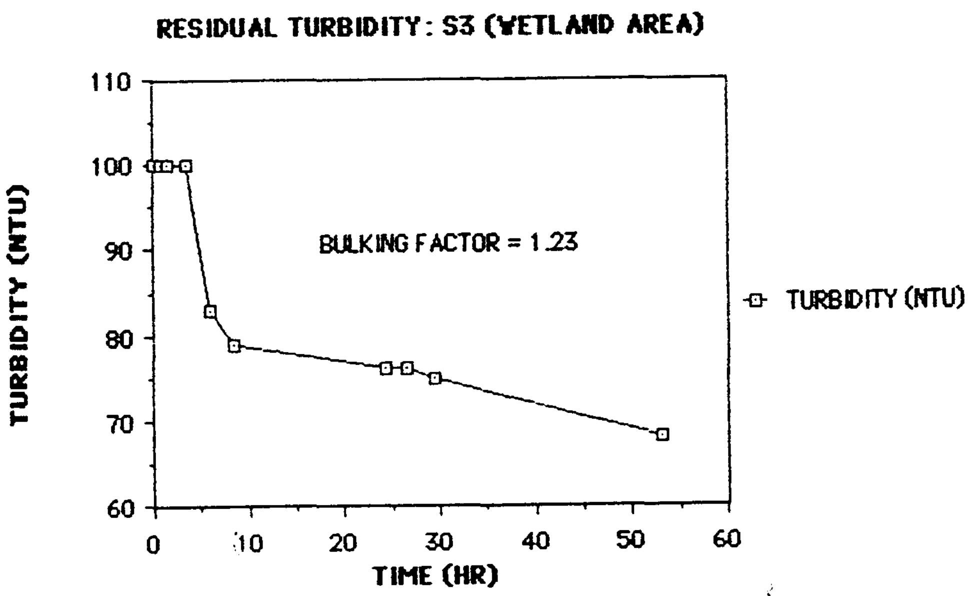
In anticipation of any dredging which may take place in the pond, settling rates, bulking factors, and residual turbidities were assessed for three samples (the two in-lake stations shown in Figure 2 and a composite of several sites in the filled area at the north end of the pond) (Figure 13). While much of the solids content settled out of the columns within ten minutes, residual turbidities never reached an acceptable level for effluent discharge (<10 NTU), suggesting that a substantial portion of the sediment particles are very fine (silt or clay range). This partly explains the persistence of turbidity in the pond after storm events or windy periods, and suggests that the effluent from any dredged material containment area will require treatment before discharge to a surface water resource.

Bulking factors were all very similar, ranging from 1.23 to 1.29. Initially, any dredged material will occupy about 25 to 30% more volume in the disposal area than it did in the pond. However, the moderate organic content of the soft sediment in the pond suggests that decomposition, shrinking, and compaction should approximately offset the bulking factor, resulting in a final disposal volume about equal to the dredged volume.

FIGURE 13


RESIDUAL TURBIDITY: S1
TURBIDITY (NTU)
110
100
90
80
70
60
0
10
20
30
40
50
TIME (HR)
BULKING FACTOR = 1.27
TURBIDITY (NTU)


RESIDUAL TURBIDITY: S2
TURBIDITY (NTU)
120
100
80
60
40
20
0
10
20
30
40
50
TIME (HR)
BULKING FACTOR = 1.29
TURBIDITY (NTU)


RESIDUAL TURBIDITY: S3 (WETLAND AREA)
TURBIDITY (NTU)
110
100
90
80
70
60
0
10
20
30
40
50
60
TIME (HR)
BULKING FACTOR = 1.23
TURBIDITY (NTU)

Phytoplankton

Phytoplankton, or algae suspended in the water column, are an important link in aquatic food webs, but may also be responsible for reduced water clarity and detectable color and odor in lakes. One useful measure of phytoplankton quantity is chlorophyll a, a pigment critical to photosynthesis. It is the same pigment that makes grass and leaves green. Chlorophyll a usually represents 0.5 to 2% of the total phytoplankton biomass and has been correlated with production and standing crop at various levels of the food web, water clarity, and phosphorus concentration (e.g., Jones and Bachmann 1976, Oglesby and Schaffner 1978, Hanson and Leggett 1982, Vollenweider 1982). Chlorophyll levels in Buttonwood Pond ranged from 3.8 to 91 ug/l, with an annual mean of 33.4 ug/l and a summer mean of 57 ug/l (Appendix B).

Chlorophyll levels are closely tied to phosphorus concentrations in many lakes. Yet summer chlorophyll levels (Appendix B) in Buttonwood Pond are about 18 to 33% lower than would be predicted from phosphorus data (Jones and Bachmann 1976, Oglesby and Schaffner 1978). Some of the phosphorus in the water column may be unavailable for algal uptake, but the presence of orthophosphorus at levels appreciably greater than 10 ug/l during most of the summer suggests that phosphorus availability is not a chronic limiting factor. Low zooplankton densities suggest that grazing by zooplankton is not a substantial, constant influence, and there is no evidence to suggest that there is any severe, persistent toxicity problem in the pond.

A slight light limitation of algal growth is postulated for Buttonwood Pond, given the sediment-induced turbidity observed in the pond, but this is more apt to affect taxonomic composition than biomass in this very shallow system. Frequent flushing undoubtedly impedes the accumulation of planktonic algal biomass in this system; distinct monthly fluctuations in chlorophyll concentration appear to be linked to local precipitation patterns. Annual mean and maximum chlorophyll levels (Table 3) are about what would be predicted from equations (Vollenweider 1982), however, suggesting that the anticipated production is often realized in the pond. Algal blooms are therefore possible, and do occur, but the phytoplankton community of Buttonwood Pond is subject to marked temporal instability resulting from erratic flushing and accompanying high turbidity.

Phytoplankton biomass is likely to constitute a major influence on water clarity in Buttonwood Pond at times, although sediment-induced turbidity is also likely to be an important influence. The mean summer secchi disk reading from Buttonwood Pond is consistent with the 0.8 m value predicted from chlorophyll measurements (Oglesby and Schaffner 1978), but the annual mean secchi disk reading was appreciably lower than the

1.6 m value predicted from the mean chlorophyll level (Vollenweider 1982) (Appendix B). This is to some degree a consequence of the shallowness of the pond (maximum depth = 1.3 m), but the pond bottom was visible at its deepest point on only three sampling dates. Non-algal turbidity (i.e., resuspended sediment) certainly decreases water clarity in this system during periods of wind or substantial precipitation.

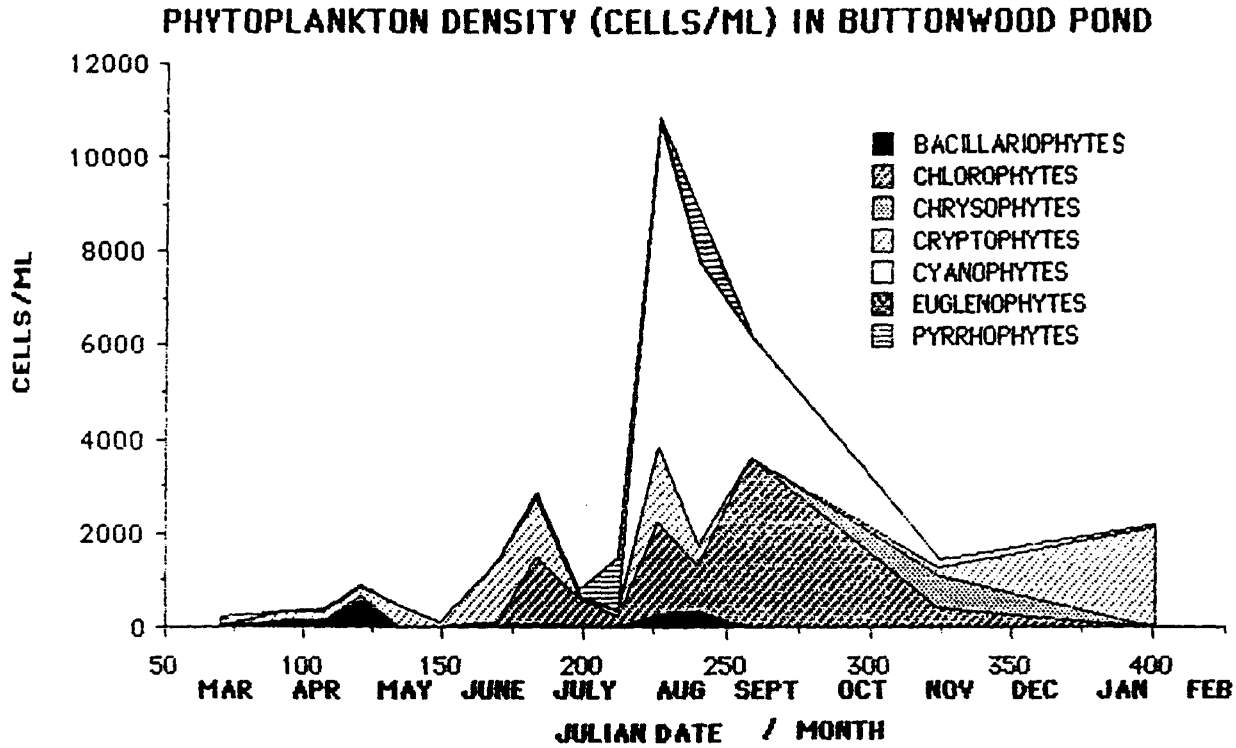
Secchi disk transparency, a measure of water clarity, ranged from 0.5 to 1.3 m during this study, with a mean of 1.0 m. Summer values were usually rather low, averaging 0.8 m. As the state standard for secchi disk transparency in waters used for contact recreation is 1.2 m (4 ft), Buttonwood Pond cannot be considered suitable for contact recreation (e.g., swimming) at this time.

Assessment of phytoplankton composition and relative abundance revealed marked shifts in the nature of the phytoplankton community over the course of this study (Figure 14, Appendix B). Bacillariophytes (diatoms) and cryptophytes (a group of small flagellates) were numerically dominant during spring, with diatoms comprising nearly all of the biomass at that time. A variety of chlorophytes (green algae) became numerically abundant during summer, but represented a major portion of the biomass only during fall, when cryptophytes and chrysophytes were also numerically abundant. Cyanophytes, or bluegreen algae, became numerically abundant in the summer, but constituted the dominant biomass component only during a dry spell in August. Pyrrhophytes, or dinoflagellates, were never numerically dominant, but the large size of most cells allowed this group to dominate the algal biomass during much of the summer and early fall.

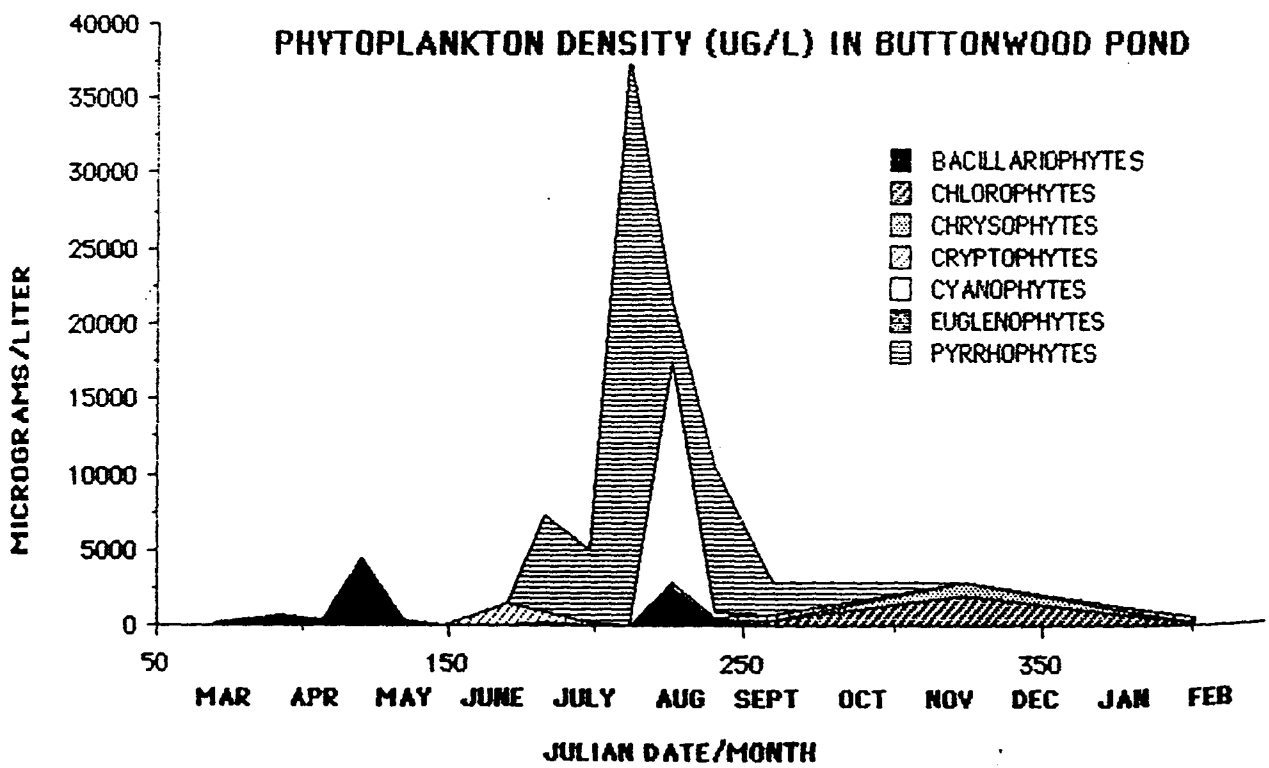
Mats of Spirogyra, a filamentous green alga, covered the pond bottom during much of the year, and sometimes floated to the surface; these mats were not included in the phytoplankton analyses, however. This macrophytic alga appears to thrive under low light conditions, and may be utilizing nutrients regenerated near the sediment-water interface. As with the other algae in Buttonwood Pond, it can be flushed from the system during storm events, but some portion of the benthic mat usually remains intact to act as a seed for further growths.

The composition of the true phytoplankton of Buttonwood Pond appears to depend on flushing rate as much as any other influence on the system. Physical removal rates and light limitations induced by turbulence are postulated as the primary determinants of phytoplankton composition and relative abundance in the pond. During warm periods of relative calm and little precipitation, bluegreen algal blooms or floating Spirogyra mats are the most visible aspects of the algal assemblage. During periods of peak

FIGURE 14



PHYTOPLANKTON DENSITY (CELLS/ML) IN BUTTONWOOD POND
12000
10000
8000
6000
4000
2000
0
CELLS/ML
BACILLARIOPHYTES
CHLOROPHYTES
CHRYSOPHYTES
CRYPTOPHYTES
CYANOPHYTES
EUGLENOPHYTES
PYRRHOPHYTES
50
100
150
200
250
300
350
400
MAR APR MAY JUNE JULY AUG SEPT OCT NOV DEC JAN FEB
JULIAN DATE / MONTH



PHYTOPLANKTON DENSITY (UG/L) IN BUTTONWOOD POND
40000
35000
30000
25000
20000
15000
10000
5000
0
MICROGRAMS/LITER
BACILLARIOPHYTES
CHLOROPHYTES
CHRYSOPHYTES
CRYPTOPHYTES
CYANOPHYTES
EUGLENOPHYTES
PYRRHOPHYTES
50
150
250
350
MAR APR MAY JUNE JULY AUG SEPT OCT NOV DEC JAN FEB
JULIAN DATE/MONTH

flow, non-algal turbidity obscures most evidence of the phytoplankton community. The relative abundance of phytoplankton species at other times appears to be a function of multiple influences, such as nutrient ratios, temperature, availability of organic compounds, and light intensity. As conditions may change rapidly in this small system, the phytoplankton community is inherently unstable. Yet it does generally exhibit the properties commonly associated with eutrophic environments (Wetzel 1983), and is capable of causing unsightly conditions in the pond.

Macrophytes

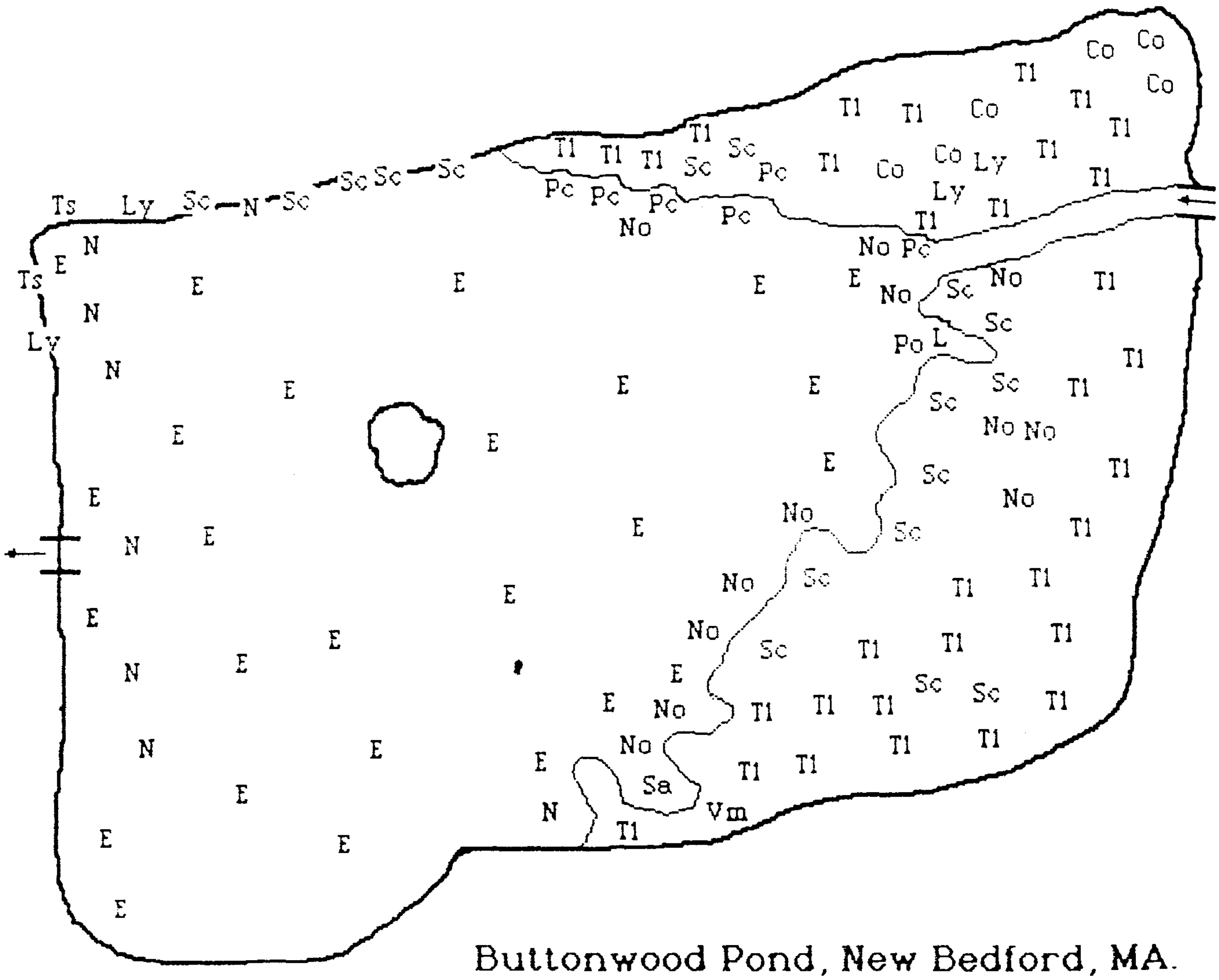
Thirteen species of macrophytes were identified in Buttonwood Pond (Figure 15), with two generally distinct assemblages occurring. The open water portion of the pond is covered by Elodea canadensis (waterweed) at variable densities, with some Nitella and mats of Spirogyra (not shown in Figure 15) present as well. The "emergent wetland" portion of the pond, which is largely the result of deltaic build-up of eroded soils, is covered by a dense plant assemblage dominated by Typha latifolia (cattail), Scirpus sp. (rush), and Cephalanthus occidentalis (buttonbush). Lythrum (loosestrife), Nymphaea (white water lily), Sagittaria (arrowhead), Polygonum (smartweed), and Pontederia (pickerelweed) are found at the interface between open water and the sediment delta. Isolated patches of Carex (tussock sedge), Lemna (duckweed), and Vaccinium macrocarpon (cranberry) were also detected.

Macrophyte densities in Buttonwood Pond are variable over space and among years, but were generally considered moderate during the study year (Figure 16). The delta area exhibited dense growths, there were several dense patches of waterweed on the bottom of the open water portion of the pond, and Spirogyra mats were sometimes extensive (not shown on Figure 16), but conditions have reportedly been worse in other years. Weather conditions are likely to greatly influence the annual development of the macrophyte community of Buttonwood Pond.

Nuisance growths of smartweed and duckweed have been noted in the past (Souza 1987), but the current problem species are mainly waterweed and Spirogyra. Waterweed growths did not reach the surface of the pond during this study, but did interfere with paddleboating and fishing. Waterweed growths have reached the surface during other years, however (Souza 1987). Spirogyra mats were observed floating on the surface on several sampling dates, but the most obvious incident of recreational and aesthetic impairment occurred the summer after field work was completed. During an especially prolonged dry period in August, mats covered

FIGURE 15

Distribution of Aquatic Macrophyte Taxa in Buttonwood Pond
New Bedford, MA; August 1986.



Buttonwood Pond, New Bedford, MA.

Key to Species

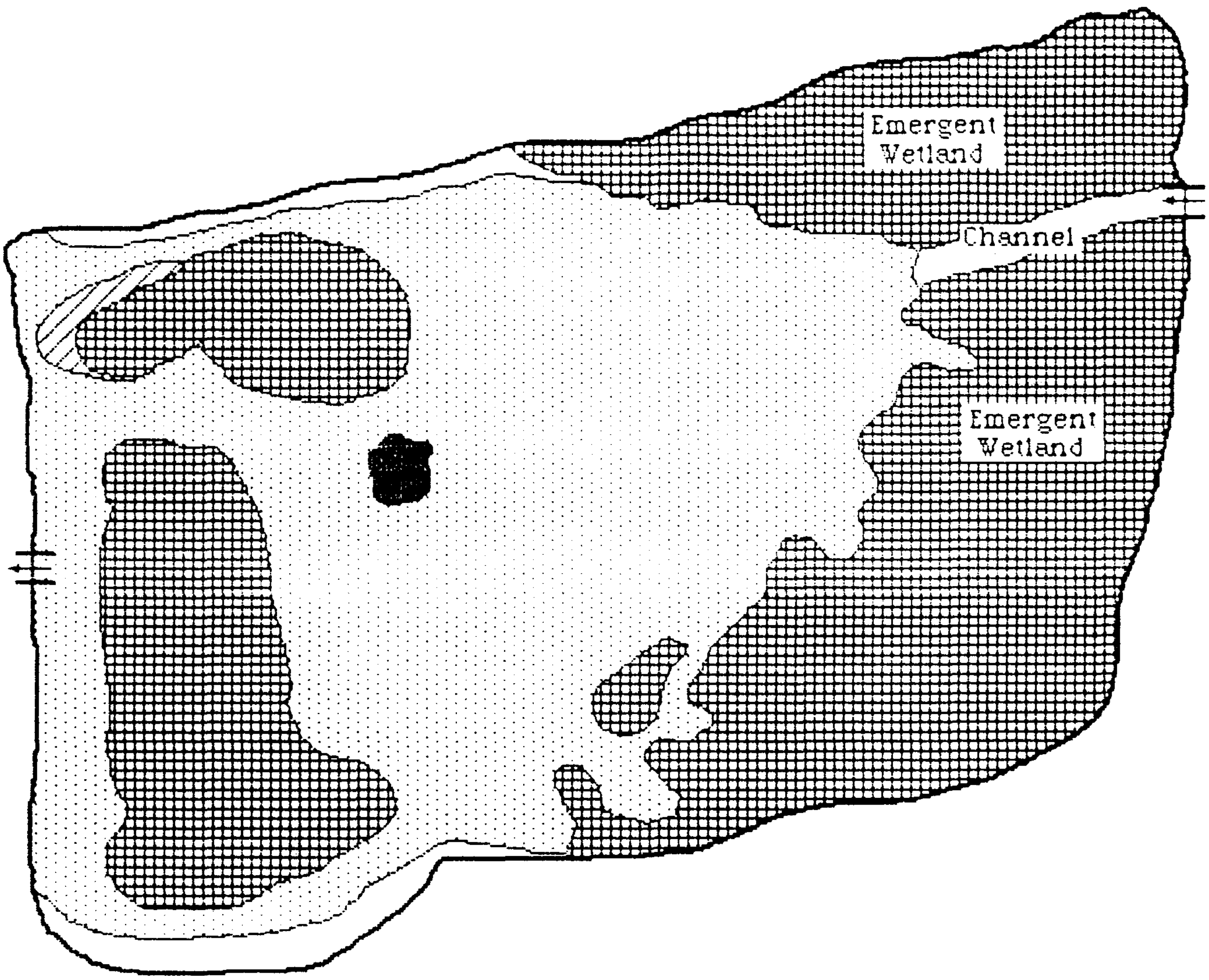
Co = Cephalanthus occidentalis (buttonbush)
E = Elodea canadensis (water weed)
L = Lemna minor (duckweed)
Ly = Lythrum sp. (spiked loosestrife)
N = Nitella sp. (stonewort)
No = Nymphaea odorata (white water lily)
Pc = Pontederia cordata (pickerel weed)
Po = Polygonum sp. (smartweed)
Sa = Sagittaria sp. (arrowhead)
Sc = Scirpus sp. (bullrush)
Vm = Vaccinium macrocarpon (cranberry)
Tl = Typha latifolia (common cattail)
Ts = Carex sp. (tussock sedge)

BEC

N

FIGURE 16

Density of Bottom Coverage by Aquatic Macrophytes in Buttonwood Pond, New Bedford MA; August 1986.



Key to Cover %	
☐	= 0 - 25%
▨	= 25-50%
⬚	= 50-75%
▦	=75-100%

Buttonwood Pond, New Bedford, MA.

→ N

BEC

much of the pond surface. A summer storm eventually flushed the floating mats from the pond and through the zoo area, but not before pond conditions evoked many complaints from park visitors and the paddleboat concessionnaire.

The species associated with the entire delta area could also be considered nuisances, depending upon one's perspective. Certain aspects of this human-induced emergent wetland enhance wildlife habitat, and a bordering fringe of emergent vegetation can be quite attractive, but the former pond area encompassed by emergent vegetation is of minimal utility to human park visitors and has only marginal value as a wildlife habitat. The dominant bird species in this area is the red winged blackbird (a very common species often considered a nuisance), and the area is largely inaccessible to fish.

Zooplankton

Spring and late summer zooplankton samples were collected from Buttonwood Pond and analyzed for composition, relative abundance, biomass, and mean length of individuals. Zooplankton densities, either as individuals or micrograms per liter, were quite low, and the mean individual length was very small (Appendix B). Small-bodied cladocerans were the dominant component of the zooplankton community, but were never abundant. A combination of wash-out and predation by abundant planktivores appears responsible for the observed features of the zooplankton community. Grazing potential is minimal, so control of algal populations by zooplankton is not expected.

Macroinvertebrates

Macroinvertebrates were not quantitatively studied in this investigation. Dragonflies and damselflies were observed at Buttonwood Pond, and chironomids were detected in the bottom sediments of the pond. Other benthic invertebrate taxa were not abundant, either as a consequence of physical conditions or predation by a fairly dense fish assemblage.

Fish

Little information is available regarding the history of the fish community in Buttonwood Pond. Private and public stocking of the pond has occurred, resulting in the establishment of populations of several warm water fish species. Bass, pickerel, and sunfish were placed in Buttonwood Pond mainly to provide fishing opportunities for area children, while shiners appear to have been introduced from the bait cans of anglers seeking bass and pickerel. Yellow perch and black crappie have also been introduced into the pond. No record of any formal survey by the Massachusetts Division of Fisheries and Wildlife was encountered by BEC while researching the historic biology of Buttonwood Pond.

BEC conducted a fish survey of Buttonwood Pond in August, 1986. A total of 396 specimens were examined, representing seven species (Table 6). Bluegills were by far the most abundant fish, at 57.1% of the catch. Golden shiners and pumpkinseeds comprised another third of the individuals captured. Largemouth bass and chain pickerel, the game fish species in Buttonwood Pond, represented only 7.5% of the catch by number; these fish represent a greater percentage by weight, but are still a relatively minor component of the fish community. A few yellow perch and black crappie were also captured. Bullheads and carp, species suited to the habitat of Buttonwood Pond, were not captured or observed at any time during this study.

The mean sizes for most species were small, but growth rates were assessed as fair to good (at or above the state average, based on MDFW 1979). The population is dominated by smaller, younger individuals, probably as a consequence of fishing pressure on larger specimens. BEC personnel have observed anglers with large bass and pickerel on several occasions, and children often keep even the sunfish and shiners which they catch. The Buttonwood Pond fishery is productive and popular, but could be greatly improved through proper management. A reduction in panfish density and enforcement of size and creel limits for gamefish are desirable.

Comparison with Other Studies

There has been little scientific study of Buttonwood Pond until recently. In 1976 the New Bedford Health Department investigated a report of a massive algal bloom in the pond during June, finding mats of Spirogyra covering 75% of the pond surface (Cambra 1976a). Fly larvae (probably chironomids) were also noted, and collected samples revealed very low coliform bacteria counts. A private contractor was retained to remove accumulated algal mats and treat the pond (chemically) for prevention of future blooms (an erroneous assumption, given the detention time of the system). Samples collected from the pond and brook shortly after the treatment indicated low concentrations of fecal bacteria. The next day a storm deposited over 2.5 cm of rainfall on the watershed. Samples taken all along Buttonwood Brook and in the pond several days after the storm revealed elevated levels of fecal bacteria. Filamentous algae were noted in the Rockdale West detention basin, including Spirogyra.

Mr. Cambra concluded that further investigation was needed to isolate bacterial sources along Route 140 and at the upstream end of the park. He speculated that the Rockdale West detention basin might be the source of the algae in Buttonwood Pond. Mr. Cambra recommended that the brook within the park area upstream of the pond be cleared of debris, and that a source of clean water for dilution and flushing be provided to the pond. Subsequent correspondence between Mr. Cambra, various City

TABLE 6

FISH POPULATION DATA FOR BUTTONWOOD POND

FISH SPECIES	COMMON NAME	# CAPTURED	% OF CATCH	MEAN LENGTH (MM)	GROWTH RATE
Lepomis macrochirus	Bluegill	226	57.1	129	Fair
Notemigonus crysoleucas	Golden Shiner	84	21.2	49	-
Lepomis gibbosus	Pumpkinseed	48	12.1	145	Good
Micropterus salmoides	Largemouth Bass	28	7.0	101	Fair
Pomoxis nigromaculatus	Black Crappie	5	1.3	206	Good
Perca flavescens	Yellow Perch	3	0.8	179	Fair
Esox niger	Chain Pickerel	2	0.5	298	-
TOTAL		396	100	-	-

NOTE: There are about 25 mm in an inch, or 4 inches per 100 mm.

officials, and the operators of the Rockdale West detention basin indicate that a physical clean up effort was requested and made in and around that detention facility, under the assumption that this would reduce the pollution of Buttonwood Pond. Further investigations by the New Bedford Health Department (Cambra 1976b) revealed at least one illegal sewage connection with the storm drain system emptying into the Rockdale West detention basin. The problem was solved shortly thereafter by proper connection with the sanitary sewer system.

Problems with Spirogyra mats cropped up again in 1977, and were dealt with through chemical treatment (Cambra 1977). Recurrent algal mats and a fish kill were observed in 1979 (Cambra 1979); chemical treatment was again recommended, along with the installation of an aerator in the pond. No such action appears to have been taken, however. Removal of dead fish was hampered by fluctuating water levels, resulting in unpleasant shoreline conditions. Similar problems appear to have surfaced in subsequent years. In 1982 the Whaling City Festival Committee inquired as to the efficacy of holding an aquatic event in the pond, with water contact likely for many participants (Lawrence 1982); the event was discouraged and apparently not held.

Potential sewage contamination in the Buttonwood Pond watershed is noted in several of Mr. Cambra's letters (e.g., Cambra 1979), apparently based on high fecal coliform levels. The influence of storm water runoff is not explicitly considered, and is a more likely source of the detected bacteria. No substantive evidence of sewage contamination was found during the BEC study, although there have been recent reports of sewage-like plumes emanating from the storm water drainage pipe at Station 4 (Sousa 1987). The problems with algal mats, specifically Spirogyra, continue to the present time, but appear to originate within the pond and not upstream in the Rockdale West detention basin.

The 1978 208 Water Quality Plan (SRPEDD 1978) contained no actual water quality data, but did note the extent of areas served by sanitary sewers and the plans to extend coverage to the entire watershed of Buttonwood Pond. That coverage is now complete. No point source discharges are shown for the Buttonwood Pond watershed, and none were detected by the BEC investigation.

Buttonwood Pond was surveyed by the Massachusetts Division of Water Pollution Control (MDWPC 1984) in August of 1984, to obtain necessary information related to priority ranking of lakes and ponds for which Phase I (Diagnostic/Feasibility) study funds had been requested. The MDWPC results correspond well with dry weather values obtained during the BEC study. A few species of macrophytes not detected in the BEC study were listed as present by the MDWPC, and several species encountered by BEC were not noted by the MDWPC. Dominant species, taxonomic distribution, and coverage were in general agreement between the two studies. Characterizations of the phytoplankton community made by the MDWPC and BEC were also in general agreement.

The MDWPC classified the pond as mesotrophic based on its own data. While the results of the one-day survey conducted by the MDWPC generally support that classification, the more extensive data base collected during the BEC investigation funded by the MDWPC suggest more eutrophic conditions. The concept of trophic state is somewhat nebulous with respect to Buttonwood Pond, however, as water quality and certain biological features of the pond can change drastically and rapidly in response to changing weather patterns.

Other studies dealing with the Buttonwood Brook system have all been directed toward the flooding problems experienced in the park and elsewhere in the system (Tibbetts Engineering Corp. 1970, SCS 1976, GHR Engineering Corp. 1980, Walker-Kluesing Design Group 1986). The reports generated by these investigations will be discussed in association with the hydrologic budget and the management options evaluation included in this report.

HYDROLOGIC BUDGET

Flow data collected from Buttonwood Pond and Brook (Appendix B) suggest a highly variable and unstable flow regime for this system. Peak flows can be two orders of magnitude higher than the low background (dry weather) flows. This phenomenon has been investigated several times over the last two decades. Peak flow estimates (at Buttonwood Pond) calculated by other firms (Appendix C) range from 495 to 867 cu.m/min (290 to 510 cfs) for a storm event with an occurrence probability of once every 10 years (10-yr storm). These calculations employ either the rational (Dunne and Leopold 1978) or SCS (SCS 1975c) method of flow estimation, and are not based on direct observations. The assumptions implicit in these methods may not be met throughout the Buttonwood Pond watershed, and overestimates are usually expected. This is desirable from an engineering viewpoint, as it provides an automatic safety factor in design work. From a water quality standpoint, however, structures designed to handle such extreme flows may not provide any water quality benefits at lower actual flows.

A peak inflow of 255 to 340 cu.m/min (150 to 200 cfs) was calculated by BEC (Appendix C) using the Weiss (1983) Method, an empirical approach based on many years of actual flow measurements for numerous watersheds. While there is certainly error incorporated into this estimate, we believe that it more accurately represents the actual peak flow likely to be observed during a 10-yr storm. Pipe diameters and slopes, debris dams, and some storage capacity upstream of the pond are likely to prohibit much greater flows. Localized flooding near catch basins and wetland areas is likely during major storms, reducing the peak flow to Buttonwood Pond and subsequent flooding within the park.

Whichever peak flow estimate one chooses to adopt, it is clear that peak flows occurring over the last several decades are not effectively handled by the drainage system and stream channels in the watershed. Even with the most recent channelization of the Buttonwood Pond inlet, flows of over 80 to 100 cu.m/min (47 to 59 cfs) cause flooding within the park above the pond, and only by using the pond as a flood storage facility can downstream flooding be reduced to a tolerable level. At greater flows, corresponding to larger storms or similar ones of greater duration, flooding often occurs even when the pond is used as a flood control structure.

In the Park Design Master Plan prepared by the Walker-Kluesing Design Group (1986), calculations and discussion of the flooding problem by GEI, Inc. indicate that Court Street (Fuller Ave.) is overtopped several times each year, resulting in substantial flooding of the zoo area and downstream edge of the park at Hawthorne and Brownell Streets. The timing of inputs to the pond and the inadequacy of flow control structures within the park are cited as the primary causes of this flooding. A synopsis of the GEI findings is included in Appendix A.

A report by GHR Engineering Corporation (1980) indicates that the low permeability of watershed soils, the rapid routing of storm water runoff to the stream channel, and continued development of the watershed result in extreme flows which are then not adequately handled by the structures within the park. These structures (e.g., channels, pond outlet, downstream culvert) were built before the watershed became developed, so the resultant flooding is not surprising.

During dry periods the flow in Buttonwood Brook can decline to undetectable levels. The mean low flow maintained over seven days is less than 0.2 cu.m/min once every two years and undetectable (zero) once every ten years (USGS 1984) at a point downstream of Buttonwood Park. Flows rarely exceeded 1.0 cu.m/min during dry periods in 1985 through 1987, but were never undetectable. Surfacing ground water (springs) at the upper edge of the Buttonwood Pond watershed supplied several tenths of a cu.m/min at all times, and much of this reached the pond. Flows slightly above the background level were observed for several days after storm events, but there were few truly intermediate flows; hydrologic inputs to Buttonwood Pond are either high or low at most points in time, with low flows dominating any long-term record.

Given the watershed area of 198 ha (489 ac), and a yield coefficient of 0.7 to 1.0 cu.m/min per square kilometer (1.0 to 1.5 cfs per square mile) of drainage area (Sopper and Lull 1970), an average flow of 1.4 to 2.0 cu.m/min (0.8 to 1.2 cfs) would be expected to pass through Buttonwood Pond. Based on the average annual New England runoff value of 53.3 cm/yr (Sopper and Lull 1970, Higgins and Colonell 1971), an average flow of 2.0 cu.m/min would be expected. The limited number of measured flows (Appendix B) yields an annual mean of over 3.0 cu.m/min, suggesting flows greater than watershed information would indicate. There is considerable potential for error, however, associated with the mean derived from a few actual measurements in a system with such variable flows. It is not the variation among expected and actual means which is alarming, however, but rather the extreme temporal variation in observed or calculated flows.

Precipitation is the major determinant of flow and consequently influences the hydrologic budget to a great extent. The long-term monthly precipitation pattern (Table 7) indicates that precipitation is greatest during the winter months, although there is also a pronounced peak in rainfall during August. New

TABLE 7

PRECIPITATION DATA FOR NEW BEDFORD, MASS.

(centimeters of precipitation as rain)

Month	Long-term NOAA Data	Study Year
J	10.3	17.7 (1987)
F	9.8	7.1 (1987)
M	10.7	7.7 (1986)
A	9.6	7.1 (1986)
M	8.5	9.3 (1986)
J	6.9	9.9 (1986)
J	6.0	15.4 (1986)
A	10.8	12.6 (1986)
S	8.5	2.9 (1986)
O	8.1	9.1 (1986)
N	10.6	18.6 (1986)
D	11.8	16.5 (1986)
Total	111.6	133.9
Maximum	181.7	
Minimum	55.5	

Data are from the NOAA New Bedford Precipitation Monitoring Station, as reported in the monthly NOAA summary reports for New England.

Bedford receives relatively little snow, and falling snow rarely lasts as snow cover for more than a week. This decreases the importance of spring thaw runoff, although precipitation events during spring can certainly generate extreme flows.

Long-term trends frequently bear little resemblance to annual patterns, however. The mean annual precipitation at the New Bedford monitoring station (from NOAA data collected between 1950 and 1980) is 111.6 cm, while the total precipitation during this one-year study was 133.9 cm (Table 7). July and August exhibited pronounced precipitation peaks, while March and September were unusually dry months. Early winter storms were severe, but late winter and spring exhibited below average precipitation. While the precipitation falling on New Bedford during this study was well above average, it was far below the record maximum of 181.7 cm. The record minimum annual precipitation is 55.5 cm, further underscoring the inherent variability in the hydrologic characteristics of the study area.

While mean flows are of little management value with respect to Buttonwood Pond, the partitioning of flow among potential sources is a useful exercise which yields information relevant to the evaluation of management options. Precipitation falling directly on the pond contributes an average of 0.05 cu.m/min (0.03 cfs), while ground water seepage into the pond provides no more than 0.03 cu.m/min (0.02 cfs) (Appendix C). Direct drainage from park land is also slight, adding approximately another 0.03 cu.m/min, based on typical runoff coefficients and the area of the park lands drained to the pond (Appendix C, WPCF 1970, Dunne and Leopold 1978). Further employing runoff coefficients in the rational approach, it appears that the 0.9 m drain (Station 4) contributes an average of 0.45 cu.m/min (0.3 cfs), and the other direct entry or proximal drains (Stations 5, 6, 8, 14 and 15) provide a flow of 0.11 cu.m/min (0.06 cfs).

Using the same approach, the flow generated by Drainage Areas 8 through 10 (Figure 7) averages 1.21 cu.m/min (0.71 cfs). From the flow data obtained on dates which were preceded by at least three days of dry weather, the background flow in Buttonwood Brook is about 0.7 cu.m/min (0.41 cfs). By subtraction, the flow contributed by storm water runoff in Areas 8 through 10 averages 0.51 cu.m/min (0.3 cfs).

Evaporation from Buttonwood Pond averages 0.03 cu.m/min (0.02 cfs) (Appendix C, Higgins and Colonell 1971), and ground water outflow is calculated at 0.15 cu.m/min (0.09 cfs). Ground water seeps out of the pond at the south end, especially around the outlet structure. As a consequence of the use of Buttonwood Pond as a flood control structure, measured outflow values may not be very meaningful. Assuming that outflow must equal inflow on average, the mean outflow via surface water in Buttonwood Brook must be 1.7 cu.m/min (1.0 cfs). This is actually not too different from the outlet flow of 1.24 cu.m/min measured by BEC.

The partioned flow values are summarized in Table 8 and Figure 17. Over 90% of the water passing through the pond enters and exits via Buttonwood Brook. Between a quarter and a third of the water passing the inlet enters the brook just above the inlet within the park, however, as runoff in storm drains (Stations 4, 5 and 8). The 0.9 m drain (Station 4) contributes almost 24% of the water entering the pond. The single largest source of water (at just over 37%) is the background flow in Buttonwood Brook, contributed mainly from Area 10 (Figure 7). This relatively constant source is augmented by sporadic inputs of storm water runoff from Areas 8 through 10, contributing slightly more than 27% of the total inflow to the pond. The resultant mean total inflow is 1.88 cu.m/min (1.1 cfs). Most observed values are substantially different from the mean, however, as it is achieved only for a brief period after storms, as the brook returns to dry weather flows.

Dividing the volume of the pond by the mean inflow, a mean detention time of 0.02 years, or 8 days, is obtained. Fluctuations in actual flow result in a detention time range of less than 0.1 day to about 30 days, however (Table 8). This equates to a flushing rate of 12.5 to 1000 times per year, with a mean of about 50 flushings per year. This supports the observation that the character of the aquatic habitat of Buttonwood Pond can change rapidly in response to hydrologic events.

The response time, calculated according to Dillon and Rigler (1975), is between 12 and 21 days for Buttonwood Pond (Table 8). The response time is an estimate of the detention time necessary for input pollutants to fully express their potential impact on the system. In the case of Buttonwood Pond, the necessary response time is exceeded only during extended dry periods. If the dry period is preceded by a storm which loads the pond with nutrients and other pollutants, serious water quality and biological problems might be expected. Even when the response time is not exceeded, however, water quality or biological problems may occur as a consequence of only partial expression of the impact of a large pollutant load on this relatively small system. Given that storm water runoff represents approximately two thirds of the water entering Buttonwood Pond, the potential for water quality problems is great.

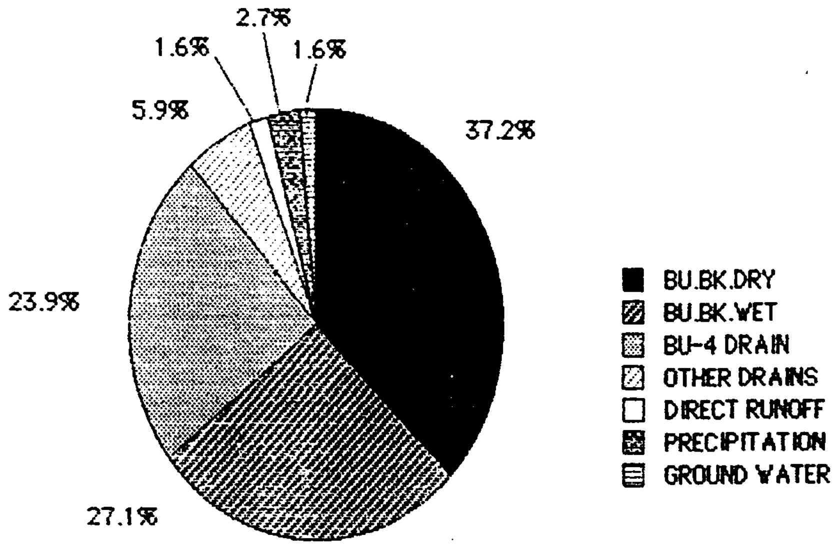
TABLE 8

HYDROLOGIC BUDGET FOR BUTTONWOOD POND

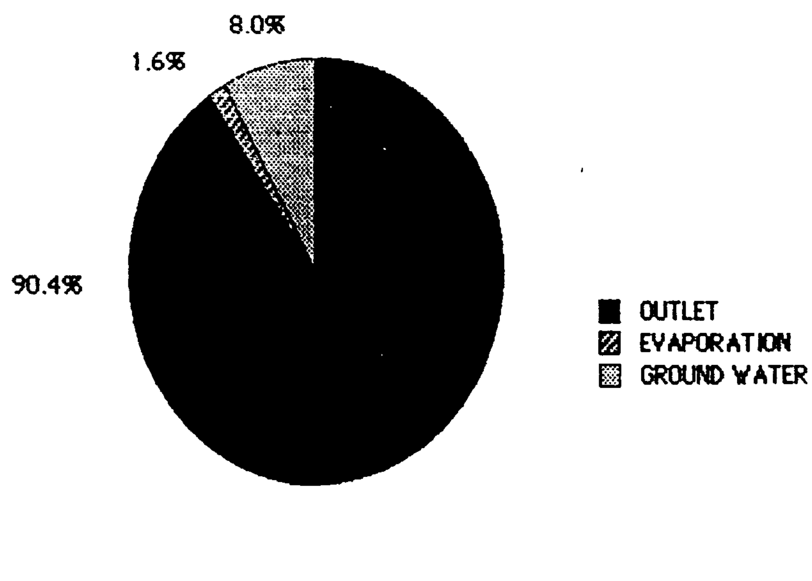
Inputs	cu.m/min	% of Total
Buttonwood Bk. Background	0.70	37.2
Buttonwood Bk. Storm Flow (@Kempton St., Bu-9)	0.51	27.1
36" Storm Drain (Bu-4)	0.45	23.9
All Other Proximal Storm Drains (Bu-5,6,8,14,15)	0.11	5.9
Direct Drainage (Park Lands)	0.03	1.6
Precipitation (Direct Input)	0.05	2.7
Ground Water (Direct Input)	0.03	1.6
Total	1.88	100
Outputs		
Outlet (Bu-3)	1.70	90.4
Evaporation	0.03	1.6
Ground Water	0.15	8.0
Total	1.88	100
Detention Time	**Years**	**Days**
Mean	0.02	8.0
Annual Range	<0.001-0.08	<0.1-30
Response Time	0.034-0.057	12-21

FIGURE 17

HYDROLOGIC INPUTS TO BUTTONWOOD POND



HYDROLOGIC OUTPUTS FROM BUTTONWOOD POND



NUTRIENT BUDGETS

Phosphorus

Export coefficients for phosphorus can be used in conjunction with land use data to estimate the load generated in the Buttonwood Pond watershed. The best of a wealth of literature values for areal phosphorus export have been summarized by Reckhow et al. (1980), and values can be selected from the range presented after evaluation of specific watershed traits such as vegetative features, soil types, and housing density. Estimation of internal loading of phosphorus is facilitated by coefficients of release given by Nurnberg (1984), who summarized another pertinent body of literature.

Chosen export coefficients and corresponding justification are presented in Table 9. The coefficients, corresponding land areas, and the results of their multiplication are given in Table 10. Based on this analysis, 464 kg of phosphorus are generated in the watershed each year. Nearly all of this phosphorus can be expected to reach Buttonwood Pond, given the watershed configuration and mode of delivery (i.e., storm flows) for most pollutants.

Another model approach to quantifying inputs involves the use of empirical equations which rely on in-lake concentrations and hydrologic features of the system to estimate the load to the lake. These equations depend upon certain assumptions, however, which appear to be violated at Buttonwood Pond. The primary problem is the short detention time; in-lake concentrations should approximate inlet concentrations, except during prolonged dry spells.

Vollenweider (1968) established loading criteria based on system morphology and hydrology; a phosphorus load of less than 17 kg/yr would be considered permissible under this scheme, while a load in excess of 34 kg/yr would be deemed critical (in a detrimental sense). This approach is subject to considerable underestimate of the tolerable load in systems with shallow depths and short detention times, however. Yet even if the permissable and critical loads were increased by an order of magnitude, the phosphorus load to Buttonwood Pond would be likely to exceed them.

The most reliable approach to load assessment involves direct measurement, although not all inputs are amenable to this approach. A combination of direct measurements and calculations based on empirical data or export coefficients was therefore applied. The mass flow of phosphorus past the inlet station (Bu-1, Table 11) suggests that careful consideration of storm-induced inputs is warranted, as much lower values are obtained when storm flows are adjusted to emulate the more frequent dry weather flow

TABLE 9

NUTRIENT EXPORT COEFFICIENTS FOR LAND USES AND OTHER SOURCES IN THE WATERSHED OF BUTTONWOOD POND

NUTRIENT SOURCE	EXPORT COEFFICIENT (KG/HA/YR) NITROGEN	PHOSPHORUS	SELECTION CRITERIA
LAND USE:			
Residential-High Density	10.0	3.0	Above average for urban land
Residential-Low Density	4.0	1.1	Below average for urban land
Commercial	8.0	2.0	Near average for urban land
Transportation	5.5	1.5	Median for urban land
Recreation/Park	5.2	1.5	Mean for open/pasture setting
Open	2.0	.8	Below average for pasture setting
Cemetery	5.2	1.5	Mean for open/pasture setting
Forest	2.5	.2	Mean for forest
Wetland	0.0	0.0	Assumes no net change
OTHER SOURCES:			
Atmospheric Deposition	17.0	.6	Low urban/high rural range
Groundwater	5.0	.25	Below average for ground water
Aquatic Birds	1.0	.2	Mean for bird inputs
Internal Loading	0.0	0.0	Assumes no internal load

TABLE 10

NUTRIENT LOAD GENERATION BY SOURCES IN THE WATERSHED OF BUTTONWOOD POND

NUTRIENT SOURCE	ASSOCIATED AREA (HECTARES)	EXPORT COEFFICIENT (KG/HA/YR)		LOAD GENERATED (KG/YR)	
		NITROGEN	PHOSPHORUS	NITROGEN	PHOSPHORUS
LAND USE:					
Residential-high dens.	117.0	10.00	3.00	1170	351
Residential-low dens.	8.9	4.00	1.10	36	10
Commercial	4.4	8.00	2.00	35	9
Transportation	10.1	5.50	1.50	56	15
Recreation/Park	8.6	5.20	1.50	45	13
Open	4.9	2.00	.80	10	4
Cemetery	11.3	5.20	1.50	59	17
Forest	28.2	2.50	.20	70	6
Wetland	4.6	0.00	0.00	0	0
OTHER SOURCES:					
Atmospheric Deposition	2.4	17.00	.60	41	1
Groundwater	2.4	5.00	.25	12	1
Aquatic Birds	187.0	1.00	.20	187	37
Internal Loading	2.4	0.00	0.00	0	0
TOTAL				1720	464

TABLE 11

NITROGEN AND PHOSPHORUS MASS FLOW IN THE BUTTONWOOD POND SYSTEM

	MASS FLOW PAST GIVEN STATION (KG/YR)			
	With Major Storm Flows		Without Major Storm Flows*	
PARAMETER	Bu-1	Bu-3	Bu-1	Bu-3
Total Phosphorus	591	75	175	75
Orthophosphorus	342	20	98	20
Ammonia Nitrogen	1214	55	665	55
Nitrate Nitrogen	2251	358	1102	358
Total Kjeldahl Nitrogen	4669	580	1695	580
Total Nitrogen	6920	938	2797	938

*To adjust values, flows on two dates (7/2/86 and 9/16/86) were reduced to 2.07 cu.m/min, the average of the flows on the other 15 sampling dates.

conditions. Depending upon whether or not flows are adjusted, the total phosphorus load passing the inlet station ranges from 175 to 591 kg/yr. The corresponding orthophosphorus load range is 98 to 342 kg/yr, representing 56 to 58% of the total phosphorus load. The actual phosphorus loads are probably intermediate to the values given. As storm flows are not represented at the outlet station (Bu-3, Table 11), the listed values are considered to be substantial underestimates, not representative of the actual load passing that site.

The range of phosphorus mass flow estimates generated is consistent with the phosphorus load generation predicted from land use data (Tables 10 and 11). The mass flow estimates given thus far are subject to considerable potential error, however; the storm-induced component should be further evaluated. By multiplying the mean flow times the mean concentration of various nutrients at each station sampled during a given storm event, estimates of the loads passing those stations during specific storm events are obtained (Table 12). By summing the load estimates for each parameter and adjusting for the ratio of represented precipitation to total annual precipitation, an estimate of the total annual wet weather load of each nutrient passing each station can be derived. Estimates of precipitation related total phosphorus (and total nitrogen) loads for the study year and an average hydrologic year are provided (Table 12).

As a consequence of the use of Buttonwood Pond as a water storage (flood control) facility, flow out of Buttonwood Pond was very low whenever measured. Loads at Station 3 are therefore considered to be unrepresentative of actual conditions. The wet weather total phosphorus load at the inlet (Station 1) is approximately 243 to 292 kg, with most of that load attributable to inputs at the 0.9 m storm drainage pipe (Station 4, Table 12). The storm drainage lines represented by Stations 5, 6, 8, 14 and 15 contribute relatively minor loads of phosphorus. The pipe represented by Station 4 therefore appears to contribute the bulk of the phosphorus load. This appears to be true for individual storms as well as the annual load estimate. A similar pattern emerges for orthophosphorus data, with orthophosphorus comprising over half of the total phosphorus load in most instances.

Substantial attenuation of the phosphorus load is apparent between Stations 10 and 12 on the west side of Route 140 (Figure 1, Table 12), possibly as a function of the associated wetland areas and/or dilution from less phosphorus-rich water from the land in this area. This is not a function of the existing detention basin, as water flows quickly through one corner of that basin, receiving virtually no detention during typical storm events. The phosphorus load builds slightly along the east side of Route 140, although the east side load is considerably smaller than the west side load. Inputs from three drainage pipes

TABLE 12

ESTIMATED NUTRIENT LOADING FROM STORM EVENTS IN THE WATERSHED OF BUTTONWOOD POND

		LOAD (KG)												
DATE	NUTRIENT	BU-1	BU-3	BU-4	BU-5	BU-6	BU-8	BU-9	BU-10	BU-11	BU-12	BU-13	BU-14	BU-15
07/02/86	AMM-N	2.7	.0	2.7	.1	.0								
08/28/86	AMM-N	23.6	.0	10.0	.2	.1		.1		.0	.4			
09/16/86	AMM-N	11.4	.1	7.8	.2	.1	.1	3.4	1.4	.9	11.1	.2		
04/28/87	AMM-N	6.5	.2	19.0	.3	.1	.1	.1	.1	.3	.8	.3	.3	.2
07/02/86	NITRATE-N	4.1	.0	1.9	.1	.0								
08/28/86	NITRATE-N	13.6	.0	7.0	.4	.1		1.4		.2	3.3			
09/16/86	NITRATE-N	24.6	.0	11.8	.3	.2	.3	11.8	10.8	1.7	20.3	.5		
04/28/87	NITRATE-N	.4	2.0	2.0	.3	.1	1.2	16.3	9.6	4.0	12.9	1.7	.6	.2
07/02/86	KNITRO	13.7	.1	9.8	.5	.0								
08/28/86	KNITRO	40.5	.3	27.2	.8	.2		.7		.3	1.2			
09/16/86	KNITRO	62.2	.3	24.1	.4	.2	.4	21.2	18.8	3.7	23.1	.8		
04/28/87	KNITRO	29.8	4.9	35.0	.7	.7	2.1	5.9	3.7	2.9	6.0	1.3	.8	.3
07/02/86	ORTHO-P	3.3	.0	3.2	.1	.0								
08/28/86	ORTHO-P	1.7	.0	1.6	.1	.0		.0		.0	.1			
09/16/86	ORTHO-P	4.0	.0	2.4	.0	.0	.0	.9	.5	.1	3.3	.0		
04/28/87	ORTHO-P	2.7	.2	2.4	.0	.0	.0	.3	.1	.1	.2	.0	.0	.0
07/02/86	TOTAL P	6.2	.0	6.4	.1	.0								
08/28/86	TOTAL P	3.4	.0	2.4	.1	.0		.1		.0	.2			
09/16/86	TOTAL P	6.4	.0	3.7	.0	.0	.0	2.5	1.6	.3	7.5	.1		
04/28/87	TOTAL P	7.0	.9	5.0	.1	.1	.1	.7	.4	.5	1.0	.2	.1	.1
SUM OF KNITRO+NITRATE-N		189.1	7.7	118.8	3.4	1.5	4.0	57.3	42.9	12.9	66.9	4.3	1.4	.5
SUM OF TOTAL P		23.0	1.0	17.5	.4	.1	.1	3.2	2.1	.8	8.7	.3	.1	.1
REPRESENTED RAINFALL (CM)		10.54	10.54	10.54	10.54	10.54	5.41	6.15	5.41	6.15	6.15	5.41	3.56	3.56
BASED ON PRECIP. IN STUDY YEAR:														
PROJECTED ANNUAL KG OF TN		2401.7	98.3	1509.1	42.7	19.4	98.4	1246.8	1062.2	281.6	1456.8	106.0	51.6	17.8
PROJECTED ANNUAL KG OF TP		291.7	12.5	221.9	5.4	1.7	2.9	70.0	51.6	17.6	189.2	8.6	4.9	4.2
BASED ON MEAN ANNUAL PRECIP.:														
PROJECTED ANNUAL KG OF TN		2001.7	81.9	1257.8	35.6	16.2	82.0	1039.2	885.3	234.7	1214.2	88.4	43.0	14.9
PROJECTED ANNUAL KG OF TP		243.1	10.4	184.9	4.5	1.4	2.4	58.3	43.0	14.6	157.7	7.2	4.1	3.5

serving residential areas east of Route 140 may be responsible for this trend, as well as runoff from Route 140 itself. The sum of the loads at Stations 10 and 11 closely approximates the load at Station 9, and the sum of the loads at Stations 4, 5, 8 and 9 is roughly equivalent to the load at Station 1 immediately downstream.

Multiplying the estimated background flow at Station 1 (0.7 cu.m/min) by the mean total phosphorus concentration during periods of background flow (20 ug/l), a background load of 7.4 kg/yr is calculated (Appendix C). Employing the same approach with the storm water component above Station 9 (mean flow of 0.51 cu.m/min, mean TP of 116 ug/l), a corresponding wet weather load of 31.1 kg/yr is derived. This suggests that most of the phosphorus load enters the system during wet weather. Furthering this approach to include data for the individually assessed storm drainage systems (Appendix C), a load of 150.4 kg/yr is obtained for Station 4 and a combined load of 6.9 kg/yr is derived for Stations 5, 6, 8, 14 and 15.

Other potential sources of phosphorus for Buttonwood Pond include birds (mainly waterfowl and pidgeons), direct drainage (overland runoff), internal loading, ground water inflow, and atmospheric deposition. No internal load is assumed as a function of release of phosphorus from bottom sediments, as no anoxia was observed. Some pumping of phosphorus from the sediments into the water column by macrophytes is likely, however; a calculation based on the research of Smith and Adams (1986) produces an estimated annual release of 15 kg (Appendix C). The atmospheric and ground water contributions estimated from export coefficients have been retained, and the direct runoff load is calculated as the product of the mean flow and the observed background concentration of phosphorus (Appendix C). Bird counts were made on each trip to Buttonwood Pond, and have been used in conjunction with literature load coefficients for different bird groups to calculate a bird-induced phosphorus load (Appendix C).

The resultant range of the total phosphorus load (Table 13) suggests that a rather large load is entering Buttonwood Pond, relative to its size and probable capacity to assimilate pollutants. The approximate partitioning of this load among potential sources (Table 13, Figure 18) strongly indicates that storm water runoff is the major contributor of phosphorus to Buttonwood Pond (77 to 87%), with the load from Drainage Area 7 (Station 4) constituting the major component of that contribution (61 to 62% of the total load). Inputs from birds account for 8 to 12% of the total load, far less than the percentage associated with storm water runoff, but greater than all remaining sources

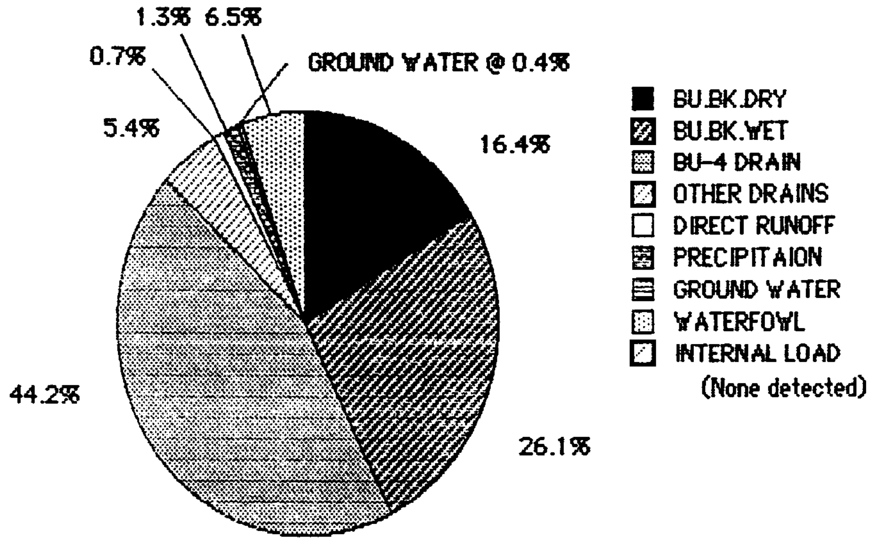
TABLE 13

NUTRIENT LOADS TO BUTTONWOOD POND BASED ON EMPIRICAL DATA AND SELECTED EXPORT COEFFICIENTS

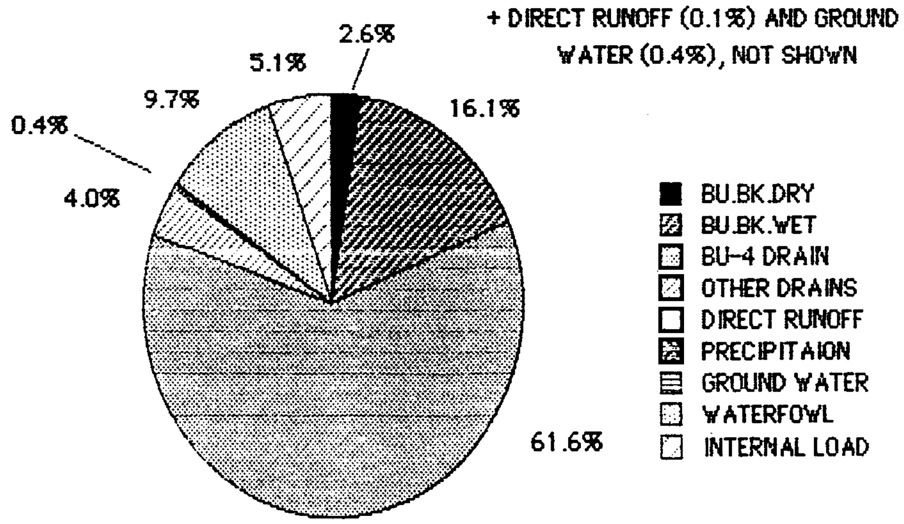
Source	Total Nitrogen kg/yr	Total Nitrogen % of total	Total Phosphorus kg/yr	Total Phosphorus % of total
Buttonwood Bk. Background	504	13.5-19.2	7.4	2.0-3.1
Buttonwood Bk. Storm Flow (@Kempton St., Bu-9)	496-1247	18.9-33.3	31.1-70.0	12.9-19.2
36" Storm Drain (Bu-4)	1258-1520	40.6-47.8	150.4-221.9	61.0-62.3
All Other Proximal Storm Drains (Bu-5,6,8,14,15)	127-230	4.8-6.1	6.9-19.1	2.9-5.2
Direct Drainage (Park Lands)	22	0.6-0.8	0.3	0.1
Precipitation (Direct Input)	41	1.1-1.5	1.0	0.3-0.4
Ground Water (Direct Input)	12	0.3-0.5	1.0	0.3-0.4
Bird Inputs (Direct Input)	170	4.5-6.5	28.3	7.8-11.7
Internal Load (Macrophyte Pumping)	0	0	15.0	4.1-6.2
Total	2630-3746	100	241.4-364.0	100

FIGURE 18

TOTAL NITROGEN INPUTS TO BUTTONWOOD POND



TOTAL PHOSPHORUS INPUTS TO BUTTONWOOD POND



combined. The load and breakdown presented in Table 13 represents the best available appraisal of phosphorus loading to Buttonwood Pond, and will be employed in the evaluation of management options.

Only a very small percentage of the total phosphorus load remains in Buttonwood Pond, which appears to have a very small retention coefficient (probably less than 0.05). However, a small fraction of a very large load is still a substantial load and can facilitate water quality deterioration. The Buttonwood Pond system contains sufficient phosphorus to allow excessive productivity most of the time; concentrations in the water column are usually appreciable, and the seemingly small sediment reserves are apparently adequate to fuel dense macrophyte growths and algal mat production.

Nitrogen

Derivation of a nitrogen budget was approached in the same manner as was the phosphorus budget. Export coefficients and resulting loads are given in Tables 9 and 10. Mass flow of three nitrogen forms and total nitrogen past the inlet and outlet of Buttonwood Pond are presented in Table 11, while a more detailed accounting of storm-induced mass flows is given in Table 12. A breakdown of the total nitrogen load by source is presented in Table 13 and shown in Figure 18. Calculation of individual loading components is presented in Appendix C.

Based on the chosen nitrogen export coefficients (Table 9), a total of 1720 kg of nitrogen are generated within the Buttonwood Pond watershed each year (Table 10). The mass flow estimates for total nitrogen, however, are considerably greater than that predicted from land use data and export coefficients. Considerably more nitrogen may be added to the system from residential areas (particularly Area 7, Figure 7) than was assumed in the export coefficient analysis (use of a higher export coefficient might have been appropriate). Considerable variability and potential error is associated with the basic mass flow analysis (Table 11), however. The more detailed analysis of mass flows of nitrogen during storm events (Table 12) indicates nitrogen loading to be intermediate to the loads suggested by the other analyses. A total nitrogen load of between 2630 and 3746 kg/yr represents the best available estimate of the nitrogen contribution to Buttonwood Pond (Table 13), with storm water runoff accounting for 65 to 88% of this load.

Except for rapid conversion of ammonia to nitrate during dry (low flow) conditions, there was little detectable interconversion of nitrogen forms in the Buttonwood Pond system. The short detention time, particularly during storms, does not facilitate noticeable changes between inlet and outlet waters. The conditions are appropriate for conversion of ammonia to nitrate to organic nitrogen compounds, as oxygen and suspended solids levels are moderate to high (oxygen is necessary to the conversion reactions, and most reactions are performed by bacteria usually associated with particles). Nitrogen loads simply move through the system too fast to exhibit substantial form changes under most circumstances.

DIAGNOSTIC SUMMARY

Buttonwood Pond is a small water body in a relatively large, urban watershed in which most storm water runoff is piped directly to the inlet stream channel or pond. The shallow pond is characterized by high concentrations of nutrients and generally low transparency. Eroded watershed soils have filled in a substantial portion of the pond over the last few decades, and emergent wetland vegetation has grown on this fill. The remaining open water portion of the pond is subjected to frequent and extensive coverage by algal mats, and submerged rooted vegetation sometimes reaches the surface in late summer. Hydrologic conditions are highly variable, resulting in considerable water level fluctuation and consequent flooding and shoreline erosion. Although pollutant inputs are diffuse, one storm drainage pipe serving a densely residential portion of the watershed delivers a majority of the nutrient load to the pond. Loads from other sources are substantial, however, necessitating a multilevel approach to water quality management in this watershed.

Once a popular site for swimming, boating, fishing, ice skating, and other water-based activities, Buttonwood Pond has experienced diminishing recreational utility as a consequence of sedimentation and water quality deterioration. Although the pond was designed as a focal point within Buttonwood Park and still functions in that capacity, its present use is limited to fishing by children, bird watching, occasional paddleboating, and marginal aesthetic appeal. A master plan for park restoration consistent with the original design intent and landscape architecture principles of F. L. Olmsted has recently been prepared, and the park will be modified in accordance with this plan over the coming years. Alteration of Buttonwood Pond is part of the master plan. Work in the park has already commenced, and the time is right for a restoration of the pond which will reduce flooding within the park and substantially improve the water quality and recreational utility of the pond.

MANAGEMENT RECOMMENDATIONS

To improve Buttonwood Pond to a condition appropriate to its desired uses and status as a recreational focal point of the restored Buttonwood Park, it will be necessary to manage the storm water runoff generated in the watershed and to take action within the pond to reverse sedimentation, sediment resuspension, shoreline erosion, and plant nuisances. As it is unlikely that the quantity of runoff generated within the watershed can be substantially reduced, it will be necessary to route, impound, and/or treat the runoff to improve inlet water quality and reduce peak flows through the pond. Within the pond itself, a major restructuring of the pond is called for by the park master plan, and is necessary to eliminate current nuisance conditions (plants and turbidity).

The key to successful management of Buttonwood Pond lies in providing alternate sites for flood control and sediment accumulation. The pond currently plays a critical role in this regard, but is not designed to handle the maximum possible flows. Additionally, there is no provision for periodic restoration of detention capacity (sediment removal). Consequently, the pond fails to provide adequate flood control under conditions which occur at least annually, and has experienced impairment of its recreational potential, habitat quality, and aesthetic appeal in the process. Actions must be taken upstream to reduce the need to use Buttonwood Pond as a flood control facility, and effort must now be expended within the pond to restore the desirable qualities lost through excessive loads of water, sediment, and other pollutants.

PART II

FEASIBILITY ASSESSMENT

EVALUATION OF MANAGEMENT OPTIONS

Management Objectives

The establishment of management objectives is critical to the evaluation of management options and necessary to the development of priorities for restoration activities. Through meetings with the New Bedford Municipal Advisory Committee and questionnaires filled out by area residents, the Walker-Kluesing Design Group was able to itemize issues of concern related to Buttonwood Park (Appendix A). Flooding around the pond and along the brook was recognized as a serious problem in need of attention. Area residents are aware of the deterioration of water quality in the Buttonwood Brook system, but did not link this deterioration, flooding, and storm water runoff together at the beginning of this study.

Park users and officials desire to use Buttonwood Pond for boating, fishing, nature observation, and as an aesthetically appealing backdrop for walking, running, and picnicking. There is some public interest in swimming, but park and City officials have no plans to bring back swimming at Buttonwood Pond. Pond features and water quality are not currently suitable for contact recreation, and may never be suitable on a continuous basis. The desired attributes of the pond include a reasonably stable water level, clear water, minimal visible vascular plant growth (except for an intermittant peripheral fringe), and rewarding fishing opportunities.

Available Techniques

The number of actual techniques available for lake and watershed management is not overwhelming (Table 14). The combination of these techniques and level of their application, however, result in a great number of possible management approaches. Since each lake is to some extent a unique system, a restoration and management program must be tailored to a specific waterbody. Techniques are essentially taken "off the rack" and altered to suit the individual circumstances of a specific lake ecosystem.

Review of the management options in light of the characteristics and problems of Buttonwood Pond and its watershed allows elimination of certain alternatives from further consideration. As there is no hypolimnion in Buttonwood Pond, hypolimnetic withdrawal or aeration is not possible, and neither is warranted in this system. Given the rate at which water and nutrients pass through the pond, the use of dyes, biocidal chemicals, and nutrient-inactivating compounds will be ineffective for more than a very brief period. Waste water is already diverted from the watershed via sanitary sewer lines, and

TABLE 14

LAKE RESTORATION AND MANAGEMENT OPTIONS

Technique	Descriptive Notes
A. In-Lake Level	Actions performed within a water body.
1. Dredging	Removal of sediments under wet or dry conditions.
2. Macrophyte Harvesting	Removal of plants by mechanical means.
3. Biocidal Chemical Treatment And Dyes	Addition of inhibitory substances intended to eliminate target species.
4. Water Level Control	Flooding or drying of target areas to aid or eliminate target species.
5. Hypolimnetic Aeration Or Destratification	Mechanical maintenance of oxygen levels and prevention of stagnation.
6. Hypolimnetic Withdrawal	Removal of oxygen-poor, nutrient-rich bottom waters.
7. Bottom Sealing/Sediment Treatment	Physical or chemical obstruction of plant growth, nutrient exchange, and/or oxygen uptake at the sediment-water interface.
8. Nutrient Inactivation	Chemical comlexing and precipitation of undesirable dissolved substances.
9. Dilution And Flushing	Increased flow to minimize retention of undesirable materials.
10. Biomanipulation/Habitat Management	Facilitation of biological interactions to alter ecosystem processes.
B. Watershed Level	Approaches applied to the drainage area of a water body.
1. Zoning/Land Use Planning	Management of land to minimize deleterious impacts on water.
2. Stormwater/Wastewater Diversion	Routing of pollutant flows away from a target water body.
3. Detention Basin Use And Maintenance	Lengthening of time of travel for pollutant flows and facilitation of natural purification processes.

TABLE 14 (CONTINUED)

4. Provision Of Sanitary Sewers	Community level collection and treatment of wastewater to remove pollutants.
5. Maintenance And Upgrade Of On-Site Disposal Systems	Proper operation of localized systems and maximal treatment of wastewater to remove pollutants.
6. Agricultural Best Management Practices	Application of techniques in forestry, animal, and crop science intended to minimize impacts.
7. Bank And Slope Stabilization	Erosion control to reduce inputs of sediment and related substances.
8. Increased Street Sweeping	Frequent removal of potential runoff pollutants from roads.
9. Behavioral Modifications	Actions by individuals.
a. Use Of Non-Phosphate Detergents.	Elimination of a major wastewater phosphorus source.
b. Eliminate Garbage Grinders	Reduce load to treatment system.
c. Minimize Lawn Fertilization	Reduce potential for nutrient loading to a water body.
d. Restrict Motorboat Activity	Reduce wave action, vertical mixing, and sediment resuspension.
e. Eliminate Illegal Dumping	Reduce organic pollution, sediment loads and potentially toxic inputs to a water body.

no evidence of leaks or misconnections was uncovered. There is no agriculture or on-site waste water disposal in the watershed of Buttonwood Pond, and motorboats are prohibited from the pond.

Not all of the applicable management techniques are appropriate for Buttonwood Pond, either. Macrophyte harvesting by large machines would be difficult in this shallow system, and would create great turbidity. Physical removal on a smaller scale has proven ineffective in the past. Water level control is currently practiced at Buttonwood Pond, but the use of the pond as a detention facility is precisely what must be avoided. Water level control for the sake of a drawdown would greatly impair the recreational utility and aesthetic appeal of the pond unless the pond were deepened substantially. Chemical treatment of the sediment for nutrient inactivation or oxidation would produce undetectable benefits, and would require at least annual application as a consequence of wash-out and new loadings.

Geotechnical Engineers, Inc., working for the Walker-Kluesing Design Group, has recommended major modifications of the pond outlet structure and stream channel within the park to minimize flooding (Walker-Kluesing Design Group 1986). The calculations appear correct and conclusions are logical within the context of the available data, but the limitation of flood prevention activities to the portion of Buttonwood Brook inside the park is not justified. While it was demonstrated that flood frequency could be greatly reduced by modification of the pond outlet, such modification will not result in improved water quality and may be avoidable through upstream actions.

The techniques which will be most appropriate for the long-term management of the Buttonwood Pond system are those which deal directly with runoff quality and quantity above the pond. The SCS, in a preliminary report to the New Bedford Planning Department (SCS 1976), recommended improvements both within and upstream of the park for the minimization of flooding. GHR Engineering Corporation, in a study of the entire Buttonwood Brook watershed performed for the Town of Dartmouth (GHR 1980), emphasized the importance of establishing and maintaining detention basins in the upper reaches of the watershed to control flooding and protect water quality. The poor permeability of watershed soils, rapid routing of storm water runoff to stream channels, and continued development of the watershed have all been cited as major factors contributing to the generation of large flows in this system. These factors are now largely uncontrollable, making it necessary to manage large quantities of water rather than prevent their generation. A substantial amount of remedial action within the pond will also be necessary as a consequence of past abuses; this system will not recover on its own.

Management techniques remaining for consideration therefore include:

1. Dredging
2. Bottom sealing
3. Dilution and flushing
4. Biomanipulation and habitat management
5. Zoning and land use planning
6. Storm water diversion
7. Detention basin use and maintenance
8. Bank and slope stabilization
9. Increased street sweeping
10. Behavioral modifications

Evaluation of Viable Alternatives

Dredging is the only available technique which will deepen the pond and actually remove accumulated sediments. The features of Buttonwood Pond make it amenable to a conventional (dry) dredging job; the pond can be drained, the soft sediments are not especially deep, and there is adequate disposal area within Buttonwood Park. Dredging will reduce turbidity from resuspension of fine sediments, remove macrophytes (including root stocks and seed beds), and eliminate internal nutrient reserves. Dredging can be used to restructure the physical contours of the pond, making it more attractive and functional, and bringing it into line with the park master plan.

Dredging by conventional means will necessitate at least temporary elimination of the Buttonwood Pond fishery, although desirable fish can be salvaged and restocked later. Removal of any portion of the fill at the northern end of the lake constitutes work within an emergent wetland, and will be subject to a rigorous permit process. Dredging of the open water portion of the pond will also require permits. Sediment disposal may also be tightly controlled, given the lead content of the pond sediments.

Dredging is also an expensive proposition. The cost of each dredging project varies with the location, sediment volume to be removed, disposal area location and features, and environmental constraints (BEC 1987). A cost in the vicinity of $15 to $20 per cubic yard (or cy; contractors work in english, not metric units) is anticipated for smaller dredging projects over the next few years. This would cover all aspects of the project, including design and survey work, permit acquisition, contractor selection, containment area preparation, sediment removal, and grading of the disposal area. In the case of Buttonwood Pond, it would also allow for some necessary outlet repairs and bank stabilization.

There are about 14,200 cy (10,824 cu.m) of soft sediment under the open water portion of the pond, and another 18,200 cy (13,869 cu.m) in the filled, or emergent wetland area (Appendix

C). The coarse sand underlying the soft sediment is "clean" at depths of over 0.3 m, but the upper layer does have some silt mixed in. Assuming that this layer were removed from most of the pond bottom, an additional 9,800 cy (7,500 cu.m) of sediment would be dredged, bringing the total dredged volume to about 42,800 cy (32,500 cu.m) (Appendix C). This suggests a dredging cost of between $642,000.00 and $856,000.00.

None of the other applicable techniques will restore open water area or increase pond depth, but there are alternatives for controlling turbidity and macrophyte growths in Buttonwood Pond. The use of a bottom sealant could restrict resuspension of sediments and macrophyte growths. A variety of sealants, or benthic barriers, are commercially available, with material prices ranging from about $25,000.00 to over $60,000.00 per hectare covered, exclusive of installation costs (Cooke et al. 1986). Installation costs raise the total expenditure by approximately 50%, suggesting a figure of $40,000.00 to $90,000.00 per hectare. Covering the 2.4 ha of open water at Buttonwood Pond would therefore cost on the order of $100,000.00 to $200,000.00. Reapplication would be necessary, with the time interval dependent on sedimentation rates and pond usage. Assuming that the tractive bed sediment load is curtailed and there is no unusual disturbance of the benthic barrier by boats, reapplication is likely to be necessary every five years.

Dilution and flushing have the potential to give the pond a more appealing appearance without actually reducing pollutant loads. Accumulated sediment could not be removed through this approach, but the quality of water in the pond after storm events could be greatly improved. Flushing under the natural flow regime has already been demonstrated to reduce algal biomass in Buttonwood Pond, but the erratic pattern of natural flushing in this system creates problems. Controlled dilution and flushing would involve supplying large volumes of low nutrient, high clarity ("clean") water to the pond during dry spells and shortly after storms to flush out and/or dilute poor quality water and accumulated algae.

To make dilution and flushing effective, a complete replacement of the water in the pond should be affected about once every week to keep the detention time well below the response time for the pond. This would require an auxilliary flow of almost 2.2 cu.m/min (1.3 cfs, or 567 gpm). The only suitable source of water for such an operation would be the City water system, but flows of that nature would require a separate line to avoid lowering water pressure in residential lines. The cost of running a separate water main to the upstream end of the pond, including road repair and operation/maintenance, would be prohibitive, however, and there is no guarantee that the needed water would be continually available.

The idea of an auxilliary water source has been suggested by others (e.g., Wm. Williams in the 1890's), but never provided for reasons of cost and practicality. It might be practical, however, to supply some water to the pond from local fire hydrants under emergency conditions (e.g., major algal blooms, oil spill reaching the pond). Such an operation was considered in August of 1987 when mats of Spirogyra covered the pond, but a storm flushed the mats from the pond several days later.

Biomanipulation is a process whereby the biological components of a system are altered to cause interactions that result in a desired condition or set of conditions. Examples include the stocking of predatory fish to reduce panfish densities and improve fishery quality, and the addition of nutrients to encourage the growth of certain algal species over others or to foster an overall increase in system productivity. A more recently developed biomanipulation approach involves removing panfish and stocking large zooplankton capable of heavily grazing algal populations. By maintaining a dense population of large zooplankters, algal biomass is reduced and water clarity increased (Shapiro and Wright 1984, Wagner 1986).

Biomanipulative approaches may provide the finishing touches to a comprehensive management plan, but they cannot alleviate the sedimentation and water quality problems currently being experienced by the pond. The fishery requires a complete overhaul to be conducive to the development of a large zooplankton population, and the often rapid flushing of the system may prohibit maintenance of such a population, especially since there are no upstream lakes from which the pond could be quickly recolonized. A restructuring of the fishery will be necessary to produce the desired angling opportunities, but this should be done only after other substantive restoration measures have been implemented.

Zoning and land use planning are never inapplicable, but the benefits of these tools are small and slow in coming when an area is already developed. The Buttonwood Pond watershed is already quite urban, and less than 20% of its area remains to be developed (Table 2, Figure 6). Of the undeveloped land, 2.3% is wetland which is clearly unsuitable for development and generally protected by law. Another 14.2% of the land in the watershed is classified as forest, although some of this land is actually forested wetland. Much of this land is either part of St. Mary's Cemetery on the west side of Route 140 or part of the Buttonwood Brook headwaters tract off Hathaway Road. The remaining developable forested tracts are generally landlocked (little possibility of road access), but the deeds to most are held by private citizens, creating the possibility of future development. Approximately 2.5% of the watershed is open or vacant land; these tracts have the highest probability of development.

With such a small percentage of the watershed remaining to be developed, zoning and land use planning must largely take the form of by-laws restricting activities or future modifications related to developed tracts. While it is important to consider such legislation to protect any investment made in the pond and to potentially improve long-term conditions, gains made through this approach will yield little relief from the conditions brought about by the current land use pattern. Prohibition of activities which increase the pollutant load to the storm sewer system (e.g., car washing, raking leaves into the street, fertilizing lawns) would be useful, but enforcement is difficult and public response usually sluggish. Prevention of illegal actions (e.g., littering, waste oil disposal) is also difficult, even though the public is aware of associated penalties. Tough enforcement and stiff penalties can increase the effectiveness of a by-law, but some loss of overall public cooperation should be expected under such circumstances. The restoration and management of Buttonwood Pond must be a cooperative effort if it is to succeed, and any action which disrupts or disheartens the community should be avoided.

Before any by-law dealing with pollutant loading of the storm sewer system can become effective, a massive public eduction campaign will probably be necessary. Such an effort would best be carried out by the Friends of Buttonwood Park or a similar group of New Bedford residents. The dissemination of educational information and suggestions for minimizing residential impacts on the pond would meet with greater acceptance if performed by "insiders." Even then, it is not reasonable to assume that a dramatic improvement in water quality will be realized in a short time span; other measures will certainly be necessary.

The diversion of storm water from the watershed of Buttonwood Pond to a point on Buttonwood Brook below the pond has great potential for markedly improving water quality in the pond and reducing flood potential. Diversions must be carefully considered, however, as they do not represent the amelioration of a problem, but rather the translocation of it. The SCS suggested the installation of a leaping weir at Kempton Street (Route 6) to allow high flows to pass from the northeast branch of Buttonwood Brook (the one with Buttonwood Pond on it) to the next most eastern branch, which runs parallel to Brownell Street just inside the Dartmouth town line (SCS 1976). The passage of storm water runoff across municipal lines in artificial channels or pipes is typically unacceptable to the receiving municipality, however, given the transfer of flooding potential. The recommended diversion channel was never constructed.

The diversion under consideration at this point in time involves the 0.9 m storm drainage pipe serving Drainage Area 7 (Figure 7 and Station 4, Figures 1 and 2). The inputs from this pipe constitute just under 24% of the water load, but represent 41 to 48% of the nitrogen load and 61 to 62% of the phosphorus load to the pond. The water load from this source is delivered only during storms, thereby contributing to flooding and not to the background flow to the pond. A minimal amount of the nutrient load is retained by Buttonwood Pond, so there is no real downstream benefit to having the water from Drainage Area 7 pass through the pond. If this water can be diverted downstream without creating additional downstream flood hazard, such diversion would be highly desirable.

The hydrologic response of the 0.9 m discharge pipe serving Drainage Area 7 is very rapid, and water from this pipe comprises the bulk of the water load to Buttonwood Pond during the early stages of a storm event. This water usurps the storage capacity of the pond, such that when the flows generated further upstream (Drainage Areas 8, 9 and 10, Figure 7) reach the pond, they cause flooding around the pond and pass downstream through the zoo where they cause additional flooding. Continued precipitation results in an additive effect between Buttonwood Brook and the drain pipe at Station 4, exacerbating the flooding problem.

If the water from the pipe at Station 4 were routed around the pond to the southwest corner of the park, it would not interact with the water generated upstream during short storms. If upstream water was detained in the existing basin (at Station 12), there might be minimal overlap in the arrival times of water from Stations 4 and 12 during longer precipitation events. This arrangement could in no way increase flooding severity or frequency, and might solve the flooding problem throughout the park, except during extreme events.

It would not be difficult or much more expensive to tie in the storm drainage systems represented by Stations 5, 6, 14 and 15 to any pipeline routing water from Station 4 around the pond. By virtue of its position with respect to Kempton Street and the brook, the pipe discharging at Station 8 could not be easily tied into the envisioned diversion pipe. As the storm drainage system represented by Station 8 is of minimal importance to the management of Buttonwood Pond, its exclusion is not cause for concern. By tying in the other noted drainage systems, the phosphorus load to Buttonwood Pond could be reduced by up to 68% with an approximate 29% decline in average storm flow and no change in the background (dry weather) flow.

The cost of the above diversion would depend on the size of pipe used, the distance traversed, and the difficulty associated with installation. The pipe can run within the park boundary, and must cross only Court Street (Fuller Ave.) to reach the southwest corner of the park. Buttonwood Brook must also be traversed, but this does not represent a difficult operation. Slightly less than 1000 m (3200 ft) of 0.9 to 1.2 m diameter (3 to 4 ft) pipe would be necessary, along with manholes and tie-ins. Including engineering aid, a cost of around $500 per linear meter ($150 per linear foot of pipe) is expected. Assuming that the pipeline follows the existing pathway within the park (the logical route to follow), an additional cost approaching $100,000 may be incurred for replacing the path and associated landscaping. A total cost between $500,000 and $600,000 is anticipated.

The use and maintenance of detention basins is receiving increased attention as a mitigating measure for development as water quality becomes an important issue in developing areas (Walker 1987). Detention basins have long been recognized as an effective means to reduce flood potential, and the use of detention facilities has been recommended previously for the Buttonwood Brook system (GHR Engineering Corporation 1980). A certain amount of natural detention capacity exists within the system, usually in association with wetlands, and limitations on flow imposed by pipe sizes and slopes create further detention of water. This detention capacity is insufficient, however, to moderate the runoff flows generated in the watershed of Buttonwood Pond.

One obvious source of additional detention is the existing but largely unused detention basin at the southeast corner of the Rockdale West development area in Drainage Area 10 (Figures 5, 7 and 11). This detention facility was apparently designed to hold water in response to flows which rarely occur at its inlet, probably as a consequence of flow calculation overestimates and engineering safety factors. As a result, the detention basin very rarely impounds water (no one contacted during this study had ever seen standing water in this basin). Although prevention of flooding is a desirable objective, occasional high flows through the pond have less impact on water quality than more frequent moderate flows, and the capacity of this basin should be used regularly to facilitate natural treatment of runoff and minimize peak flows to Buttonwood Pond.

By placing a V-notch weir or perforated stoplogs at one of the two outlets to the existing detention basin and sealing off the other (conversion to a crested weir), water could be retained in proportion to the magnitude of the flows experienced. By setting the base of the weir or log pile at an elevation slightly above the current floor of the basin, a permanent standing pool could be created. Standing pools harbor organisms which improve pollutant removal processes, thereby increasing the efficiency of the detention basin (Walker 1987). By removing accumulated debris and excavating the basin slightly, detention capacity could also be increased.

The current area of the basin is just over 0.5 ha (58,500 sq.ft or 1.34 ac), with a possible depth of 1.2 to 1.8 m (4 to 6 ft), yielding a volume of 6600 to 9900 cu.m (234,000 to 351,000 cu.ft). A 10-yr storm will result in peak flows of 75.5 to 182.8 cu.m/min (44.4 to 107.5 cfs) at Station 12 (Figure 1), by the calculation method of Weiss (1983) (Appendix C). Under these circumstances, water could be detained for 0.6 to 2.2 hrs, and particles larger than 14 to 20 um would settle out (Appendix C). Given the distribution of the pollutant load among the particle size fractions examined (Appendix B), this situation would yield only slight water quality improvement. It would, however, reduce the probability of flooding at the pond considerably, and would be unlikely to cause any flooding around the detention basin (Appendix C), unless the pipes delivering water to the basin became clogged or backed up under the head pressure that could be created.

A much larger detention basin area would be necessary to hold the runoff generated by a 10-yr storm and allow any substantial reduction in pollutant load. A basin with a volume of 57,300 cu.m (over 2 million cu.ft) would be necessary to hold the runoff generated by a 10-yr storm. At a depth of 1.5 m (5 ft), such a basin would have an area of almost 4 ha (almost 9 ac). A basin with an area of up to 1.7 ha would be necessary to settle out particles of 10 um in diameter, but 1 um particles could not be settled out in a basin smaller than that necessary to completely detain the runoff generated by a 10-yr storm. As an alternative to the construction of a very large detention facility, it would be possible to manipulate storm flows to place the best quality water in Buttonwood Pond at the conclusion of large storms. Small scale upstream detention would play a major role in that manipulation.

As much detention capacity should be supplied as is conveniently possible, but more emphasis should be placed on detaining runoff from storms with high probabilities of occurrence. The action of physical settling and biological uptake on these smaller water volumes will do more to improve the water quality of Buttonwood Pond than the detention of very large volumes of runoff. The low retention coefficient for phosphorus in Buttonwood Pond suggests that the quality of water passing through the pond during a major storm is much less important than the quality of the water left in the pond at the conclusion of elevated flows. Detention of larger volumes of runoff would be primarily for the purpose of flood control. Water quality impacts should be considered in any proposed flood control program.

During a 2-yr storm approximately 8.6 cm (3.4 in) of rain (SCS 1975b) falls on the 94 ha (232 ac) watershed draining into the existing detention basin. Assuming a runoff coefficient of 0.5 for this area (WPCF 1970), about 40,600 cu.m (over 1.4 million cu.ft) of runoff would be generated over a 24 hr period. On average, the existing detention facility could provide up to almost 6 hr of detention, although the detention time could be as low as 1.4 hrs during peak flows of 29.4 to 78.0 cu.m/min (17.3 to 45.9 cfs) (Appendix C).

At these flow rates the water level in the basin should never exceed 1.2 m (4 ft) above the pre-storm level, precluding flooding around the basin. Flooding downstream should be sharply curtailed, and particles greater than 8 to 14 um should settle out in the detention basin. This will still not result in the removal of a majority of the nutrient load, based on the observed distribution of pollutant loads among particle size fractions (Appendix B), but additional removal is expected in conjunction with detention in downstream wetland areas. Also, the creation of a standing pool in the detention basin will improve removal efficiency, and this analysis addresses only physical settling and not chemical reactions or biological uptake. A substantial improvement in water quality is anticipated during events as large as a 2-yr storm.

Lesser storm events will receive increasing detention and treatment, and modifications of the outlet structure which would selectively impound the most phosphorus-laden waters in the "first flush" are possible. The runoff generated by a rainfall of up to 1.1 cm (0.4 in) could be completely detained by the proposed detention facility. Almost 71% of the daily precipitation events recorded in 1986 deposited less than 1.1 cm each. The use of various angles in the V-notch weir (a right angle is assumed in this analysis), employment of perforated stoplogs or crested weirs (better detention, but more risk of localized flooding), and installation of a baffle system (to lengthen the flow path and facilitate shunting) should be considered in the design phase of the project. Factors of concern include the elevation of the existing pipes discharging into the basin, the partitioning of outflow among the two basin outlets, and basin maintenance. A total cost of less than $100,000 is anticipated for likely modifications of the existing detention basin, including design costs.

Other sources of detention include the wooded wetland tract immediately north of the existing detention basin, the channels on each side of Route 140, and portions of Buttonwood Park. This last option is not a realistic one, given the planned use of park lands (Figure 10) and the extreme capacity which would be needed to handle flows from either Buttonwood Brook or the 0.9 m storm drain pipe (Station 4). The unappealing lagoon which would be created would be about as large as Buttonwood Pond; it makes more sense to modify Buttonwood Pond for legitimate use as a detention facility than to create an eyesore within the park. It makes more sense yet to strive for adequate upstream detention of runoff.

The other areas mentioned as possible detention sites (Figure 19) cover approximately 11 ha and could potentially impound a volume of 163,500 cu.m of water. The eastern side of Route 140 borders a residential area which is at an elevation not much higher than the ditch suggested as a detention site (#3). As this site has the smallest capacity of the three sites noted, and poses the most risk to surrounding property, its use is not recommended. Site #2 provides some detention capacity now, as the culvert under Route 140 at its southern end restricts flows during major storms. Expanded capacity is possible in this area, however, and its physical features (primarily a linear wetland) make it an ideal candidate. Site #1 impounds runoff generated in Drainage Area 9 (Figure 7), and is minimally linked to the remainder of the watershed. This area could be modified to accept runoff from Drainage Area 10, but the cost would be substantial (multiple hundreds of thousands of dollars).

Site #2 is therefore the logical choice for additional detention capacity, should such capacity be required. The major concern with this site is its proximity to Route 140 and the cemetary. It would be essential that any detention design prevent flooding of that transportation artery and active cemetary area. The land involved belongs primarily to the Massachusetts Department of Transportation and to St. Mary's Cemetary. A test of this area's effectiveness could be made by constructing a sandbag or gabion weir just upstream of the culvert under Route 140 on its western side. It is possible that no further modifications will be necessary, and the height of the weir could be adjusted to alter the depth and area of the detention pond as necessary.

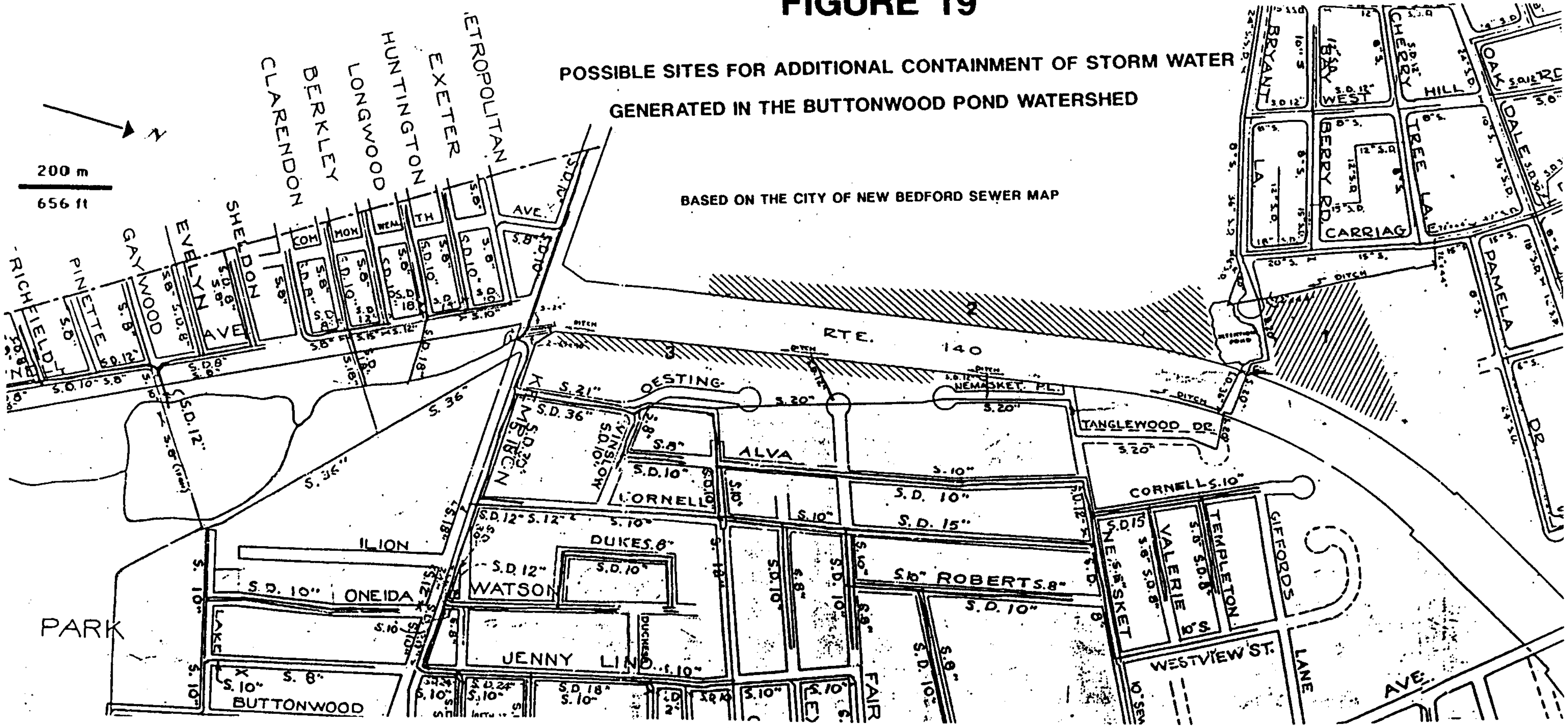
As much as 84,000 cu.m of detention capacity could be provided in this manner, although a runoff reception capacity of half that volume is more realistic, given the need to prevent flooding and provide a standing pool of water. At a capacity of about 40,000 cu.m, such a detention facility could impound over half of the runoff generated in the drainage area which it would serve during a 10-yr storm and over 80% of the runoff generated by a 2-yr storm.

Negotiation for land usage and the permit/approval process are likely to greatly delay the creation of a detention facility at Site #2, and it appears appropriate to postpone any action on that site until the effectivenesss of the diversion and previously discussed detention options can be empirically

FIGURE 19

POSSIBLE SITES FOR ADDITIONAL CONTAINMENT OF STORM WATER GENERATED IN THE BUTTONWOOD POND WATERSHED

BASED ON THE CITY OF NEW BEDFORD SEWER MAP



SITE	AREA (HA)	VOL. (CU.M @ 1.5 M DEPTH)
1	4.5	67,500
2	5.6	84,000
3	0.8	12,000

appraised. This option should be held in reserve, however, as a potentially powerful augmentation to the recommended management program. Some investigation of flooding potential for adjacent lands is likely to be required by permitting agencies, at a cost of up to $10,000. A cost of no more than $50,000 should suffice to implement this option, if no substantial site preparation is required by permitting agencies.

Bank and slope stabilization are especially applicable within the boundary of Buttonwood Park. Erosion of stream channels and especially the shoreline of the pond has created unsightly conditions and promotes further damage and flooding. Complete channelization of the stream corridor is not practical or wise, but modifications much like those recommended in the past (e.g., by Williams in 1902, SCS in 1976, and GEI in 1986) are warranted. Of primary importance, however, is the much needed alteration of the pond shoreline to minimize erosion and changes in pond area during water level fluctuations. The diversion and detention options seek to minimize those fluctuations, but it is still advisable to provide reinforced, steeper banks at Buttonwood Pond.

Alteration of the shoreline can be accomplished in association with the proposed dredging program. The primary obstacle to bank stabilization is the need to avoid "hard edges" (as would be created by rip-rap) if the project is to remain consistent with Olmstedian principles of park landscape architecture and the master plan for Buttonwood Park. Given that constraint, it would be best to line the pond edge with filter fabric or a similarly porous sheet material, cover it with soil, and plant a dense vegetative cover. The impression of a "soft edge" would thereby be created while providing erosion protection.

One area where a hard edge is unavoidable is along Court Street, where granite blocks are used to define the southern edge of the pond. Fluctuating water levels and erosion in this area has damaged some blocks and caused some to fall into the pond. Repair/replacement of this shoreline is needed for structural and aesthetic reasons. Eventual removal of Court Street would negate the need for repairs to the southern shore and outlet structure, but Court Street is expected to remain for the forseeable future; repairs are therefore necessary. All bank stabilization measures associated with Buttonwood Pond should be achievable for a cost of under $50,000.

Increased street sweeping, along with routine catch basin cleaning, might improve the quality of runoff entering Buttonwood Pond, but a major effort would be necessary. Vacuum sweepers, at a cost of over $100,000 each, would be necessary to ensure that the very fine particulate matter with which the bulk of the pollutant load is associated are removed from the streets. Sweeping by one machine would have to be nearly continuous to cover the watershed between storms (precipitation occurs once every three days, on average). The use of two machines plus a vacuum catch basin cleaner would be preferable, assuming non-continuous use and some downtime. In addition to a capital cost of approximately $350,000, operation and maintenance costs of $70,000 to $90,000 per year (20 to 25% of capital cost, exclusive of personnel costs) are anticipated.

Additional problems with street sweeping include interference with parked or moving vehicles on many streets (some are rather narrow), decreased efficiency of sweeping when interference occurs, disposal of accumulated material (landfill space is severely limited), and the policy of the Clean Lakes Program (likely major funding source) not to fund operation and maintenance costs. Given the potential for successful environmental management through other approaches involving less maintenance, increased street sweeping and the use of vacuum sweepers are not viewed as preferable alternatives at this time.

Potentially applicable behavioral modifications for residents of the Buttonwood Pond watershed include the elimination of illegal dumping (including littering), minimization of lawn fertilization, cessation of car washing at residences or on the street in general, halting of leaf and grass raking into the street, minimization of salt and sand usage in the winter, and prevention of any activity which leads to the entrance of oil, grease, fertilizer, or other pollutants into the storm drainage system. Use of the storm drainage system as a disposal facility for any substance must be avoided. Serious changes in residential practices require serious effort by those wishing to bring about those changes; old habits are hard to break, and behavioral modifications of this sort are difficult to enforce.

Behavioral modifications can be effective in producing decreased pollutant loadings only if participation is high among watershed residents. In areas where a watershed or lake association is a strong entity with extensive support, behavioral modifications can result in detectable water quality improvements. In the absence of strong voluntary support, legislative restrictions must be imposed. Such restrictions are often unpopular and difficult to enforce. It is advisable to cultivate support through education prior to any legislative effort, as noted previously in connection with zoning and land use bylaws. The educational effort is more likely to be successful if it is initiated from within the community, as with programs sponsored by the Friends of Buttonwood Park.

One cost-effective approach to educating watershed residents about their potential impact on Buttonwood Pond involves the production of a slide show which could be presented at public meetings and at schools. Distribution of a brochure which discusses recommended practices and detrimental actions in residential areas may also be helpful. Although consultant aid should be sought, the marketing of the "product" should be by local citizens. A cost of approximately $10,000 should cover the production of a slide show and brochure for watershed residents.

Environmental stewardship in the form of behavioral modifications is a matter of civic pride and environmental awareness. That pride and awareness must be fostered before any gains can be realistically expected. Even then, behavioral modifications will not be sufficient by themselves to improve water quality to the desired level, and will in no way decrease the probability of flooding. The problems at Buttonwood Pond are largely a consequence of engineering actions, and must be rectified by further engineering.

RECOMMENDED MANAGEMENT APPROACH

After consideration of pond and watershed characteristics and the available options for improving the existing conditions, the following actions are recommended for the management of Buttonwood Pond:

1. The storm water drainage systems represented by Stations 4, 5, 6, 14 and 15 should be routed around Buttonwood Pond to the southwestern corner of Buttonwood Park.
2. The existing detention basin serving Drainage Area 10, located at the southeast corner of the Rockdale West development, should be altered to detain as much runoff as possible without causing localized flooding.
3. All soft sediment and the upper layer of sandy underlayment should be removed from the open water portion of Buttonwood Pond, and most of the filled, emergent wetland area should be dredged if permitted under the Wetlands Act. Peripheral emergent wetlands of moderate or high quality should be preserved, however.
4. The majority of the Buttonwood Pond shoreline should be graded and stabilized with a porous sheet material and revegetated. The granite blocks along the Court Street edge of the pond should be repaired/replaced as warranted. The wetland nature of the northern shoreline should be maintained.
5. An education program should be conducted to inform watershed residents of their role in determining the quality of water in Buttonwood Pond. A slide show about watershed management should be prepared and presented.

Recommended management actions #1, #2 and #5 should be implemented as soon as possible, with recommended actions #3 and #4 initiated after the effectiveness of the diversion and detention programs have been evaluated and deemed sufficent. Should additional detention capacity appear warranted, a test of the effectiveness of Site #2 (Figure 19) is recommended above the other detention alternatives. A monitoring program will be necessary to assess project progress and facilitate adjustments in approach. The logistics of providing water for dilution and flushing on an emergency basis should also be further investigated by the New Bedford Department of Public Works and the Fire Department. Finally, a restructuring of the fishery is recommended in conjunction with the dredging program. Involvement in this effort by the Massachusetts Division of Fisheries and Wildlife is desirable, if only in an advisory role.

IMPACT OF RECOMMENDED MANAGEMENT ACTIONS

The recommended management program will result in substantial changes in the quality and quantity of water passing through Buttonwood Pond. With respect to water quality, the diversion program will have the most impact, reducing the phosphorus load to the pond by up to 68%, the nitrogen load by up to 54%, and in-lake turbidity by up to 20% (Table 15). The detention program will reduce overall nutrient loads and turbidity by up to 15%, but a lesser effect is anticipated during large storms as detention time decreases. The load during larger storms passes quickly through the pond, however, minimizing its effect on the pond. Detention and purification of runoff entering the upstream basin near the end of the storm is important, however, as this water will then pass downstream and into the pond, determining water quality until the next storm event.

If successful, the education program might reduce overall pollutant loads by 5%. Macrophyte density is unlikely to be affected by the diversion, detention, and education programs. The proposed dredging program will affect macrophyte density, reducing it by 60 to 80%. By removing the fine material which is readily resuspended, dredging will also yield a 30 to 60% decrease in turbidity. A slight reduction in the phosphorus load is also anticipated as a consequence of dredging. The entire proposed project will result in a 68 to 89% decrease in total phosphorus load, a 45 to 95% decline in total nitrogen load, a 40 to 95% reduction in turbidity, and a 60 to 80% lowering of macrophyte density. The water quality and physical appearance of Buttonwood Pond will be improved markedly.

Flood control benefits are somewhat more difficult to quantify. Flood analysis depends on many uncertain factors, most notably the assumed storm hydrograph. Once a "design storm" is chosen, any of several methods of flood routing can be employed. Assumptions relating to runoff generation and time of concentration can greatly affect the analysis. The widely varying values obtained by various firms for the peak flow during a 10-yr storm (Appendix C) are a good case in point. There will always be a risk of flooding in this rather urban watershed, but the proposed project will reduce that risk substantially.

The most appropriate approach to evaluating the impact of the proposed project on flooding would seem to be a comparison of flows under present and proposed conditions, applying the same methods and assumptions to both situations. While the generated numbers may be disputed, assessment of one situation relative to the other should be valid. Employing this approach (Appendix C), one finds that under the conditions assumed for a 10-yr storm, no

TABLE 15

ANTICIPATED CHANGES IN BUTTONWOOD POND
TO RESULT FROM THE PROPOSED
MANAGEMENT PROGRAM

Management Plan Element	% Decrease in Selected Parameters			
	TP-Load	TN-Load	Turbidity	Macrophyte Density
Detention at Rockdale West	0-10	0-15	0-10	0
Diversion of 5 Storm Drain Inputs	64-68	45-54	10-20	0
Dredging of Buttonwood Pond	4-6	0	30-60	60-80
Education	0-5	0-5	0-5	0
Total	68-89	45-74	40-95	60-80

NOTES: 1. As one can often see the shallow bottom now, even at elevated turbidities, the 30% decrease in turbidity calculated from anticipated Secchi disk readings is misleading. Water clarity should improve quite perceptibly.

2. Detention, diversion, and dredging will also result in a pronounced decrease in the frequency of flooding within Buttonwood Park.

flooding is expected under the average flows anticipated, but that the post-project flows into and out of Buttonwood Pond are over 27% lower than the pre-project flows.

The indication of no flooding under the average flows produced by a 10-yr storm is very interesting, especially in light of the occurence of floods in Buttonwood Park several times each year. Flooding is more a function of peak discharge than total volume of runoff generated, with precipitation of little more than a centimeter in an hour capable of inducing flood conditions. It is therefore the storm hydrograph, or distribution of precipitation over time within a storm, which is the most important determinant of flooding under current conditions in Buttonwood Park.

Flows of less than 85 cu.m/min (50 cfs) are desirable in the inlet channel to prevent flooding in that area, while a vertical rise of less than 0.3 m (1 ft) is desirable within Buttonwood Pond to prevent flooding around the shoreline and maintain an outflow of less than 85 cu.m/min (50 cfs). Downstream at the Hawthorne Street culverts, flows of more than about 145 cu.m/min (85 cfs) cannot be passed without flooding. When precipitation results in flows or head increases in excess of these limits, flooding occurs.

Applying a "typical" hydrograph, one in which there is an early peak of precipitation and a tapering off of rainfall thereafter, it is easy to see why there is flooding throughout Buttonwood Park during periods of intense precipitation (Appendix C). For the precipitation associated with a 10-yr storm, distributed according to the "typical" hydrograph, a peak flow of almost 260 cu.m/min (152.5 cfs) is calculated for the inlet to Buttonwood Pond. The resultant rise in the water level of the pond is about 0.5 m (1.6 ft), yielding an outlet flow of almost 189 cu.m/min (111 cfs). The corresponding peak flow at Hawthorne Street is almost 194 cu.m/min (114 cfs); flooding all along the path of Buttonwood Brook should (and does) occur under these conditions.

Applying the same hydrograph to the conditions which would result from the proposed project, the peak flow in the inlet channel would be about 189 cu.m/min (111.1 cfs). This would cause flooding of the land adjacent to the inlet channel for about an hour, as compared to pre-project flooding of this area at a 68% greater flow for at least two hours. The corresponding rise in the water level of Buttonwood Pond under the proposed conditions would be just under 0.3 m (0.9 ft), which is 44% less than the rise associated with current conditions. The anticipated inflow to Buttonwood Pond would result in a peak outflow of just over 72 cu.m/min (42.6 cfs), or about 38% of the outflow calculated for current conditions. The corresponding peak flow at Hawthorne Street would be under 110 cu.m/min (64.4 cfs), which is only 56% of the predicted current flow at that location. There should be no flooding of the pond perimeter, the zoo area, or Hawthorne Street under the proposed conditions during a 10-yr storm with the given hydrograph (Appendix C).

The key to flood prevention in Buttonwood Park is the temporal separation of flow peaks generated at different points in the watershed. While the peaks do not currently coincide, they are close enough together in time to have a detrimental additive effect. By further separating the peak flows from major sub-watersheds, the proposed project reduces additive effects. Certainly there will still be flooding in conjunction with occasional high intensity precipitation events (e.g., several consecutive hours of rain at over 1.3 cm/hr (0.5 in/hr)), but these events are considerably more rare than the flood-inducing rainfalls which now occur two or three times per year. Additionally, the flooding which would occur under the proposed conditions would be considerably less severe than that which occurs now. A more formal analysis should be conducted when a specific design for the detention area is prepared.

The anticipated physical, chemical and biological improvements to Buttonwood Pond are expected to greatly enhance recreational opportunities at the pond. The aesthetic appeal of the pond will be markedly improved, making walks around the pond on the promenade (part of the park master plan) far more pleasant. Paddleboating will not stir up the pond bottom, minimizing turbidity and maintaining water clarity. Additional boating and possibly swimming will be facilitated, although there are no current plans by the City to institute either at the pond. Fish habitat will be enhanced in terms of physical and chemical conditions. With some fishery manipulations made possible by the dredging program (during drawdown), the park fishery should be much more attractive to anglers; it would be possible to stock the pond with trout for spring fishing.

In addition to facilitating the well-known warm-weather activities, the proposed project should improve ice skating conditions by stabilizing the hydrologic regime. Currently erratic flushing causes unstable and intermittant ice conditions; ice cover should be less affected by inflows after project implementation. Winter ice fishing would also be accommodated.

Beyond the direct benefits to the pond and its users are some overall park benefits; flooding of the zoo area downstream of the pond and in areas peripheral to the pond would be lessened. Such flood control is necessary to protect the investment being made in the park through the Olmsted Historic Landscape Preservation Program.

DETENTION PROGRAM

The general format and premises of a potentially effective detention program have been laid out in the previous section regarding the evaluation of management options. Modification of the existing detention basin at the Rockdale West development is recommended. Debris removal, slight grading/deepening, and alteration of the outlet structures is expected to yield substantial flood control benefits during large storms and considerable water quality benefits during smaller precipitation events.

The debris and soil removal or regrading are intended to be simple operations which will yield increased detention and more effective use of the available space. Trenching to create a baffle system during low flows may be desirable to lengthen the flow path and facilitate pollutant removal. Cattails currently cover most of the basin, and past growths have resulted in the build-up of a substantial mat of organic debris. Leaf litter and woody debris have apparently been tossed into the basin as a means of disposal. It is estimated that 4400 cubic yards (cy; contractors prefer the use of english units) of material could be removed from the existing detention basin and used deposited in a landfill. Much of the material removed from the basin would make excellent cover for the New Bedford landfill, if the necessary tests for sediment quality are favorable.

Removal of the material by conventional equipment (backhoe, front end loader, dump trucks) is easily facilitated by the dry state of the basin. The potential for the ground water table to be contacted during excavation is not a concern, as the creation of a permanent standing pool of water is desirable for increased runoff treatment efficiency. If a standing pool is not created by excavation, the outlet structure will have to incorporate provisions for maintaining a pool, decreasing the maximum storage capacity of the basin slightly.

The outlets should be modified to facilitate greater detention of low flows while maintaining the ability to pass larger flows without causing localized flooding. With a basin depth of 1.5 m (5 ft), exclusive of the standing pool depth, a V-notch weir with a 90-degree angle would pass the maximum inflow without overtopping the basin. Other outlet designs may be equally plausible, and could yield increased detention of lower flows.

The major concern for flow management at the existing detention basin involves the inlet pipes. At a basin depth of 1.2 m (4 ft), the major inlet pipe would just be flowing full, while the smaller, adjacent pipe would already be submerged under at least 0.3 m (1 ft) of water. The slope of these pipes appears sufficient to prevent backflooding at the catch basins on the streets served by these drainage pipes, even at the desired basin depth of 1.5 m, but reduced flow passage is anticipated.

Two alternative conceptual designs are compared with the current outlet structure in Figure 20. A mixture of regular and perforated stoplogs would provide the most versatile detention characteristics for the least expense, but maintenance costs are likely to be higher, and manipulation of the logs during large storms may be necessary to prevent overtopping of the basin. Alteration of the angle used in the V-notch weir or a combination of the two designs (V-notch with auxilliary stoplogs) is possible as well.

The potential for using only one or both of the current outlets from the basin adds additional flexibility to the design process. The eastern outlet feeds the channel running along the east side of Route 140. This channel has less capacity than the one on the western side of the highway; it is therefore recommended that the majority of the flow be passed through the western outlet from the detention basin during high flow conditions. By installing a crested weir at one outlet, which would supply auxilliary outflow capacity during larger storms, the outflow from the other weir could be further restricted to supply greater detention during lower flows. The precise outlet configuration is a subject for the design phase of this project; several options are likely to be workable.

A summary of detention program elements and anticipated costs is provided in Table 16. The major expense is associated with sediment (and debris) removal from the basin. Up to $3,000 is allotted for the modification of each outlet structure. No expenditures are included for any detention tests of the area downstream of the existing detention basin (Site #2 in Figure 19), the most appropriate area for the creation of additional detention capacity, if needed. An inexpensive sandbag weir for such a test would cost only a few thousand dollars, and the test could be performed by Department of Public Works personnel, if desired in the near future. It is recommended that additional detention areas not be created, however, until the performance of the modified, existing basin can be evaluated. A total expenditure of $76,300 is estimated for the recommended modification of the existing detention facility.

FIGURE 20

POSSIBLE OUTLET STRUCTURES FOR THE EXISTING DETENTION BASIN UPSTREAM OF BUTTONWOOD POND

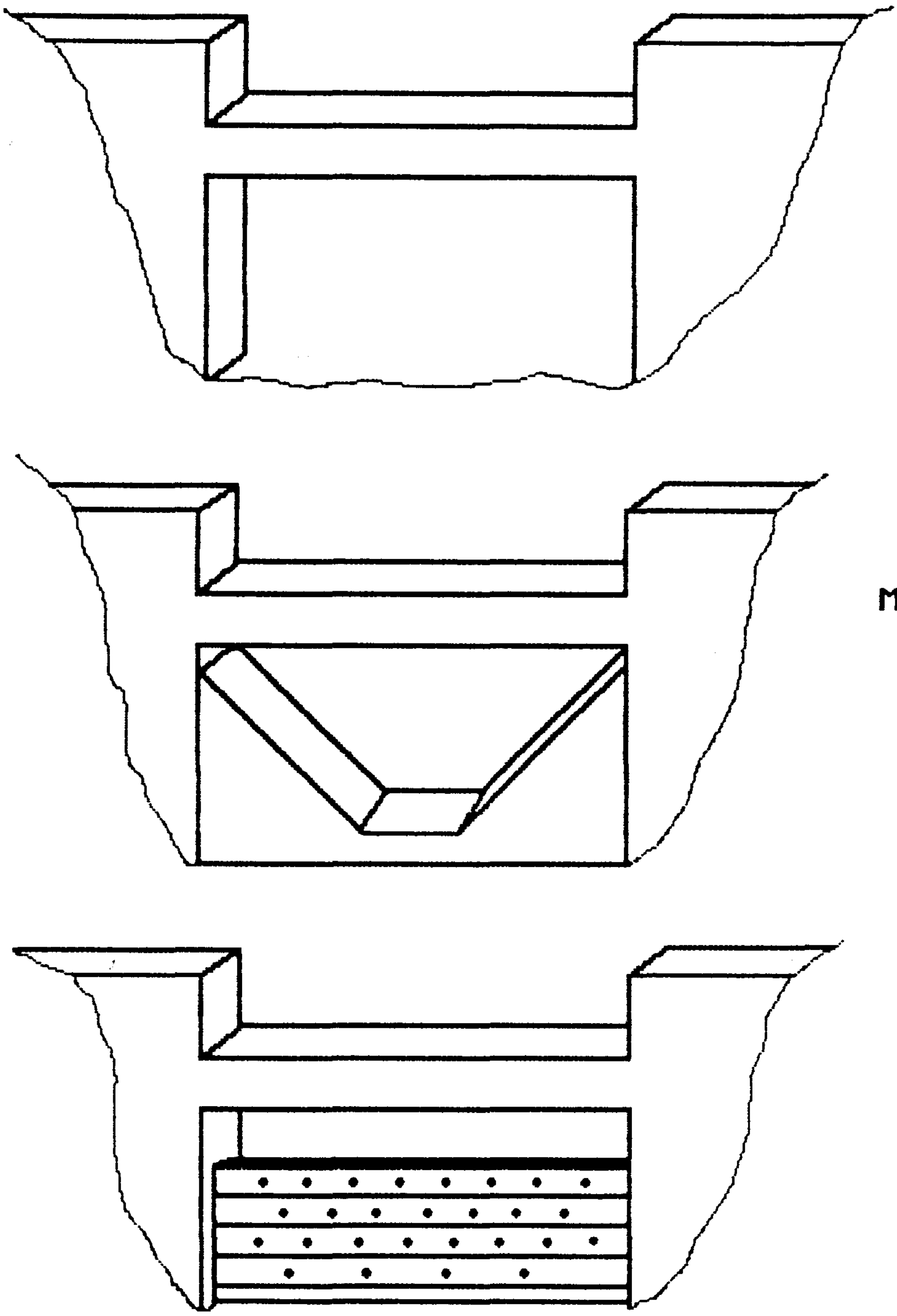


TABLE 16

ELEMENTS AND COSTS ASSOCIATED WITH THE PROPOSED DETENTION PROGRAM
AT THE ROCKDALE WEST DETENTION AREA

Item/Task	Cost/Unit	Units	Estimated Cost ($)
1. Engineering Design (Surveying, outlet design, bid document prep.)	Lump Sum (Based on man hours & direct costs)		$ 5,000
2. Contractor Selection (Advertisement, bid selection supervision)	Lump Sum (Based on man hours & direct costs)		1,500
3. Permits (EIR, applications, meetings/ hearings)	Lump Sum (Based on man hours & direct costs)		5,000 *
4. Sediment removal	$12/CY	4400 CY	52,800
5. Outlet modification	$3,000/outlet	2 outlets	6,000
6. Construction supervision	$500/day	6 days	3,000
7. Meetings, Reports, Travel	Lump Sum (Based on man hours & direct costs)		3,000
Total			$ 76,300 **

* Depending on the interpretation of the existing Order of Conditions, an EIR or permits may not be required. Only EIR preparation, at approximately $3,500, is eligible for funding under the MA Clean Lakes Program.

** Future basin and outlet structure maintenance will be necessary, with an estimated average annual cost of $4,000. This cost is not eligible for funding under the Massachusetts Clean Lakes Program.

Although working during a dry weather period is clearly desirable, the proposed modifications could be made at any time during the year. All of the operations involved have rather short timetables, facilitating rapid completion of tasks. Sediment removal and outlet modifications could be made simultaneously. Precautions should be taken, however, to trap any sediments which may be suspended in the outflow during the sediment removal operation. The use of filter fabric at the outlets and slightly downstream should constitute a sufficient preventative action.

DIVERSION PROGRAM

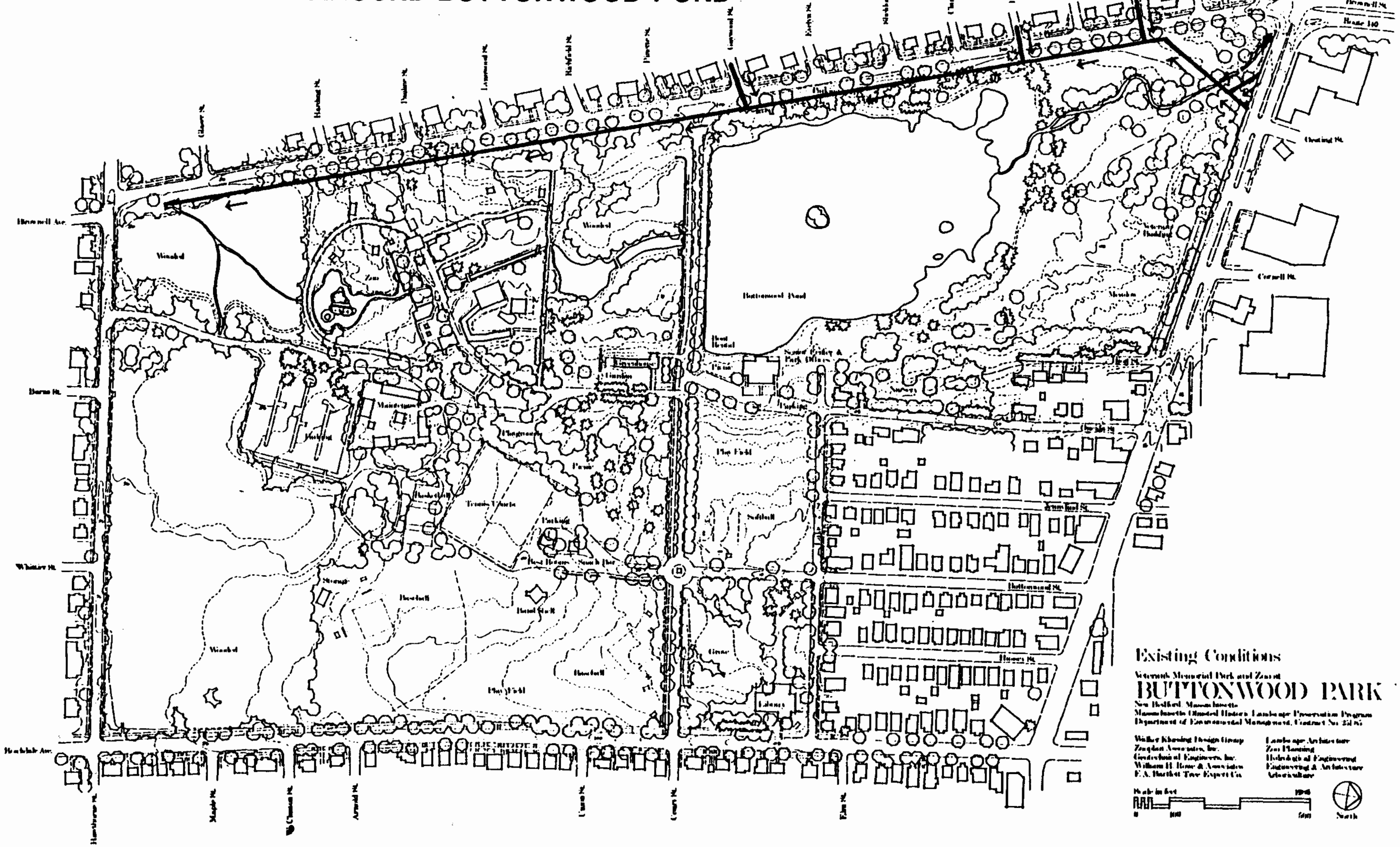
Diversion of one major and four minor storm drainage systems, as described in the previous section of this report, will result in about a two thirds reduction of the phosphorus load entering Buttonwood Pond. There will be no loss of background flow, so dry weather detention time and water level in the pond will not be altered by this action. During storms, however, about a third of the storm water which now enters the pond will be routed to the southwest corner of the park. By arriving at that point several hours earlier than it would have otherwise, peak flows from the diverted drainage pipes can pass through the system with less interaction with peak flows generated by other sources, reducing the probability of flooding.

The mechanics of the proposed diversion would include continuing the existing 0.9 m (3 ft) discharge pipe at Station 4 across the stream (actually under it, as has been done with sanitary sewer lines in the area) and out to the walkway along the east side of Brownell Avenue (Figure 21). From that point a pipeline of probably 1.2 m (4 ft) diameter would run nearly the length of Brownell Avenue, discharging just upstream of the Hawthorne Street culverts. There is a vertical drop of approximately 4.6 m (15 ft) over this distance of about 915 m (3000 ft), providing a slope of around 0.005. The pipe discharging at Station 5 (Figures 1, 2 and 11) would be tied into the pipe upstream of Station 4, while the pipes represented by Stations 14, 6 and 15 would be tied into the new pipeline running along Brownell Avenue. Manholes would certainly be installed at the tie-in locations along Brownell Avenue, although additional manholes may be desirable at other locations as well.

The proposed route for the new pipe is relatively unencumbered by obstacles, but a few potential problem points do exist. The continuation of the pipe at Station 4 across the stream must be done carefully to avoid future leakage. Sanitary sewer lines in the area must be avoided, but accurate location maps are available from the City of New Bedford Public Works Department. The new pipe will have to cross Court Street (Fuller Ave.) near its western terminus, but no other street crossings are necessary. Storm drains in this area which now discharge into Buttonwood Brook below the pond but above the zoo could be tied into the new line as well, if desired.

FIGURE 21

PROPOSED PIPELINE PATHWAY FOR THE DIVERSION OF STORM WATER AROUND BUTTONWOOD POND



BASED ON THE MASTER PLAN MAP PREPARED BY WALKER-KLUESING DESIGN GROUP

A total cost of $531,500 is anticipated for the proposed diversion program (Table 17). The cost of the new pipe, with installation, represents the major expense involved. A substantial amount of money has also been allocated for refurbishing the pathway which will be disrupted by pipe installation in accordance with the standards set by the Buttonwood Park Master Plan. Funds from this allocation would also be used to patch Court Street at the crossing point. The work associated with the diversion program could be performed at almost any time, although a dry weather period would be clearly preferable. Minimum interference with park users would probably be achieved by a late fall or winter installation.

Money has also been allocated under the permits budget to perform a preliminary investigation of possible sources of sewage pollution in the drainage area (Area 7) served by the pipe system discharging at Station 4. The use of conductivity, orthophosphorus, nitrate, and fecal bacteria as parameters in an areawide sampling program is recommended. Final location and elimination of sources of contamination are the responsibility of the New Bedford Department of Health, but a preliminary survey should reduce the size of the area requiring more detailed investigation (e.g., individual house dye tests). Elimination of any sources of sewage for the storm drainage system may be a prerequisite to approval of the diversion program.

TABLE 17

ELEMENTS AND COSTS ASSOCIATED WITH
THE PROPOSED DIVERSION PROGRAM

Item/Task	Cost/Unit	Units	Estimated Cost ($)
1. Engineering Design (Surveying, pipe selection bid document prep.)	Lump Sum (Based on man hours & direct costs)		$ 15,000
2. Contractor Selection (Advertisement, bidders meeting, bid selection supervision)	Lump Sum (Based on man hours & direct costs)		3,000
3. Permits (EIR, applications, meetings/ hearings)	Lump Sum (Based on man hours & direct costs)		10,000 *
4. Install Drainage Pipe	$120/ft	3,200 ft	384,000
5. Install Access Manholes	$3,500/manhole	3 manholes	10,500
6. Tie-in smaller drainage pipes	$1,500/tie-in	4 tie-ins	6,000
7. Replace path over pipeline	$5/SF	19,200 SF	96,000
8. Construction supervision	$500/day	8 days	4,000
9. Meetings, reports, travel	Lump Sum (Based on man hours & direct costs)		3,000
Total			$531,500

* Permit/approval requirements will depend upon review of any proposed design by the EOEA MEPA Unit and the New Bedford Conservation Commission. Only EIR preparation, at approximately $7,000, is eligible for funding under the MA Clean Lakes Program.

DREDGING PROGRAM

The need to dredge Buttonwood Pond has been elucidated in the section of this report in which management options were evaluated. Except for the potential for high flows through the pond during intense precipitation events, this is a relatively easy dredging project. To minimize flood damage to dredged areas, the dredging should be performed between August and December after the detention and diversion programs have been implemented. Once the pond is drained via the subsurface outlet pipe, the substrate will support conventional excavation equipment, which can move dredged material to a containment area constructed adjacent to the pond (Figure 22). Despite the moderately high lead levels in the soft sediment, initial disposal and eventual reuse within Buttonwood Park does not pose any special problems or hazards.

Conventional, or dry dredging is the method of choice in this case, given the drawdown capability of the outlet structure, pond sediment characteristics, and easy access to the pond for excavation equipment. If the sediment in the pond dries as well as expected when the pond is drained, work should proceed quickly and the construction of the containment area need not be elaborate. Creation of a small earthen berm by bulldozers around the containment area perimeter will be necessary to control runoff, but most of the features depicted in Figure 23 may not be essential. Deposition and grading of dredged material to form a gentle slope toward a berm with a channel at its base (directing runoff to a small holding area and then back to the pond) is recommended.

The critical aspect of the dredging program involves the actual sediment removal operation, which must be sensitive to the potential for water level fluctuations and the desirability of preserving certain emergent wetland areas. Although the potential for flooding will be greatly reduced by the proposed detention and diversion programs, the pond drain cannot pass the flows which will still result from even moderate precipitation events. A drawdown can therefore not be sustained during any precipitation except a light rainfall. The use of a haybale barrier (Figure 24) or similar structure composed of sandbags is recommended around each small (perhaps a half acre to an acre) area where active dredging is occurring. This precaution will limit resuspension and downstream transport of disturbed sediment during wet or dry conditions.

Alternatively, the outlet structure could be removed to allow greater flow through the drained pond, but the expense associated with reconstructing the outlet would be quite high. If the suggested eventual closing and removal of Court Street were to take place prior to the dredging program, the outlet

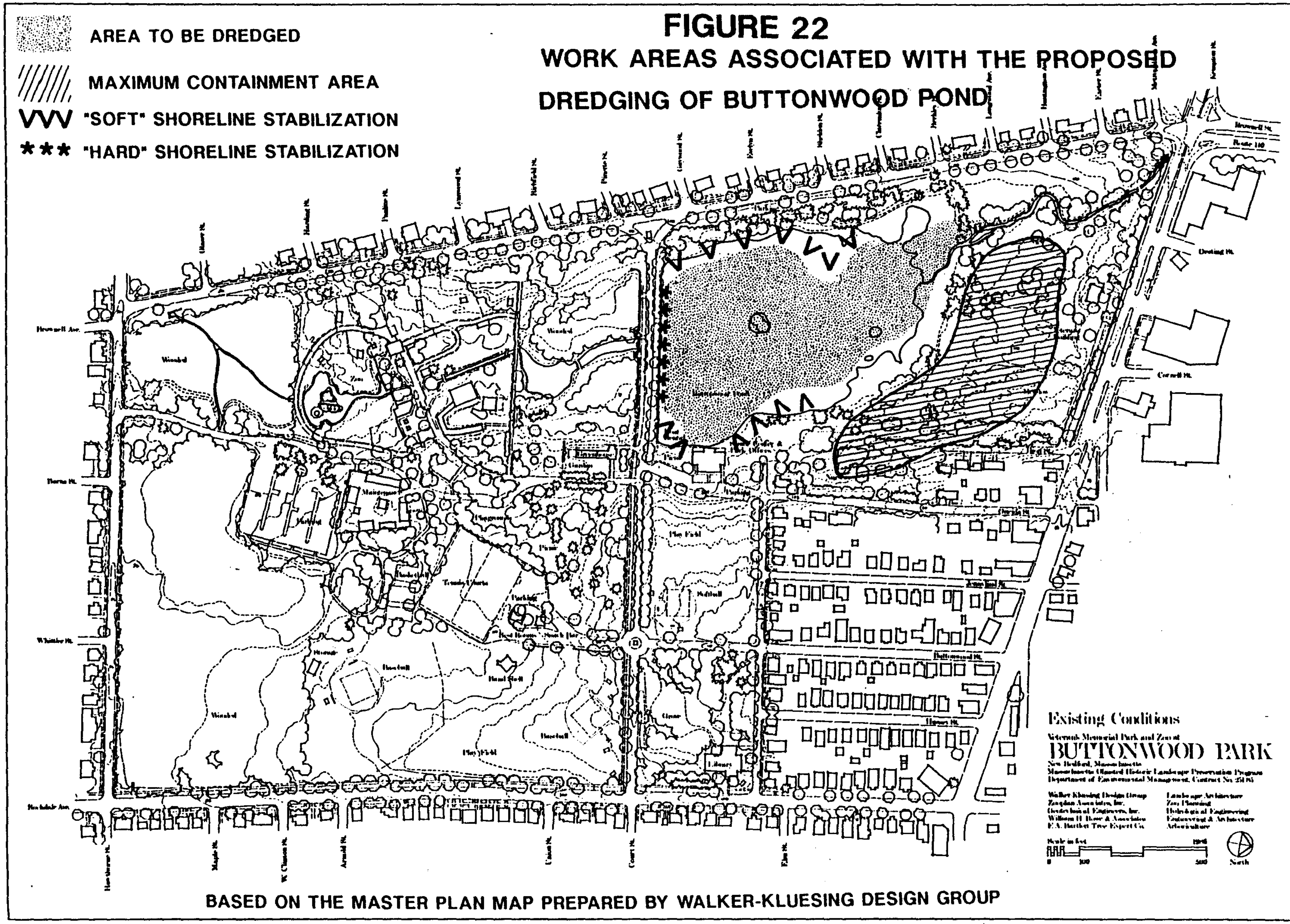
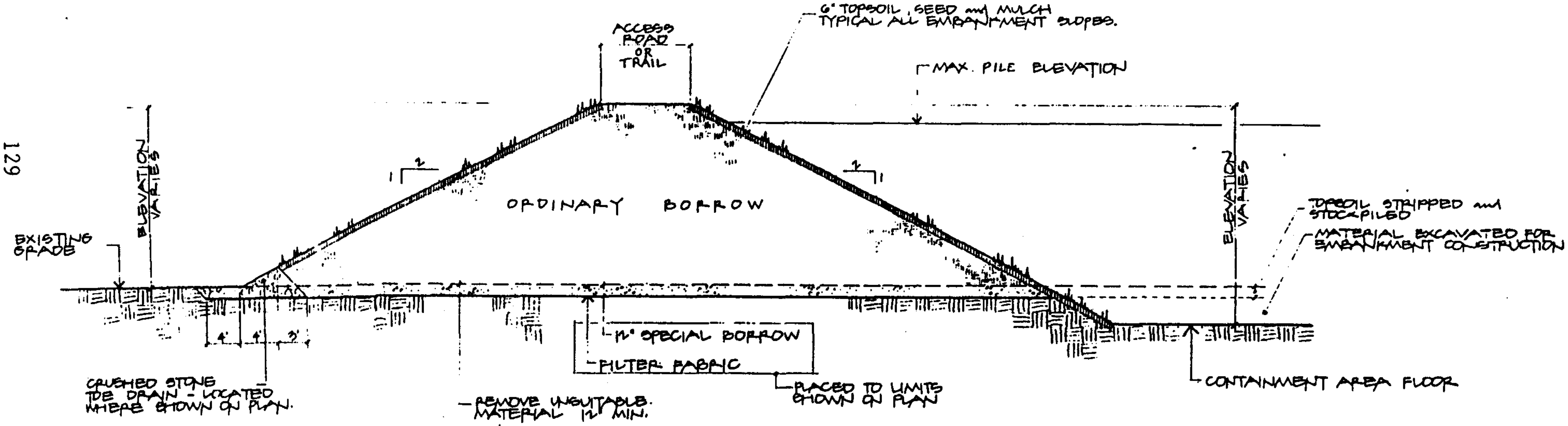


FIGURE 22
WORK AREAS ASSOCIATED WITH THE PROPOSED DREDGING OF BUTTONWOOD POND

BASED ON THE MASTER PLAN MAP PREPARED BY WALKER-KLUESING DESIGN GROUP

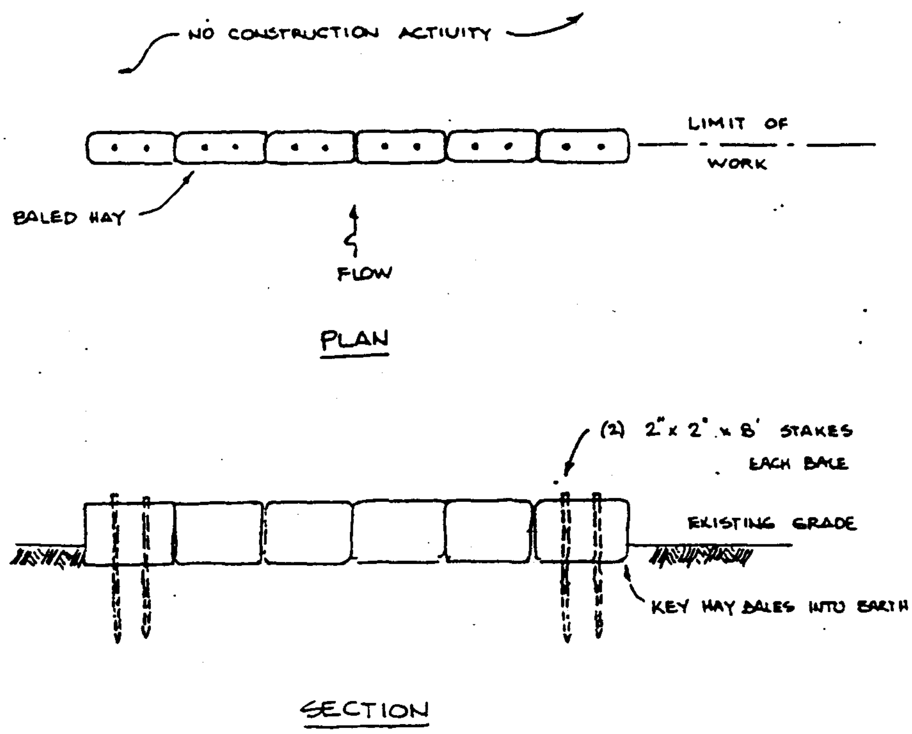
FIGURE 23



TYPICAL EMBANKMENT

NOT TO SCALE

FIGURE 24



HAYBALE SILT BARRIER

NOT TO SCALE

could be removed and not replaced at its current location at all. Assuming that some form of outlet structure will be necessary at its current location for some time, however, it would be more economical to maintain flexibility in the dredging plan than to incur the cost of outlet replacement (particularly if that outlet structure is eventually removed). Some money has been included in the accompanying cost estimate for outlet repair, but the anticipated repairs are restricted to patch work intended to improve water level control and structural integrity.

Assuming that the removal of the fill in much of the emergent wetland area of the pond is permitted, there will still be portions of that wetland which should be preserved. Peripheral stands of vegetation are desirable for shoreline stabilization and habitat diversity, and there are a few wetland pockets in the present configuration which merit preservation for their vegetative beauty, habitat value, and educational utility (e.g., the cranberry patch along the northeastern shore). The intent of the dredging in this area is to remove the silt, tires and trash-laden topsoil and the extensive, dense stands of cattail and rushes associated with this soil.

The dredging contractor must also be aware of and avoid damage to the sanitary sewer line which passes under the pond. No sign of this pipe was detected by visual inspection or probing of the bottom by a diver, but it could be contacted during sediment removal. Although no pond problems have been linked to this rather old (cast iron) pipe, officials of the City of New Bedford should evaluate the efficacy of replacing it, as the drawdown and dredging activities will provide an excellent opportunity to do so, if desired.

Approximately 42,800 cy (again, contractors prefer to deal with english units) of sediment would be removed from the pond area during the proposed dredging program. Spread over a six acre containment area (up to 7 ac available), an average depth of less than 4.5 ft would be achieved. After an appropriate drying period (weather dependent, probably several months), this material would be available for use in conjunction with planned park revitalization projects. Some of the dredged material would probably be used in the recommended bank stabilization.

The badly eroded banks along the east and west shorelines should be stabilized with a porous sheet material under soil and dense vegetation (wetland plants or grass) to minimize future damage in a manner consistent with the park master plan. Some fill will be necessary to reestablish shoreline shape and slope in these areas (Figure 22). The granite blocks which form the shoreline along Court Street should be repositioned or replaced, as needed, unless the Court Street removal coincides with the dredging program.

The resultant shape of the pond would approximate that requested in the park master plan, although the islands and certain cosmetic/aesthetic shoreline features have been deleted from the dredging plan proposed in this report; these do not appreciably affect water quality or system hydrology and could not be funded by the Massachusetts Clean Lakes Program (Haynes 1988). The functional intent of the dredging program is to provide a hydrologically more stable system in which turbidity and plant nuisances are kept to a minimum. Increased aesthetic appeal will also result from the proposed dredging program.

The general sequence envisioned for this program involves construction of the containment area during summer, drawdown of the pond around Labor Day, establishment of one or a few work areas with haybale or sandbag barriers, and commencement of sediment removal during early to mid-September. As dredging is completed in delineated areas, new, adjacent areas would be established and dredged. Dredging would be halted during precipitation events producing inflows of more than about 15 cfs. Outlet repair would be performed during the dredging operation, as would periodic grading of the containment area. When dredging was completed, shoreline stabilization would commence. All construction work could be completed as early as December, weather permitting. Contractors should expect weather delays after early December, as precipitation (as rain, seldom snow) is generally greatest during winter in the New Bedford area. A single dredging season should be planned, lasting no later than to the beginning of May, to minimize interference with park activities.

The anticipated total cost of the proposed dredging program is $775,900 (Table 18), although there is the potential for a substantial cost savings related to the containment area, if simple, small, bulldozed berms are deemed sufficient. The majority of the cost is associated with actual excavation and final disposal ($256,800 each), which are assumed to have a unit cost of $6.00/cy. An allottment of $107,000 has been made for containment area construction. All other itemized tasks have associated cost estimates of less than $50,000 each.

TABLE 18

ELEMENTS AND COSTS ASSOCIATED WITH
THE PROPOSED DREDGING PROGRAM

Item/Task	Cost/Unit	Units	Estimated Cost ($)
1. Engineering Design (Surveying, equipment selection, containment area design, dredging plans/specs)	$1/cy	42,800	$ 42,800
2. Contractor Selection (Advertisement, bidders meeting, bid selection supervision)	Lump Sum (Based on man hours & direct costs)		3,000
3. Permits (EIR, applications, meetings/ hearings)	Lump Sum (Based on man hours & direct costs)		15,000 *
4. Containment Area Construction (Clearing, access road, berms, security)	$2.50/cy	42,800 cy	107,000
5. Protective haybales or sandbags (Around areas being dredged)	$20/LF	500 LF	10,000
6. Outlet Repair (Patch work, spillway repair)	Lump Sum (Based on materials/labor)		20,000
7. Excavation	$6/cy	42,800 cy	256,800
8. Bank Stabilization			
a. Replacement of stone blocks	$200/block	30 blocks	6,000
b. 6" Sand/loam over filter fabric/enkamat	$25/sq.yd.	1500 sq.yd.	37,500
9. Ultimate Disposal and Grading of Dredged Material	$6/cy	42,800 cy	256,800
10. Construction Supervision	$500/day	30 days	15,000
11. Other Meetings, Reports, Travel	Lump Sum (Based on man hours & direct costs)		6,000
Total			$775,900

* Only EIR preparation, at approximately $10,000, is eligible for funding under the MA Clean Lakes Program.

EDUCATION PROGRAM

Environmental education is critical to the improvement and safeguarding of natural resources, as the potential impacts arising out of human demand can exceed the technological and economic capacity to repair the damage once it is done. By informing watershed residents of their role in determining the quality of water resources, it is hoped that many impacts can be avoided or reduced in magnitude, making technological fixes unnecessary or at least affordable. In the case of Buttonwood Pond, much damage has already been done, and the necessary technological solution is an expensive one. An appropriate educational program, therefore, should be directed at preserving the improvements which technology (and many dollars) will provide, and at avoiding additional hazards not currently threatening the pond.

A dual approach is recommended, involving the presentation of a slide show and distribution of a brochure to watershed residents. The slide show should be specific to the Buttonwood Pond watershed, depicting the activities and features which affect water quality and quantity, and emphasizing the link between human actions and conditions in the pond. This slide show should be presented at public meetings and special park events, such as those sponsored by the Friends of Buttonwood Park, and in the New Bedford school system. The brochure should provide a summary of the relationships elucidated in the slide show, and make specific recommendations regarding residential practices which affect water quality. Although the brochure may be prepared by a consultant it should be distributed under the auspices of a New Bedford organization, such as the Office of Neighborhood Development or the Friends of Buttonwood Park.

The primary target of the brochure (and to some extent the slide show) should be the storm water drainage system as a link between residents and the Buttonwood Brook system. The concept of a watershed was not found to be especially familiar to public meeting participants, and is greatly complicated by the largely unseen storm drainage system. It is important that residents recognize that the inputs to that system reach natural water courses without treatment. The impact of the use of the storm drainage system as a disposal facility for waste oil, wash water, or solid refuse must be made clear. Residential practices which minimize inputs to this system (e.g., washing cars only on grass and with a minimum of water, and bagging leaves or grass clippings) should be stressed.

In addition to residential practices which impact water quality, there should be some emphasis placed on proper land stewardship by abutters and park users. Disposal of leaves, grass clippings, and other refuse on park property is neither a right nor a privilege. Keeping vehicles off vegetated areas is another necessity, one which will become more critical as money is spent on ornamental horticulture in the park.

A total of $10,000 has been allocated for an educational program. Certainly a descriptive slide show and informational brochure can be developed for this price, and several thousand brochures produced as well. The choice of presentation or distributional mode is left to City officials, but an approach which involves as many local citizens as possible in the actual transfer of information is desirable. Distribution at the zoo is one possible approach with much merit and low cost.

WATERSHED MANAGEMENT PROGRAM

The detention and diversion programs constitute watershed management programs, although they are aimed more at controlling inputs than at curtailing them. The education program should result in some reduction in pollutant loadings, but few of the other watershed management techniques are readily applicable to the Buttonwood Pond watershed. There is little developable land left in the watershed, the watershed is already sewered, there is no active agricultural land involved, and only education or a very expensive vacuum street sweeping program would appreciably alter the quality of runoff in this urban watershed. The street sweeping program was judged unworkable, and the educational program has already been recommended and discussed. Erosion control is always applicable, but most of the erosional damage has already been done by past development projects. With few such projects possible in the watershed today, only clean-up and minor precautionary efforts are possible.

The problem with managing the Buttonwood Pond watershed is that it largely involves engineering an already heavily engineered system. With each layer of engineering, the complexity of the system increases and the factors which must be considered in future engineering efforts multiply. What is needed is a clear set of priorities by which to govern watershed management. If the competing interests of transportation, housing, utilities, parks, wildlife, and water quality are to be satisfactorily resolved, it will be necessary to reach a consensus on what attributes of the urban environment are most important to its residents. The questionnaire survey conducted by the New Bedford Municipal Advisory Committee (Appendix A) was an important step in this direction, and continued efforts of this type are encouraged.

MONITORING PROGRAM

A monitoring program will be necessary to assess the success of management actions and aid in the formulation of appropriate management policies and supplementary management programs. Of primary interest are the water flow through the system, concentrations of phosphorus and fecal coliform bacteria, the turbidity level, and the density of macrophytes. Changes in the depth of water and soft sediment in the pond should be monitored as well. Samples of sediment from the pond should be tested for settling rate and residual turbidity.

Macrophyte coverage, water depth, and the distribution of soft sediment can be measured annually in the pond, while flow and the water quality parameters should be assessed monthly at the inlet and outlet of both Buttonwood Pond and the upstream detention basin. In addition to monthly sampling at four stations, flow and water quality along Buttonwood Brook upstream of Hawthorne Street should be evaluated during three storm events per year. The storm water quality assessment should incorporate size fractionation of the phosphorus load at several key stations (basin inlet and outlet, inlet of Buttonwood Pond).

This monitoring program will allow evaluation of the effectivenss of the detention, diversion and dredging programs, along with the need for further management actions. Establishment of a layperson flow monitoring program much like that employed near the beginning of this study is also advisable to gather additional flow data. This will facilitate a better analysis of the impact of the overall project on flooding in the park. A total annual monitoring cost of $23,300 is anticipated (Table 19), with costs rising slightly each year after the initial year of monitoring. Some cost savings could be realized, however, if park personnel were trained to perform certain repetitive or simple monitoring tasks.

FUNDING ALTERNATIVES

Several sources of funding are available for management activities in Buttonwood Pond and its watershed (Table 20). The Clean Lakes Program, which sponsored this study, is the likely key source of support. Special grants from the Massachusetts Department of Environment Management (DEM), through the Olmsted Historic Landscape Preservation Program, Rivers and Harbors Program, or as legislative budgetary line items, could provide substantial funding as well. A project of this magnitude will likely require multiple sources of funding. Other sources noted in Table 20 are less stable or appropriate to the proposed

TABLE 19

ELEMENTS AND COSTS ASSOCIATED WITH
A ONE YEAR MONITORING PROGRAM

Item/Task	Frequency	Cost ($)/ Units	Estimated Cost ($)
1. Macrophyte Monitoring			
a. Field evaluation of assemblage composition and density	Annual	$1,500	$ 1,500
2. Sediment Monitoring			
a. Prepare bathymetric and soft sediment isopach maps. Assess sediment features (settling rate, residual turbidity)	Annual	2,500	2,500
3. Surface Water Quality Monitoring			
a. Assessment of total phosphorus, ortho-phosphorus, turbidity, fecal coliform & flow at inlet & outlet of det. basin, inlet & outlet of Buttonwood Pond	Monthly	800	9,600
b. Assessment of above parameters at up to 10 stations during storm events (composite samples), with size fractionation at up to 3 stations	3/Yr	1,900	5,700
4. Meetings and Reports			4,000
Total Per Year			$23,300

NOTE: Inflation is likely to raise costs slightly each year.

TABLE 20

POTENTIAL FUNDING SOURCES FOR THE PROPOSED
MANAGEMENT OF BUTTONWOOD POND

Source	Funding Level	Notes
Massachusetts Clean Lakes Program (Ch. 628 of the Acts of 1981, DEQE)	75%	Sound program; July 1 application deadline; likely source.
Federal Clean Lakes Program (Sec. 314 of PL 92-500, USEPA)	50%	Financially restricted; few new projects accepted.
Rivers and Harbors Program (Division of Waterways, DEM)	75%	Recently reorganized, Jan. 15 deadline. If renewed in subsequent FY appropriations it could supply 50% funding.
Small Watershed Protection Program (PL 83-566, SCS)	(up to) 100%	Requires high cost-benefit ratio. Funding cutbacks have limited this program.
Resource Conservation and Development Program (Food & Agric. Act of 1962, SCS)	(up to) 100%	Requires established RC&D district, very limited funding opportunities at present.
Federal Land and Water Conservation Fund; Division of Conservation Services, EOEA (Federal Pass Through)	50%	Acquisition of lands for outdoor recreation; could be useful in obtaining land for additional detention capacity, if warranted.
Mass. Self Help Program M.G.L. Chap. 132A, Sec. 11 (DCS/EOEA)	(up to) 80%	Grants to Conservation Commissions for land acquisition; requires an approved open space plan. Funds available.
Line items in DEM budget: possible grants through the Olmsted Parks Restoration Program	(up to) 100%	Possible allocations related to further park improvements. Requires consistency with established Master Plan.

TABLE 21

PERMITS AND APPROVALS REQUIRED IN CONNECTION WITH
THE PROPOSED IMPROVEMENTS TO BUTTONWOOD POND

Permit/Review/Approval	Contact Office/Telephone No.
Mass. Commission Against Discrimination Approval	Commission Against Discrimination 1 Ashburton Place Boston, MA 02108 (617) 727-7309
Executive Order 215 (Fair Housing Order) Approval	Executive Office of Communities & Development 100 Cambridge Street, Room 1404 Boston, MA 02202 (617) 727-7130
Certification of Title to Project Site	DEQE, DWPC Westview Building Lyman School Grounds Westborough, MA 01581 (617) 366-9181
Division of Fisheries and Wildlife Notification	Southeast Wildlife District Bournedale Road Buzzards Bay, MA 02532 (617) 759-3406
Historical Commission Approval	Historical Commission 294 Washington Street Boston, MA 02108 (617) 727-8470
Natural Heritage Program Review	Natural Heritage Program 100 Cambridge Street Boston, MA 02202 (617) 727-9194
Mass. Environmental Policy Act Review	Executive Office of Environmental Affairs MEPA Unit 100 Cambridge Street, 20th Floor Boston, MA 02202 (617) 727-5830
Wetlands Protection Act Permit	New Bedford Conservation Commission City Hall Williams Street New Bedford, MA 02740 (617) 999-2931

TABLE 21 (CONTINUED)

Permit/Review/Approval	Contact Office/Telephone No.
Army Corps of Engineers Sec. 404 Permit	ACOE Regulatory Branch 424 Trapelo Road Waltham, MA 02254 1-800-362-4367
Chapter 91 Waterways License	Division of Waterways/Wetlands Regulation DEQE 1 Winter Street Boston, MA 02108 (617) 292-5517
Water Quality Certificate	Permits Section DWPC 1 Winter Street Boston, MA 02108 (617) 292-5673
New Bedford Dept. of Public Works Approval	NBDPW City Hall Williams Street New Bedford, MA 02740 (617) 999-2931
Buttonwood Park Master Plan Consistency Approval	Office of Neighborhoods City Hall Williams Street New Bedford, MA 02740 (617) 999-2931

The review by the EOEA (MEPA unit) will be initiated by the filing of the attached ENF (Appendix D); New Bedford officials (presumably the Office of Neighborhood Development) should file this document at their earliest convenience. The New Bedford Conservation Commission will be reviewing this report, but a formal Notice of Intent should be filed by City officials to initiate the approval process associated with the Wetlands Protection Act.

The remaining three approval processes are directly related to the proposed dredging of Buttonwood Pond. An application must be filed with the Division of Waterways and Wetlands Regulation in Boston to receive approval of the operation and acquire a dredging permit (Chapter 91 Waterways License). The City of New Bedford is responsible for filing this application, but the Phase II consultant can assist in its preparation; this application is not filed until a definitive dredging plan has been drafted.

An ACOE permit, known as a Section 404 permit, must also be obtained through application to the ACOE in Waltham. This permit is required for any fill activities in wetlands (including ponds) and for state-sponsored dredging programs. This application is also filed by City officials, but the Phase II consultant should assist in its preparation as with the Chapter 91 Waterways License request.

The Water Quality Certificate, issued by the MDWPC, endorses a project as consistent with water quality goals in the project area. Review of the project by the MDWPC is initiated along with the Chapter 91 and Section 404 permit approval processes. A copy of the application to be filed is attached to the ENF (which it also accompanies) in Appendix D.

Although the Division of Fisheries and Wildlife will already have reviewed the proposed project, additional notification should be given about a month before the pond is drained for dredging. Aside from being a requirement for pond draining in Massachusetts, it would be wise to seek input and possible assistance from the DFW in any fish salvage operation which may be performed.

PUBLIC PARTICIPATION

In addition to review by the agencies mentioned in the Environmental Evaluation section of this report, the public at large was involved with the development of management alternatives. To date, two public meetings and numerous informal discussions have been conducted by BEC in the City of New Bedford. In addition to the official public meetings required by the Clean Lakes Program, BEC representatives attended 10 meetings of the New Bedford Municipal Advisory Committee, which were open to the public, and participated in the public meeting regarding the park master plan.

Participants in meetings were encouraged to express their views and make recommendations. Local support for the project has been high, as it is perceived as one of the major elements of the park revitalization program now underway. The Advisory Committee, which is itself comprised of private citizens and City officials, has steered the development of management alternatives in accordance with the technical, economic, social, and political constraints perceived in New Bedford. All comments received from participants of public meetings are included in Appendix E.

RELATION OF PROJECT TO EXISTING PLANS AND PROGRAMS

The proposed project is intended to be entirely consistent with the Buttonwood Park Master Plan for restoration and maintenance under the Olmsted Parks Restoration Program sponsored by the Massachusetts Department of Environmental Management. Care has been taken to minimize interference with any public works projects currently underway or slated for the near future. Construction schedules which minimize interference with park visitors and activities have been recommended.

FEASIBILITY SUMMARY

An evaluation of possible management options was conducted, and those alternatives which were not appropriate or feasible were eliminated from further consideration. Remaining options included storm water diversion and detention, dredging of Buttonwood Pond, bank and slope stabilization, environmental education, emergency dilution and flushing, and fishery management in conjunction with dredging. The primary elements of the recommended management plan are the diversion and detention of storm water and the dredging of the pond with concommittant shoreline stabilization.

A tentative implementation schedule and associated costs are presented in Table 22. An implementation monitoring program and the production of an educational slide show and brochure are included. The total anticipated cost of the management program is $1,455,350.00. Potential funding sources have been discussed, with the Massachusetts Clean Lakes Program targeted as the likely primary source. Additional funding through programs sponsored by the Massachusetts Department of Environmental Management is also possible and is being pursued.

The anticipated impacts of the proposed management plan include reduction of the phosphorus load to Buttonwood Pond by 68 to 89%, reduction of the corresponding nitrogen load by 45 to 74%, a 40 to 95% decline in turbidity, a 60 to 80% decrease in macrophyte density, and a reduction of flooding potential of 30 to 50%. Storm water runoff in the watershed will be managed to minimize impacts on the pond. The physical features of the pond itself will be altered to produce a more functional and aesthetically appealing water body consistent with the park master plan.

TABLE 22

SUMMARY OF MANAGEMENT ACTIONS, IMPLEMENTATION SCHEDULE, AND ASSOCIATED COSTS

Item/Task	Spring-Fall 1989	Winter 1990	Spring 1990	Summer 1990	Fall 1990	Winter 1991	Spring 1991	Summer 1991	Fall 1991	Winter 1992	Spring-Fall 1992	Total Cost ($)
Grant Arrangements w/DEQE, Line up Potential Additional Funding Sources	X	X	X									Unde-termined Adminis. Cost
Permits			10,000	5,000			7,500	7,500				30,000
Detention Program				6,500	64,800	?	?	?	?	?		71,300
Diversion Program				12,000	238,950	270,550						521,500
Dredging Program							40,000	112,800	323,300	284,800		760,900
Monitoring Program				5,825	5,825	6,100	6,100	6,100	6,100	6,400	19,200	61,650
Education Program					5,000	5,000						10,000
Total Cost ($)	X	X	10,000	29,325	314,575	281,650	53,600	126,400	329,400	291,200	19,200	1,455,350

NOTE: Should additional detention facilities be warranted, additional costs would be incurred under the detention program. If performed under the existing Order of Conditions, the proposed detention program could be shifted forward in time to 1988-89 and reduced in cost. Additional detention facilities would still be eligible for funding under the Clean Lakes Program.

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APPENDIX A

INFORMATION PROVIDED BY MEMBERS OF THE NEW BEDFORD MUNICIPAL ADVISORY COMMITTEE

MEMBERS OF THE OLMSTED

MUNICIPAL ADVISORY COMMITTEE

Robert C. Bromley, Chairman
David A. Kennedy, City Planner
Edward Lowney, Supt. of Parks
Kathleen Burns, Commissioner DPW
Joseph Arsenault, Asst. Supt Parks
Karen McAfee-Bromley, Zoo Director
Phil Paleologos, NB Park Board
Denise Bunnewith, City Planning
Dana Souza, OHAND
Edward Girard, Mayor's Office
Sharon Pinho, Buttonwood Library
Peter F. Jackson, DEM
Walker-Kluesing Design Group
Dr. Kenneth Wagner, BEC

Jean Bennett, Co-Chairperson
Roland Hebert, NB Tennis
Thalia Cartwright, Zoo Soc.
Carole Farrell
Donna Huse
Bonnie Oliveira
Linda Houston
Atty. Bruce W. Lider
Claire McDonald
Susan Underwood
Brenda R. Ross
Rick Taylor
Allen C. Haskell

BUTTONWOOD PARK: HISTORIC SUMMARY

Joy Kestenbaum, Historic Consultant
Olmsted Historic Landscape Preservation Program

Buttonwood Park was acquired as part of the City of New Bedford's first effort to create a municipal park system. In 1892 three sites were obtained in the three undeveloped districts: the North, West, and South Ends. Located one mile from the city center at the western limit of the city near the border of the Town of Dartmouth, Buttonwood Park was intended to be the central park of this system. While it was the intention of Stephen A. Brownell, the principal advocate of the New Bedford park system, that the parks of the North and South End border, respectively, the Acushnet River and Buzzards Bay, Buttonwood Park was envisioned as an inland park, its main feature being a large pond which would encourage both winter and summer recreational activities.

In 1894, two years after the acquisition of park lands, Stephen A. Brownell, mayor-elect and Chairman of the Park Commissioners, sought the advice of Olmsted, Olmsted & Eliot. After touring the principal park areas in the company of city officials, Eliot offered recommendations for the development of these parks in the form of a written report of his visit. By the end of the year the Olmsted firm was under contract to prepare a preliminary plan for Buttonwood Park. In February of 1895 Eliot, as the principal designer, completed the plan and accompanying report in which he elaborated upon the ideas contained in the report of his visit.

Eliot's plan for Buttonwood Park would have created a quintessential Olmsted park. The Eliot design was a crystalization of the principles found in the large country parks designed by Olmsted and his partners, only on a smaller scale and for a smaller city. For what was intended as a park of roughly 150 acres, Eliot proposed the two principal elements of pastoral scenery, the pond and the meadow. Following the wishes of the New Bedford Park Commissioners, he proposed the enlargement of the existing ice pond of some six acres to a lake of twenty acres bordered by a picturesque shoreline. He designed the large meadow to provide expansive views and, like the pond, to provide for passive as well as active recreation. The plan incorporated the separation of ways that the Olmsted firm had devised for their other large city parks. The one vehicular drive was restricted to the perimeter so that the interior, with its strategically planned footpaths, was accessible only to pedestrians. And in order to provide restful scenery "removed from the noise and sights of the town", a dense mass of trees and shrubbery was to be planted around the perimeter of the park so as to conceal the bordering streets.

Unfortunately, the Olmsted firm was not retained to execute this plan, which, with the aid of surveys, was carefully adapted to improve this rather flat, undeveloped site. The plan was not formally adopted, but only placed on file. The economic and political climate in New Bedford in the late nineteenth century didn't encourage generous spending on public parks, and in fact, the ambitious scheme for the muncipal park system, as was the case for Buttonwood Park, was postponed and never actually developed according the original intent. Today New Bedford has 68 recreational grounds including playgrounds and parks which are located throughout the city; however, none of the three major scenic parks of the early system was developed according to a cohesive plan.

The early development of Buttonwood Park diverged from the proposed Eliot plan. Initially the park was only about sixty acres. Despite the recommendations of the Olmsted firm and the park board to acquire additional acreage, during the first ten years of its independent existence, the park retained its irregular and awkward boundaries. Early development as executed by the park superintendent and city engineer was restricted to this area. From 1903 to 1935 several additional parcels were added, but these additions have not been successfully integrated into the overall design of the park. By the early years of the twentieth century the park had more or less taken its present form. Court Street was substantially laid out through the park, and the roadway above the newly constructed stone dam formed its western extension. In 1894 a small menagerie was begun. The animal collection and related facilities have continued to grow over the years. Encouraged by the formation of the local zoological society, the greatest expansion has occurred during the past twenty years. From the earliest years, the large rectangular field of about ten-and-a-half acres to the west of Rockdale Avenue was designated as a ball field.

As early as 1905 Warren H. Manning, consulting landscape designer and former Olmsted associate, had recommended that another general plan of the whole park be prepared which would take into consideration the present uses and boundaries of the park. At this time Manning was hired primarily to prepare a planting plan for what was then the southwestern portion of the park, the area which contained the zoo and which was plagued by flooding and drainage problems. He recommended the creation of a lagoon dotted with islands the whole length of the newly constructed canal; he believed that the lagoon would resemble the central feature of the 1895 plan and would be the least expensive way to improve upon the design of the canal, which he felt to be "neither distinctly formal or distinctly informal." As with the Olmsted, Olmsted & Eliot plan, Manning's recommendations were not adopted.

During the course of the twentieth century Buttonwood Park has fulfilled the prediction of the early park commissioners and has become the largest and most frequented park in the New Bedford park system. Its central location in the city, its opportunities for active and passive recreation, and the continuing presence of a collection of animals have added to its popularity over the years. With the advent of the automobile the park has become more accessible to the community at large.

However, this intensive use has created certain stresses on the limited acreage of this small "country park," which is faced today with certain ongoing problems. Unresolved hydrological problems and water quality have worsened in recent years due to increased building and roadway construction in the watershed area to the north as well as inside the park. Extensive vegetative decline and traffic congestion create safety hazards for park users and detract from the park's scenic intent. Limited park appropriations over the years have severely affected the park. Buildings, monuments, and site furnishings have not received adequate routine maintenance and are in varying states of disrepair.

The Olmsted Historic Landscape Preservation Program provides an opportunity to correct the long-term problems of Buttonwood Park, particularly as related to flooding and drainage and circulation. The park is in need of an improved and well-thought out circulation plan and of a defined program for tree planting and removal and vegetation management. The principles contained within the original Eliot plan provide a guide for intelligent park planning. The 1895 plan created a balance between active and passive recreation, between scenic values and utilitarian needs. The master planning of Buttonwood Park must establish methods for correcting the ongoing problems, and, at the same time, must address the value of the original design intent, the early developments and later additions, and the contemporary needs of park users.

SUMMARY CHRONOLOGY OF BUTTONWOOD PARK, NEW BEDFORD

Joy Kestenbaum, Historic Consultant
Olmsted Historic Landscape Preservation Program

1892 On January 26 the first regular meeting of the Park Commission of New Bedford is held with the joint special committee of the City Council to discuss the establishing of a park system.

An Act of the Legislature, Chapter 150, is passed on April 6, authorizing New Bedford to borrow money for park purposes by the issuing of bonds to the amount of $100,000.

The Board of Park Commissioners buys about 62 acres of land at the West End for $34,000.

1894 On March 16 Park Commissioners and Superintendent Drake of the Public Works inspect West End Park to determine what improvements need to be made.

On April 20 the lands previously acquired for park purposes are legally declared as such; West End Park is named Buttonwood Park.

May 11: Mayor Stephen A. Brownell, Chairman of Park Commission, writes to Charles Eliot seeking advice about New Bedford parks.

May 31: Mayor Brownell and William F. Williams, City Land Surveyor, visit the office of Olmsted, Olmsted & Eliot requesting consultation regarding the laying out of the parks.

June 7: Charles Eliot tours the parks of New Bedford and adjoining sites in the company of city officials.

June 13: Eliot prepares a written report of his visit to New Bedford parks.

During the summer, following the report of Williams, pond is dredged and its depth increased and the mud used to grade the surrounding land. Other minor improvements are made for the convenience and enjoyment of park visitors. Menagerie is started.

October 3: George F. Bartlett, Park Commissioner, calls on Eliot to discuss possible employment for West or Buttonwood Park.

On December 7 New Bedford Park Commission sends a communication to the City Council recommending further appropriation for purchase of additional park property and improvements of park lands.

On December 21 Park Commissioners vote to enter into contract with Olmsted, Olmsted & Eliot to furnish preliminary plans for Buttonwood park; on December 31 the Board of Park Commissioners receives a copy of the Articles of Agreement from the Olmsted office.

1895 In February Charles Eliot of the firm of Olmsted, Olmsted & Eliot completes the preliminary plan and report on Buttonwood Park.

March: The New Bedford Park Commission receives the preliminary report and plan and places it on file. The involvement of Olmsted, Olmsted & Eliot with the New Bedford park system is terminated.

Work on the park continues.

1896 Baseball field laid out on lot south of Court Street.

The drive at the west end of the park is extended around the deer pen.

1897 A bandstand and monkey and bear houses are constructed.

1902-5 Heavy flooding destroys old dam and sluiceway south of the pond; new stone dam with roadway above is built as a replacement after plans of Williams; Williams redesigns stream south of dam as a canal lined with riprap to be flanked by walkways.

1902-10 A variety of native and ornamental trees and shrubs are planted in the park. Pin oaks are first planted along the Court Street roadway.

1903 About 11 acres of land west and north of the pond and extending to Kempton Street are sold to the City as an addition to Buttonwood Park.

1905 Warren H. Manning, landscape designer, prepares a general plan and report with recommendations for the future development of the southwest portion of Buttonwood Park and a planting plan and list of the same. His recommendations are not adopted.

1910 Real estate promoter F. William Oesting erects eight cottages on Lake and Jenny Lind Streets on land originally proposed for Buttonwood Park as part of Parkview development.

1911 Land is purchased extending the park's northern boundary eastward on Kempton Street and making Lake Street the northern border east of the pond.

1913 About 18 acres of wooded land to the south to Hawthorn

Street is purchased from Sylvia Ann Howland Estate and Hetty Green as an addition to the park.

1914 September: the Barnard Monument is erected at the intersection of Court and Buttonwood Streets.

1921 Greenhouse and comfort station are constructed in the park.

1922 Additional land at the northern end and adjacent to the park is taken by eminent domain.

Park barn and wagon shed for maintenance are erected in the park.

1923-6 Perennial garden is established to the east of the greenhouse and a couple of years later a formal garden is laid out to the west.

1931 Extensive planting of ornamental trees and shrubs at Buttonwood Park is carried out through the generosity of Garden Clubs of the City; the first Japanese flowering cherry trees are planted at this time.

1934-41 Park undergoes extensive rehabilitation with federal assistance.

The brick warming house, an E.R.A. project, is erected to the east of the pond.

1935 Approximately two acres of privately owned property west of Oneida Street is taken by the City for failure to pay taxes; this parcel forms the last addition to Buttonwood Park.

1936 The new bear den of field stone and concrete is erected to replace the old frame bear house.

1936-38 The British Memorial Monument, the first of several memorials to local war dead and deceased municipal workers, is erected in the park.

1960 The new Buttonwood Branch Library opens to the public at the northeast corner of the park at Lake Street and Rockdale Avenue.

1961 The lower section of canal is cement-lined in an attempt to improve the soggy condition of the ground and to replace riprap which, because of poor maintenance and rodent control, is said to be a haven for rats.

1966 Buttonwood Park receives a grant from the Federal Bureau of Outdoor Recreation to plan for the renovation and redesign of the zoo and park.

1967 Connell Associates, landscape architects and engineers of Malden, prepare plans and specifications for the rehabilitation of the park. Improvements include new zoo facilities and shelters, lagoon and islands, walks, bridges, playgrounds, parking area and roadways.

New species, including an elephant, a timber-wolf, and two lions, are acquired for the zoo.

1968 The first of three consecutive local zoological societies is formed to promote development of the Buttonwood Park Zoo.

1969 Buttonwood Park is renamed, "Veterans Memorial Park at Buttonwood" as part of a park construction project. The surplus from the old Soldiers and Sailors Memorial Fund is used by the World War I Veterans to construct a Veterans Memorial building in the park and to construct new zoo facilities.

The Buttonwood Park Redevelopment Project is funded by the Bureau of Outdoor recreation and the City of New Bedford on a 50-50 basis.

1972 World War I Veterans Memorial Building is dedicated.

1974-5 A comprehensive development program prepared by the Park Board, Zoo staff, Planning Department and the City Council's Special Committee is planned to upgrade the Zoo to meet the requirements of the Animal Welfare Act. The program is funded by a Federal Community Development Block Grant of $100,000. Seals and sea lions and other animals are added to zoo population.

1975-6 Fox and coyote shelter and contact area are constructed in the Zoo area with matching funds from the Massachusetts Bicentennial Commission. Plans are made to try to control flooding, which contributed to the cause of the death of two seals.

1976-7 The warming house is renovated for use as the headquarters for the Department of Parks and as a Senior Citizens Center.

1978-9 Department of Public Works and the consulting firms of Camp, Dresser & McKee and Tibbets Engineering, Corp., prepare plans, which are not executed, for the reconstruction of Brownell Avenue and construction of new concrete culvert at the outlet of the brook at Hawthorn Street to help eliminate flooding conditions.

1982 New Bedford's parks are no longer patrolled by special park police; responsibility transferred to city's police department.

WALKER·KLUESING DESIGN GROUP
LANDSCAPE ARCHITECTURE · SITE PLANNING · URBAN DESIGN

MEMORANDUM
17 April 1986

Partial Summary of Major Issues
as identified by New Bedford Municipal Advisory Committee members
BUTTONWOOD PARK
New Bedford, Massachusetts

By: Nancy Salustro

The following is a summary of the concerns for Buttonwood Park obtained by a discussion of the major issues with most of the New Bedford Municipal Advisory Committee members on an individual basis. Our intent is to continue this discussion with the members we have not yet reached and we hope that the members we have talked with will continue their input.

This list is prioritized by the most frequently discussed issues first, to the individually suggested topics last. This is by no means comprehensive or complete, but an initial probing to identify the major issues at hand. It is not meant to de-emphasize any particular issue at this time.

PARKING: Everyone felt that the parking situation at the park needed study and improvement. Existing parking is inadequate, inaccessible and isolated. This results in needless vandalism, loitering and parking in undesignated areas. If one perceives the existing lots to be unsafe, users will park closest to their place of recreation or destination. Ball players park on the ball field, staff closest to their place of work, and senior citizens on the lawn in front of the center.

BUTTONWOOD POND: Flooding of the pond and surrounding lands along the Buttonwood Brook is a major problem which inhibits use and access in these areas. With the pond being one of the nicest amenities in the park it was felt that attention to this area should be immediate.

CIRCULATION: Many felt that the circulation patterns in the park need to be improved. Attention must be paid to vehicular circulation as well as pedestrian circulation. Service vehicles and user vehicles drive on the interior grounds. Park entrances are congested. Court Street is used as a drag strip and a thoroughfare. Areas are inaccessible and some roads are inappropriate. Pedestrian circulation is also limited in that many areas are inaccessible, not secure or not clearly defined. This results in pedestrians either not taking advantage of all of the park amenities or users making his or her own path to a facility. Bicyclists, joggers and skaters have no clearly marked paths for their use.

VANDALISM AND SECURITY: Just about every member mentioned how unfortunate it was that so many of the lovely buildings, plantings and facilities have been vandalized. Buildings have been spray painted, trees have been stolen, cars have been broken into and visitors have been hassled. Many identified the parking lot off Hawthorn as a place where drugs are purchased, cars drag and a lot of drinking takes place. Several people mentioned that the security is inadequate with no real enforcement of park closing times, speeders on Court Street and vandalism to park property including the comfort stations, tennis courts and zoo property.

MAINTENANCE: Almost everyone mentioned the need to improve maintenance in the park. Vegetative maintenance is important, as is general park facilities maintenance. More clean up and repairs to buildings, recreational equipment and the zoo were all suggested. Many of the trees and shrubs in the park need to be cleaned out and taken down. All members felt that this would improve the visual quality of the park immensely.

FORMAL GARDENS: Several mentioned that they wanted the formal garden area restored in the park. Many had fond memories of this area and said that this area attracted many new visitors to the park.

ZOO IMPROVEMENTS: Another priority is to improve the zoo. The zoo attracts visitors from all over the region and many people frequent the zoo many times during the season. The perimeter of the zoo needs to be clearly defined with a designated area for zoo expansion outlined. It was suggested that a walkway be provided around the exterior of the zoo and that the zoo be better separated from other high use areas.

VETERANS BUILDING: It was suggested that the veterans building may be put to better use by making it more a part of the park's heritage, perhaps as a park museum or gathering place.

LIBRARY: It was mentioned that the library grounds might be improved to take advantage of its location in the park. A outdoor reading area was suggested as was an enclosed solarium. It was also suggested that a canopy be installed at the front entrance of the library to improve its visual quality.

INACCESSIBLE AREAS: It was suggested that areas in the park were inaccessible and therefore wasted. One such area named was the south woods. More attention should be paid to these areas so that visitors could enjoy a walk through the woods.

OTHER TOPICS:

It was suggested that the Whaling Festival be better controlled and that the city in some way be compensated for the services provided during the festival. A user fee or a bond were ways that several members thought would provide the city with some compensation for the considerable cash and staff outlay that it experiences during the festival. Several members also thought that another appropriate spot for the festival could be found in another area of the city.

Improvements to the commercial establishments along Route 6 was suggested as a way to help the park's definition and character as well as visual quality.

Consideration should be given to removing the band shell and relocating this function to another area of the city more appropriate for concerts.

It was suggested that the park provide a uniform sign system throughout and uniform light fixtures, perhaps old fashioned gas lamps.

Problems with abutting neighbors and their dogs was also indentified.

WALKER·KLUESING DESIGN GROUP
LANDSCAPE ARCHITECTURE · SITE PLANNING · URBAN DESIGN

MEMORANDUM
17 April 1986

Summary of Public Questionaire Results
BUTTONWOOD PARK
New Bedford Massachusetts

By: Nancy Salustro

We were provided with copies of the first 10 responses to the questionaires returned to the City on the likes and dislikes in Buttonwood Park. The results are not surprising and in fact mirror the concerns of the New Bedford Municipal Advisory Committee members. By far the biggest problems are the parking and activities in the parking lots, flooding around the pond, circulation and general maintenance.

The respondents would like to see more foot paths, formal gardens, picnic tables and benches, and better overall security.

Several respondents felt that the Whaling Festival was inappropriate and should not be allowed in the park, or that it at least be better controlled.

On the positive side, many respondents have very fond memories of the gardens, the pond and natural areas around the park, although most use the park's recreational facilities. Some would like to see improvements to the zoo with a reduction in artificial barracades, like chain link fences, and a better pedestrian circulation system throughout.

FLOODING POTENTIAL IN BUTTONWOOD PARK

1. Introduction

A major problem at Buttonwood Park is the frequent level of flooding which occurs at several locations within the park and zoo. Flooding over Court Street and within the zoo is reported to occur several times a year. Flooding over Court Street impairs driving ability. Flooding represents a hazard to park visitors and to the animals within the zoo. At present, the animals must be moved to high ground during major rainstorms.

The purpose of this section of the report is to identify those structures within the park and zoo which are contributing to the present level of flooding and to identify those areas which are most susceptible to flooding. The Master Plan will address corrective measures for those structures to reduce their flooding potential.

2. Buttonwood Brook Watershed

The watershed evaluated in this flood potential analysis is outlined in Fig. 1. The total drainage area of 565 acres is subdivided to fit the purposes of this study. The southernmost portion of the watershed, south of Buttonwood Pond and Court Street dam, north of Hawthorne Street and bounded by Brownell Avenue and Rockland Avenue, is the 59-acre area of the park evaluated for flooding problems. This area contains the zoo. A more detailed plan of this area is shown in Fig. 2. Two minor ponds labeled in Fig. 2 are located in this area. They are referred to as the upstream pond and the downstream pond.

The 506-acre area north of Court Street dam, including Buttonwood Pond, is evaluated for its ability to contribute flood waters to the lower area. This area is subdivided into four components depending on the degree of urbanization in that area. The more urbanized areas will contribute a larger amount of runoff per acre increasing the flooding potential downstream.

The 96-acre area north of Rte. 6 and east of Rte. 140 is the most urbanized, paved over area. This area is drained mostly by storm drains. The 347-acre area north of Rte. 6 and west of Rte 140 has less densely spaced lots and fewer storm drains. It also has more open space, including a cemetery and woods. Two smaller drainage areas are below Rte. 6. A few streets in a 26-acre area to the west of the park have storm drain outlets into the brook and pond. The fourth area is the 37-acre portion of the park north of Court Street, including the pond.

3. Identified Flood Problem Areas

Several locations within the park have been identified as being most susceptible to periodic flooding. These areas are identified for the 10- and 100-year return period test floods in Fig. 2. The depth of flooding along the channel centerline is presented in the water surface profile of Fig. 3. The flow restricting structures responsible for the flooding are labeled on both figures.

The test floods provide a standard measure against which to compare existing conditions with proposed remedial measures. The test floods used here are the 10- and 100-year floods. The peak discharges at Court Street are 510 and 1090 ft3/sec, respectively, and may change if additional development occurs in the upstream areas or if improvements are made to the culverts at Rte. 6. These floods have a 10 and 1 percent chance of occurring in a single year. On average they will occur once every 10 and 100 years, respectively, though either flood could occur at any time. These floods were chosen as rational design floods for remedial measures. It is reasonable to allow occasional flooding in the zoo and over Court Street to avoid the costs and inconvenience of substantial channel and spillway enlargements. Therefore, we have assumed that it is acceptable to allow flooding within the zoo on average every 10 years and over Court Street on average every 100 years.

The most critical areas of flooding are over Court Street and along the trapezoid-shaped concrete channel between the culvert draining the fountain and the channel entrance. Court Street will be flooded by up to 6 inches of water during the 10-year event and by up to 8 inches of water during the 100-year event. The paved path over the fountain outlet will be overtopped by 1.3 ft and 1.9 ft for the 10- and 100-year floods, respectively, due to the small discharge capacity of the 24-inch culvert underneath the road. The road acts as a control for the floodflow. The result is the backwater to the channel entrance seen in Fig. 3. This area is critical because of the buildings and cages that could be flooded in that area.

The depths of flooding over the road and pathways above the other critical structures are summarized in Table 1 and profiled in Fig. 3. The floodflows are quite substantial, namely 510 and 1090 ft^3/sec, and they can be reduced by providing greater storage capacity in Buttonwood Pond or upstream of the pond. The control structures, including the culverts and spillways, are too small to pass the present test floods without causing the floodwaters to rise to flood stages. Also, the stream channels are too small to carry the floodwaters without the waters exceeding their banks.

4. Inflow Hydrograph Development

The flood potential evaluation for the existing conditions consists of three components: the inflow design flood (test flood) development, the flood routing through Buttonwood Pond and the routing through the park south of Court Street.

The test flood was developed using a stream network model. The watershed components and predominant land uses were discussed in Section 2. The 24-hour duration design rainstorms were estimated using data from the Rainfall Frequency Atlas of the National Weather Service. The 10-year storm depth is 4.8 inches of rainfall in 24 hours and the 100-year storm depth is 7.0 inches of rainfall in 24 hours.

The runoff from the test flood rainstorms is estimated using the Soil Conservation Service (SCS) curve number technique. Soil maps developed by the SCS were used along with the data from the USGS topographic map and a field reconnaissance on April 22, 1986. Using this information, summaries of the watershed subareas were developed according to land use, soil group and percent of available storage due to ponds and marshes. Weighted average curve numbers and impervious area fractions were calculated for each subarea. These values were used in runoff equation to calculate the test storm runoff.

The hydrographs for each test flood were developed using another SCS technique. Estimates of the stream channel length and the watershed average slope from the USGS topographic map and the runoff curve number were used in a series of equations to generate the distribution of the hydrograph in time. This hydrograph was then routed through Buttonwood Pond. The peak discharge entering the pond is 730 ft^3/sec for the 10-year flood and 1240 ft^3/sec for the 100-year flood. The amount of runoff is 1.8 inches for the 10-year flood and 3.0 inches for the 100-year flood.

5. Flood Routing Through Buttonwood Pond

Buttonwood Pond acts as a detention storage pond for the test flood. It reduces the peak flood discharge from 730 to 510 ft^3/sec for the 10-year flood and from 1240 to 1090 ft^3/sec for the 100-year flood. At the time of the peak outflow over Court Street, Buttonwood Pond impounds an additional 31 acre-feet of water during the 10-year flood and an additional 37 acre-feet of water during the 100-year flood.

The flood routing through Buttonwood Pond required elevation-storage and an elevation-discharge data in addition to the inflow hydrograph. The elevation-storage curve was obtained by measuring the pond surface area at different elevations using planimetry of a topographic map provided by Walker-Kluesing Design Group at a size of 1 inch = 100 feet. The surface area-elevation data were converted to elevation-storage data using a conic approximation and the corresponding geometric formula.

The elevation-discharge rating curve is a combined rating for the spillway discharge and the overtopping discharge. When there is roadway overtopping, it predominates. At the 100-year flood maximum pond elevation, 99 ft, the combined discharge of 1090 ft^3/sec is divided into 1040 ft^3/sec over the roadway and 50 ft^3/sec through the spillway. At the 10-year flood maximum pond elevation the combined discharge of 510 ft^3/sec consists of 45 ft^3/sec through the spillway and 465 ft^3/sec over the road. The road overtopping uses the standard assumption that the road responds as a weir.

The spillway discharge passes through multiple controls. First it passes over an 11-ft-long concrete spillway crest. It then passes through a masonry arch culvert, 1.6 ft high by 6.5 ft at its base. The existing arch culvert is the top portion of the original arch culvert through Court Street, reduced in size by the addition of the outlet works gate and spillway crest. For the purposes of this flood study, the outlet works gate is assumed to be closed. The flow restricting control at the spillway switches from the crest to the arch at pond elevation 96.7 ft with a spillway discharge of 10 ft^3/sec.

6. Flood Routing Through Buttonwood Park South of Court Street

Flood routing through this 1680-ft reach of Buttonwood Brook was accomplished using a standard hydraulic routing of the peak test flood discharges. The discharges of 510 ft^3/sec and 1090 ft^3/sec for the 10- and 100-year floods, respectively, were routed from Court Street to Hawthorne Street using the U.S. Army Corps of Engineers computer program, HEC2. The reach was modeled using 26 cross sections along the channel, with extra sections added at each culvert and channel inlet area. The centerline channel bottom is depicted on Fig. 3. Channel roughness estimates were obtained from a standard hydraulics text. They were estimated based on a site reconnaissance on April 22, 1986 and from the aereal photograph provided by Walker-Kluesing Design Group, flown on September 17, 1985.

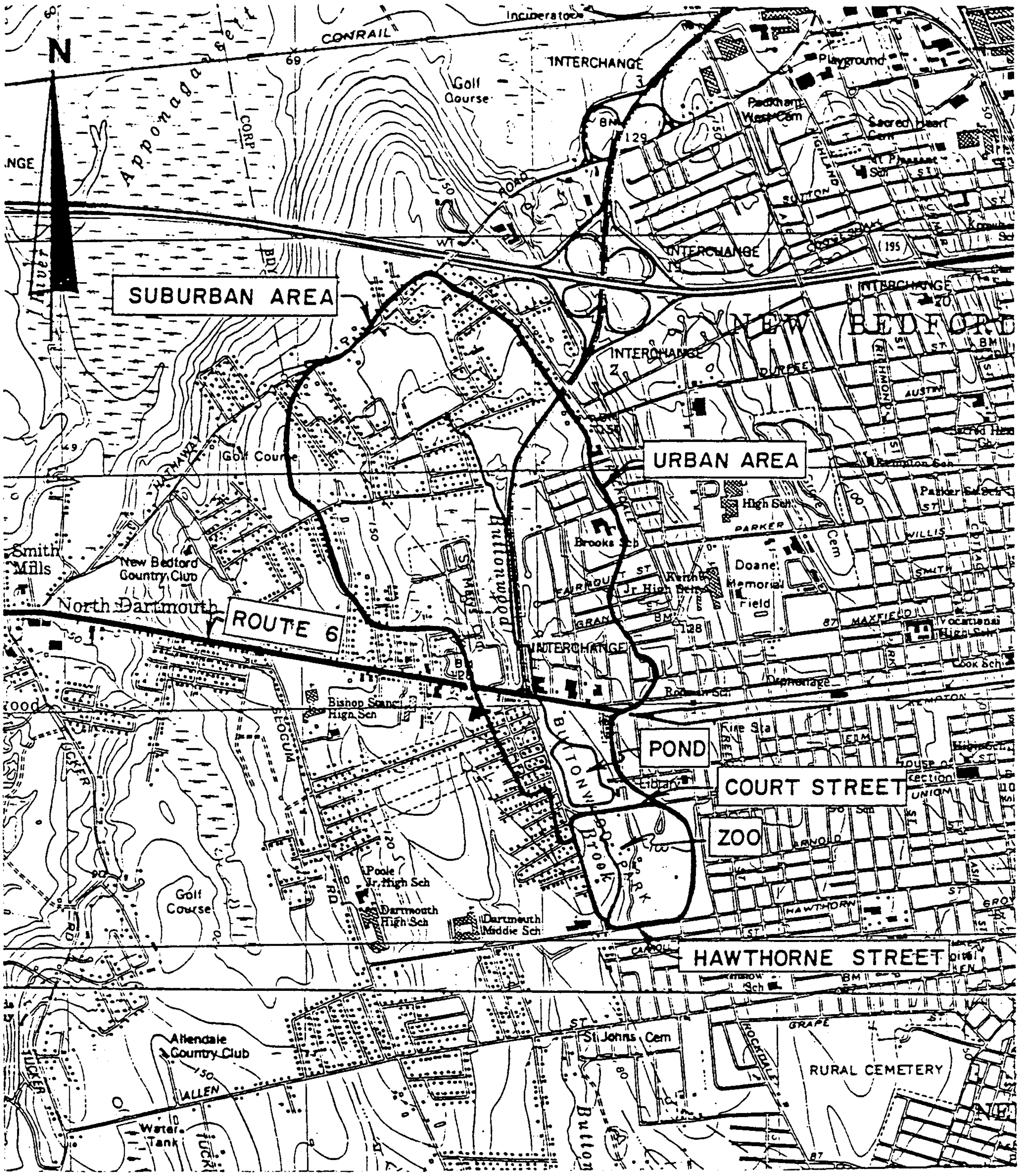
The four culverts at the intersection of Hawthorne Street and Brownell Avenue are the downstream endpoint of the study. Stage discharge rating curves for each of the culverts were added together to provide the downstream boundary conditions for the backwater calculations. The culverts consist of three 34-in. corrugated metal pipe culverts (CMP) and one 36-in. CMP, all set in a stone headwall. The rating curve also includes the overtopping flow over Brownell Avenue.

The results are presented in Figs. 2 and 3. Key results are summarized in Table 1 and discussed in Section 3. Figure 2 shows the area of the zoo and park flooded by the peak 10- and 100-year test floods. Figure 3 shows a centerline water surface profile with all the critical structures identified.

TABLE 1 - CRITICAL FLOODING AREAS[1]
BUTTONWOOD PARK AND ZOO

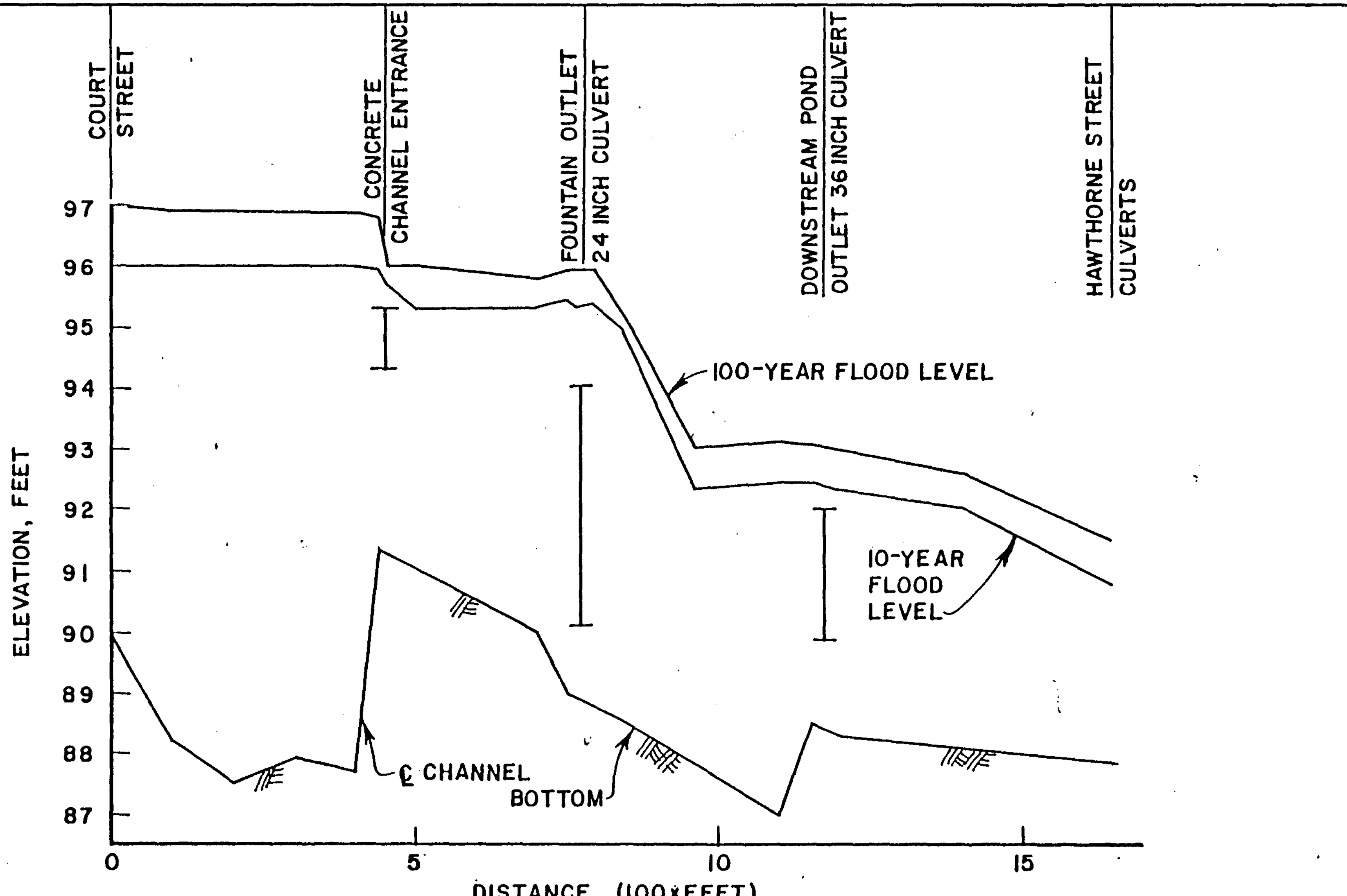
Control Structure	Water Surface Elevation, ft Flood, Years 10	100	Roadway Overtopping Depth, ft Flood, Years 10	100
Court Street Spillway	98.5	98.7	0.5	0.7
Trapezoid Channel Entrance	95.9	96.8	0.6	1.5
Fountain Outlet, 24-inch Culvert	95.3	95.9	1.3	1.9
Downstream Pond, 36-inch Culvert	92.4	93.1	0.4	1.1
Hawthorne Street Culverts	90.8	91.5	0.8	1.5

1) Results from water surface profile analysis.



Source: USGS Topographic Quadrangle
New Bedford North, Massachusetts
7.5-Minute Series
Scale: 1 inch = 2083 feet

Walker-Kluesing Design Group Boston, Massachusetts	Buttonwood Park New Bedford, MA	WATERSHED BOUNDARY MAP
GEOTECHNICAL ENGINEERS INC. WINCHESTER • MASSACHUSETTS	86965	May 27, 1986 Fig. 1



Walker-Kluesing Design Group Boston, Massachusetts	Buttonwood Park New Bedford, MA	WATER SURFACE PROFILE 10 AND 100 YEAR FLOODS
GEOTECHNICAL ENGINEERS INC. WINCHESTER • MASSACHUSETTS	Project 86965	May 27, 1986 Fig. 3

APPENDIX B

DATA GENERATED BY THE BEC STUDY

FLOW (CU.M/MIN) IN THE BUTTONWOOD POND SYSTEM

STATION DATE	BU-1	BU-3	BU-7
03/11/86	5.10	5.10	
04/03/86	2.04	.17	
04/17/86	1.36	.42	.17
05/01/86	1.78	1.70	.09
05/15/86	.68	.07	.05
05/29/86	1.10	.95	.17
06/19/86	.82	.85	.17
07/02/86	48.96	.17	.17
07/17/86	1.24	1.02	
07/31/86	.59	.82	
08/14/86	.49	2.55	
08/28/86	7.82	.17	
09/16/86	30.60	.34	
10/22/86	.92	.17	
11/20/86	2.21	2.21	
12/18/86	2.04	1.70	
02/05/87	2.89	2.72	
MEAN	6.51	1.24	.14
MAXIMUM	48.96	5.10	.17
MINIMUM	.49	.07	.05

FLOW (CFS) IN THE BUTTONWOOD POND SYSTEM

STATION DATE	BU-1	BU-3	BU-7
03/11/86	3.00	3.00	
04/03/86	1.20	.10	
04/17/86	.80	.25	.10
05/01/86	1.05	1.00	.05
05/15/86	.40	.04	.03
05/29/86	.65	.56	.10
06/19/86	.48	.50	.10
07/02/86	28.80	.10	.10
07/17/86	.73	.60	
07/31/86	.35	.48	
08/14/86	.29	1.50	
08/28/86	4.60	.10	
09/16/86	18.00	.20	
10/22/86	.54	.10	
11/20/86	1.30	1.30	
12/18/86	1.20	1.00	
02/05/87	1.70	1.60	
MEAN	3.83	.73	.08
MAXIMUM	28.80	3.00	.10
MINIMUM	.29	.04	.03

FLOW MEASUREMENTS NEAR THE INLET TO BUTTONWOOD POND, BASED ON MONITORING BY PARK OFFICIALS

Date	Weir Height (in.)	Estimated Flow (cfs)	Estimated Flow (cu.m/min)
May 14	4.5	0.4	0.7
15	4.0	0.3	0.5
16	4.0	0.3	0.5
19	4.0	0.3	0.5
20	4.0	0.3	0.5
21	4.25	0.4	0.7
22	over embankment	>30.0	>51.0
23	4.25	0.4	0.7
27	3.0	0.2	0.3
29	4.0	0.3	0.5
30	4.0	0.3	0.5
June 2	4.25	0.4	0.7
3	4.25	0.4	0.7
4	4.0	0.3	0.5
5	4.0	0.3	0.5
6	4.0	0.3	0.5
9	3.0	0.2	0.3
10	3.0	0.2	0.3
11	3.0	0.2	0.3
12	4.0	0.3	0.5
25	3.0	0.2	0.3
26	3.0	0.2	0.3
27	3.0	0.2	0.3
30	2.25	0.1	0.2
July 1	2.0	0.1	0.2
2	21.0	25.0	42.5
3	4.5	0.5	0.9
7	3.0	0.2	0.3
8	3.0	0.2	0.3
9	3.0	0.2	0.3
10	3.0	0.2	0.3
11	3.0	0.2	0.3
14	3.0	0.2	0.3
15	6.25	2.8	4.8
16	7.0	3.7	6.3
17	7.0	3.7	6.3
18	4.0	0.3	0.5
21	3.0	0.2	0.3
22	3.0	0.2	0.3
23	3.0	0.2	0.3
Mean		1.9	3.2
Mean without flows >1.0 cfs (background)		0.3	0.5

BUTTONWOOD PARK POND

Measurements

Sunday, May 18th:

Weather: Clear, sunny - Time 10:00 A.M.

Weir Dam: 3 3/4"

36" Pipe: 11"

11" Pipe: Fully out of the water

Notes: A strong sewage odor was being emitted from the 36" storm pipe.

Thursday, May 22nd:

Weather: Steady light rain for 18 hours with several heavy downpours. Time: 3:30 P.M.

Weir Dam: Completely submerged with water flowing up and around the dam. To the North side of the dam the water was 5" over the plywood on the South or far side the water was 7" over the plywood. Going around the dam on the North side (NS) the water flow was 2" in depth and approximately 5" to 6" from the end corner of the plywood. On the South side (SS) the water flow was 4" to 5" in depth and was 1 1/2' to 2' from the end corner of the dam.

36" Storm Pipe: Water level to inside seam of the pipe 7". A grey ooze was being emitted from the pipe; slightly dark towards the bottom and to the right; lighter in color at the surface and to the left.

11" Storm Pipe: Surface to inside seam 4" to 5" .

Notes: The water was flowing at the top of the canal and some areas it overflowed the canal banks. Looking at the field it was evident that the entire canal water level rose over the canal banks and flooding the field. At the old cement bridge abutments the water rose and flowed over the near side abutment, created a new stream and flowed down to the general area of the clay field drain pipe outlet.

Thursday, May 22nd:

Weather: Drizzle - Time: 7:30 P.M.

Weir Dam: Blocked severely with canal debris

36" Pipe: Surface to seam 8" to 9"

11" Pipe: Completely out of water; water about 4" from pipe.

May 22nd. Notes: Oil (#6) was spilled on Route 140; at the height of the downpours, the oil was seen flowing through the Zoo. Also, at the inlets at Route 6 the left inlet was approximately 10" in clearance (surface to arc) and the right was 18" to 22" in clearance (surface to arc).

ORTHOPHOSPHORUS (UG/L) IN THE BUTTONWOOD POND SYSTEM

STATION DATE	BU-1	BU-2S	BU-2B	BU-3	BU-7
03/11/86	43	17	32	21	
04/03/86	10	10	10	10	
04/17/86	10	10	10	10	10
05/01/86	10	10	10	10	10
05/15/86	10	10	10	30	10
05/29/86	20	40	60	40	30
06/19/86	14	48	79	59	22
07/02/86	76	47	51	62	71
07/17/86	17	34	53	38	
07/31/86	28	36	44	47	
08/14/86	12	26	25	25	
08/28/86	150	17	12	20	
09/16/86	155	17	24	25	
10/22/86	10	17	22	15	
11/20/86	20	30	30	30	
12/18/86	200			20	
02/05/87	95	146		26	
MEAN	52	32	31	29	26
MAXIMUM	200	146	79	62	71
MINIMUM	10	10	10	10	10
MASS FLOW (KG/YR)	341.69			19.53	

TOTAL PHOSPHORUS (UG/L) IN THE BUTTONWOOD POND SYSTEM

STATION DATE	BU-1	BU-2S	BU-2B	BU-3	BU-7
03/11/86	150	130	100	180	
04/03/86	55	76	63	69	
04/17/86	10	50	70	50	30
05/01/86	26	48	59	36	49
05/15/86	10	20	20	50	10
05/29/86	30	40	90	60	10
06/19/86	14	95	87	59	22
07/02/86	150	120	130	120	150
07/17/86	30	75	120	90	
07/31/86	43	200	180	230	
04/18/86	14	101	74	100	
08/28/86	300	119	125	91	
09/16/86	247	101	109	91	
10/22/86	17	61	63	56	
11/20/86	30	60	80	50	
12/18/86	250			50	
02/05/87	122	264		61	
MEAN	88	98	91	85	45
MAXIMUM	300	264	180	230	150
MINIMUM	10	20	20	36	10
MASS FLOW (KG/YR)	591.13			75.40	

AMMONIA NITROGEN (MG/L AS N) IN THE BUTTONWOOD POND SYSTEM

STATION DATE	BU-1	BU-2S	BU-2B	BU-3	BU-7
03/11/86	.07	.04	.04	.05	
04/03/86	.13	.04	.02	.05	
04/17/86	.02	.02	.03	.02	.02
05/01/86	.12	.01	.03	.02	.50
05/15/86	.02	.01	.01	.08	.03
05/29/86	.05	.12	.16	.07	.03
06/19/86	.04	.01	.01	.01	.04
07/02/86	.06	.01	.05	.10	.07
07/17/86	.04	.01	.01	.01	
07/31/86	.03	.01	.01	.01	
08/14/86	.01	.01	.01	.03	
08/28/86	2.10	.01	.01	.20	
09/16/86	.44	.01	.01	.21	
10/22/86	.01	.01	.01	.01	
11/20/86	.03	.04	.04	.05	
12/18/86	1.10			.10	
02/05/87	.38	.26		.13	
MEAN	.27	.04	.03	.05	.08
MAXIMUM	2.10	.26	.16	.21	.50
MINIMUM	.01	.01	.01	.01	.01
MASS FLOW (KG/YR)	1214.00			55.07	

NITRATE NITROGEN (MG/L AS N) IN THE BUTTONWOOD POND SYSTEM

STATION DATE	BU-1	BU-2S	BU-2B	BU-3	BU-7
03/11/86	.27	.12	.15	.20	
04/03/86	.46	.02	.04	.01	
04/17/86	.62	.02	.02	.02	.64
05/01/86	.50	.01	.03	.04	.82
05/15/86	.43	.02	.03	.08	.31
05/29/86	.34	.02	.02	.06	.52
06/19/86	.89	.04	.02	.03	.84
07/02/86	.10	.02	.06	.09	.08
07/17/86	.29	.02	.01	.01	
07/31/86	.83	.03	.04	.02	
08/14/86	1.52	.07	.05	.06	
08/28/86	1.21	.05	.03	.04	
09/16/86	.95	.04	.02	.15	
10/22/86	1.10	.06	.07	.11	
11/20/86	1.03	.42	.37	.35	
12/18/86	1.90			.85	
02/05/87	1.47	1.20		1.20	
MEAN	.82	.14	.06	.20	.53
MAXIMUM	1.90	1.20	.37	1.20	.84
MINIMUM	.10	.01	.01	.01	.08
MASS FLOW (KG/YR)	2250.67			358.37	

KJELDAHL NITROGEN (MG/L AS N) IN THE BUTTONWOOD POND SYSTEM

STATION DATE	BU-1	BU-2S	BU-2B	BU-3	BU-7
03/11/86	.45	.44	.40	.46	
04/03/86	.41	.77	.67	.48	
04/17/86	.38	.69	.91	.61	.33
05/01/86	.37	.29	.37	.31	.52
05/15/86	.23	.52	.74	.51	.38
05/29/86	.25	.53	.90	.48	.57
06/19/86	.38	.70	.44	.72	.29
07/02/86	.33	.58	.71	.64	.41
07/17/86	.42	.68	.76	.64	
07/31/86	.70	1.70	1.20	2.20	
08/14/86	.21	1.20	1.40	1.20	
08/28/86	3.60	1.30	1.50	1.40	
09/16/86	2.40	1.17	1.27	1.05	
10/22/86	.55	.46	.49	.55	
11/20/86	.39	.52	.31	1.64	
12/18/86	2.50			.73	
02/05/87	1.60	1.24		.52	
MEAN	.89	.80	.80	.83	.42
MAXIMUM	3.60	1.70	1.50	2.20	.57
MINIMUM	.21	.29	.31	.31	.29
MASS FLOW (KG/YR)	4669.24			580.33	

NITROGEN:PHOSPHORUS RATIOS IN THE BUTTONWOOD POND SYSTEM

STATION DATE	BU-1	BU-2S	BU-2B	BU-3
03/11/86	11.0	9.8	12.6	8.4
04/03/86	36.1	23.8	25.7	16.4
04/17/86	228.5	32.4	30.4	28.8
05/01/86	76.5	14.4	15.5	22.5
05/15/86	150.8	61.7	88.0	27.0
05/29/86	44.9	31.4	23.4	20.6
06/19/86	207.3	17.8	12.2	28.9
07/02/86	6.6	11.4	13.6	13.8
07/17/86	54.1	21.2	14.7	16.5
07/31/86	81.3	19.8	15.7	22.1
04/18/86	282.4	28.8	44.7	28.7
08/28/86	36.6	25.9	27.9	36.3
09/16/86	31.0	27.4	27.0	30.2
10/22/86	221.8	19.6	20.2	26.8
11/20/86	108.2	35.8	19.4	90.9
12/18/86	40.2			72.2
02/05/87	57.5	21.1		64.4
MEAN	98.5	25.1	26.1	32.6
MAXIMUM	282.4	61.7	88.0	90.9
MINIMUM	6.6	9.8	12.2	8.4

TEMPERATURE (C) IN THE BUTTONWOOD POND SYSTEM

STATION DATE	BU-1	BU-2S	BU-2B	BU-3	BU-7
03/11/86	6.5	3.1	3.1	4.5	
04/03/86	12.0	14.8	14.6	11.0	
04/17/86	7.0	10.8	11.1	10.5	7.0
05/01/86	9.0	13.1	12.9	13.2	9.2
05/15/86	9.3	14.5	14.0	13.0	9.0
05/29/86	13.0	19.0	18.0	18.0	14.0
06/19/86	14.5	21.5	19.0	19.9	13.1
07/02/86	16.5	20.7	18.2	20.8	17.0
07/17/86	19.0	24.5	24.5	23.5	
07/31/86	16.7	19.9	19.9	19.6	
08/14/86	17.2	23.5	21.5	22.4	
08/28/86	16.0	18.3	18.3	17.8	
09/16/86	14.7	16.1	16.0	16.2	
10/22/86	14.0	15.5	13.5	14.0	
11/20/86	4.8	2.1	2.1	2.4	
12/18/86	3.2			1.0	
02/05/87	-.5	-.5		-.2	
MAXIMUM	19.0	24.5	24.5	23.5	17.0
MINIMUM	-.5	-.5	2.1	-.2	7.0

DISSOLVED OXYGEN (MG/L) IN THE BUTTONWOOD POND SYSTEM

STATION DATE	BU-1	BU-2S	BU-2B	BU-3	BU-7
03/11/86	11.8	14.2	14.1	13.5	
04/03/86	12.3	12.0	9.0	6.4	
04/17/86	8.8	11.2	11.9	10.6	9.3
05/01/86	7.8	12.2	9.1	11.0	7.7
05/15/86	9.8	11.8	12.6	7.0	8.0
05/29/86	8.1	8.4	5.5	5.8	5.2
06/19/86	8.1	8.2	9.3	7.6	6.7
07/02/86	7.5	7.6	5.2	3.2	7.2
07/17/86	6.6	13.0	4.8	5.0	
07/31/86	8.4	8.2	6.9	7.4	
08/14/86	8.0	9.6	4.7	3.5	
08/28/86	7.7	8.3	7.7	3.3	
09/16/86	7.4	8.3	7.2	2.3	
10/22/86	9.3	11.1	10.1	7.4	
11/20/86	10.2	8.9	8.9	10.3	
12/18/86	11.4			13.2	
02/05/87	14.4	14.2		15.2	
MEAN	9.3	10.4	8.5	7.8	7.4
MAXIMUM	14.4	14.2	14.1	15.2	9.3
MINIMUM	6.6	6.6	4.7	2.3	2.3

TEMPERATURE-DISSOLVED OXYGEN PROFILE DATA
BUTTONWOOD POND (STATION 2)

DATE	DEPTH (m)	TEMP (C)	D.O. (mg/l)
03/11/86	0.0	3.1	14.2
	0.5	3.0	14.1
	1.0	3.0	14.1
	1.3	3.2	14.1
04/03/86	0.0	14.8	12.0
	0.5	14.8	11.8
	1.0	14.7	11.7
	1.3	14.6	9.0
04/17/86	0.0	10.8	11.2
	0.5	10.9	11.1
	1.0	10.9	11.0
	1.3	11.9	11.9
05/01/86	0.0	13.1	12.2
	0.5	13.1	12.4
	1.0	12.9	12.5
	1.3	12.9	9.1
05/15/86	0.0	14.5	11.8
	0.5	14.5	12.0
	1.0	14.5	12.0
	1.3	14.0	12.6
05/29/86	0.0	19.0	8.4
	0.5	19.0	7.9
	1.0	19.0	7.9
	1.3	18.0	5.5
06/19/86	0.0	21.5	8.7
	0.5	21.0	8.8
	1.0	19.0	9.0
	1.3	19.0	9.3
07/02/86	0.0	20.7	7.6
	0.5	20.0	7.4
	1.0	18.3	6.3
	1.3	18.2	5.2
07/17/86	0.0	24.5	13.0
	0.5	24.5	11.3
	1.0	22.0	9.3
	1.3	21.0	4.8
07/31/86	0.0	19.9	8.2
	0.5	19.9	7.9
	1.0	19.9	7.9
	1.3	19.9	6.9
08/14/86	0.0	23.5	9.6
	0.5	23.0	9.5
	1.0	21.8	6.2
	1.3	21.5	4.7
08/28/86	0.0	18.2	8.3
	0.5	18.2	8.0
	1.0	18.2	7.8
	1.3	18.2	7.7
09/16/86	0.0	16.1	8.3
	0.5	16.1	8.2
	1.0	16.0	7.8
	1.3	16.0	7.2
10/22/86	0.0	15.5	11.1
	0.5	15.3	11.2
	1.0	15.0	11.4
	1.5	13.5	10.2
	1.7	13.5	10.1
11/20/86	0.0	2.1	8.9
	0.5	2.1	8.9
	1.0	2.1	8.9
	1.3	2.1	8.9

PERCENT OXYGEN SATURATION IN THE BUTTONWOOD POND SYSTEM

STATION DATE	BU-1	BU-2S	BU-2B	BU-3
03/11/86	96	106	105	104
04/03/86	111	146	144	100
04/17/86	73	101	108	94
05/01/86	78	125	122	126
05/15/86	108	116	115	66
05/29/86	77	91	58	61
06/19/86	79	93	100	83
07/02/86	77	85	55	36
07/17/86	71	156	58	59
07/31/86	86	90	76	81
08/14/86	83	113	53	40
08/28/86	78	88	82	35
10/22/86	90	111	97	72
11/20/86	79	65	65	75
12/18/86	85			93
02/05/87	97	96		103
MEAN	85.6	105.4	88.4	76.8
MAXIMUM	111.4	155.9	143.6	125.9
MINIMUM	71.2	64.6	53.3	34.7

TOTAL SUSPENDED SOLIDS (MG/L) IN THE BUTTONWOOD POND SYSTEM

STATION DATE	BU-1	BU-2S	BU-2B	BU-3	BU-7
03/11/86	1.2	2.0	.4	.8	
04/03/86	2.0	4.0	9.6	.8	
04/17/86	.8	2.8	20.0	2.4	11.0
05/01/86	6.0	5.2	10.0	6.8	7.6
05/15/86	4.0	2.0	9.2	11.0	11.0
05/29/86	3.6	4.0	4.8	4.4	13.0
06/19/86	5.6	7.6	8.0	7.2	8.8
07/02/86	70.0	4.0	8.4	2.8	32.0
07/17/86	.4	4.4	.4	2.4	
07/31/86	.4	4.4	2.0	2.0	
08/14/86	6.0	5.2	13.0	7.6	
08/28/86	28.0	3.0	2.0	1.0	
09/16/86	179.0	4.4	19.0	18.0	
10/22/86	.4	13.0	12.0	6.0	
11/20/86	3.2	1.2	4.0	2.8	
12/18/86	4.0			4.0	
02/05/87	.2	12.4		1.2	
MEAN	18.5	5.0	8.2	4.8	13.9
MAXIMUM	179.0	13.0	20.0	18.0	32.0
MINIMUM	.2	1.2	.4	.8	7.6

TOTAL ALKALINITY (MG/L AS CACO3) IN THE BUTTONWOOD POND SYSTEM

STATION DATE	BU-1	BU-2S	BU-2B	BU-3	BU-7
03/11/86	18	16	16	16	
04/03/86	26	24	25	28	
04/17/86	31	21	21	21	30
05/01/86	32	26	25	25	32
05/15/86	32	23	23	24	33
05/29/86	32	22	22	22	30
06/19/86	32	23	23	23	32
07/02/86	6	21	13	25	6
07/17/86	27	17	18	17	
07/31/86	25	20	20	21	
08/14/86	35	18	19	20	
08/28/86	30	18	18	20	
09/16/86	5	18	18	19	
10/22/86	28	13	14	15	
11/20/86	19	15	15	13	
12/18/86	28			15	
02/05/86	22	15		18	
MEAN	25	19	19	20	27
MAXIMUM	35	26	25	28	33
MINIMUM	5	13	13	13	6

PH (S.U.) IN THE BUTTONWOOD POND SYSTEM

STATION DATE	BU-1	BU-2S	BU-2B	BU-3	BU-7
03/11/86	6.9	7.1	7.0	7.0	
04/03/86	6.9	7.2	7.2	6.7	
04/17/86	7.0	7.2	7.4	7.2	6.9
05/01/86	6.9	7.7	7.7	7.4	6.9
05/15/86	7.0	7.8	8.4	7.0	6.9
05/29/86	7.0	7.0	7.0	7.0	7.0
06/19/86	6.9	7.1	7.1	7.0	6.9
07/02/86	5.7	7.2	6.8	6.9	5.7
07/17/86	6.9	7.7	7.2	7.6	
07/31/86	6.9	6.9	6.9	6.9	
08/14/86	7.0	7.7	7.5	6.9	
08/28/86	6.9	7.0	7.0	6.8	
09/16/86	6.3	7.0	6.9	6.3	
10/22/86	7.2	7.5	7.7	6.9	
11/20/86	6.5	6.4	6.5	6.3	
12/18/86	7.0			6.8	
02/05/87	6.8	6.8		6.7	
MAXIMUM	7.2	7.8	8.4	7.6	7.0
MINIMUM	5.7	6.4	6.5	6.3	5.7

TOTAL DISSOLVED SOLIDS (MG/L) IN THE BUTTONWOOD POND SYSTEM

STATION DATE	BU-1	BU-2S	BU-2B	BU-3	BU-7
03/11/86	149	159	153	153	
04/03/86	137	119	145	129	
04/17/86	152	132	138	137	155
05/01/86	167	137	120	132	188
05/15/86	117	128	124	132	157
05/29/86	169	88	104	91	180
06/19/86	187	115	121	124	175
07/02/86	56	89	61	91	64
07/17/86	119	53	57	61	
07/31/86	139	80	71	83	
08/14/86	176	91	99	76	
08/28/86	151	64	68	68	
09/16/86	85	105	88	108	
10/22/86	160	95	53	99	
11/20/86	155	76	80	75	
12/18/86	201			164	
02/05/87	257	181		280	
MEAN	152	107	99	118	153
MAXIMUM	257	181	153	280	188
MINIMUM	56	53	53	61	64

CONDUCTIVITY (UMHOS/CM) IN THE BUTTONWOOD POND SYSTEM

STATION DATE	BU-1	BU-2S	BU-2B	BU-3	BU-7
03/11/86	355	360	360	385	
04/03/86	280	300	295	285	
04/17/86	290	280	280	280	290
05/01/86	325	270	275	270	315
05/15/86	300	280	280	290	300
05/29/86	245	205	205	205	280
06/19/86	315	205	205	200	320
07/02/86	125	152	186	200	121
07/17/86	192	110	105	103	
07/31/86	176	103	106	107	
08/14/86	200	104	102	104	
08/28/86	220	98	108	103	
09/16/86	78	115	112	122	
10/22/86	248	120	118	118	
11/20/86	254	141	145	147	
12/18/86	180			120	
02/05/87	400	280		440	
MEAN	246	221	212	198	210
MAXIMUM	400	400	360	440	440
MINIMUM	78	98	102	103	103

CHLORIDE (MG/L) IN THE BUTTONWOOD POND SYSTEM

STATION DATE	BU-1	BU-2S	BU-2B	BU-3	BU-7
03/11/86	65	72	70	74	
04/03/86	50	56	56	57	
04/17/86	46	52	50	55	55
05/01/86	52	45	47	46	49
05/15/86	40	53	52	53	40
05/29/86	47	34	35	33	48
06/19/86	43	28	27	28	39
07/02/86	24	31	26	31	23
07/17/86	46	26	24	26	
07/31/86	76	26	25	26	
08/14/86	46	23	25	26	
08/28/86	53	28	26	25	
09/16/86	16	28	29	29	
10/22/86	49	27	31	30	
11/20/86	60	31	32	32	
12/18/86	49			59	
02/05/87	136	96		155	
MEAN	53	41	37	46	42
MAXIMUM	136	96	70	155	55
MINIMUM	16	23	24	25	23

FECAL COLIFORM (N/100 ML) IN THE BUTTONWOOD POND SYSTEM

STATION DATE	BU-1	BU-2S	BU-3	BU-7
03/11/86	0	500	220	
04/03/86	1100	0	0	
04/17/86	15			218
05/01/86	600	95	32	420
05/15/86	65	41	4	0
05/29/86	0	60	20	80
06/19/86	200	0	0	0
07/02/86	5900	100	100	100
07/17/86	0	0	0	
07/31/86	300	200	400	
08/14/86	8	10	60	
08/28/86	1800	300	200	
09/16/86	900	36	1300	
10/22/86	6	20	200	
11/20/86	100	600	300	
12/18/86	100		400	
02/05/87	2000	23	1000	
MEAN (GEOMETRIC)	82	33	56	18
MAXIMUM	5900	600	1300	420
MINIMUM	0	0	0	0

FECAL STREPTOCOCCI (N/100 ML) IN THE BUTTONWOOD POND SYSTEM

STATION DATE	BU-1	BU-2S	BU-3	BU-7
03/11/86	60	55	50	
04/03/86	63	8	20	
04/17/86	38	16	29	48
05/01/86	1580	25	17	1610
05/15/86	80	55	29	
05/29/86	640	20	0	530
06/19/86	2500	34	31	1200
07/02/86	35100	2100	10500	50000
07/17/86	460	220	450	
07/31/86	700	400		
08/14/86	400	140	800	
08/28/86	100000	161	3300	
09/16/86	77000	7000	57000	
10/22/86	0	0	0	
11/20/86	31	200	300	
12/18/86	5100		800	
02/05/87	3500	29	119	
MEAN (GEOMETRIC)	644	75	132	1197
MAXIMUM	100000	7000	57000	50000
MINIMUM	0	0	0	48

FC:FS RATIOS IN THE BUTTONWOOD POND SYSTEM

STATION DATE	BU-1	BU-2S	BU-3
03/11/86		9.1	4.4
04/03/86	17.5		
04/17/86	.4		
05/01/86	.4	3.8	1.9
05/15/86	.8	.7	.1
05/29/86		3.0	
06/19/86	.1		
07/02/86	.2		
07/17/86			
07/31/86	.4	.5	
08/14/86		.1	.1
08/28/86		1.9	.1
09/16/86			
10/22/86			
11/20/86	3.2	3.0	1.0
12/18/86			.5
02/05/87	.6	.8	8.4
MEAN	2.6	2.5	2.1
MAXIMUM	17.5	9.1	8.4
MINIMUM	.1	.1	.1

SECCHI TRANSPARENCY (M) IN THE BUTTONWOOD POND SYSTEM

STATION DATE	BU-2
03/11/86	1.2
04/03/86	1.2
04/17/86	1.2
05/01/86	1.3
05/15/86	1.3
05/29/86	1.1
06/19/86	1.3
07/02/86	.8
07/17/86	.9
07/31/86	.7
08/14/86	.6
08/28/86	.8
09/16/86	.5
10/22/86	.9
11/20/86	1.1
12/18/86	
02/05/87	1.2
MEAN	1.0
MAXIMUM	1.3
MINIMUM	.5

CHLOROPHYLL A (UG/L) IN THE BUTTONWOOD POND SYSTEM

STATION DATE	BU-2S
04/03/86	17.0
04/17/86	16.6
05/01/86	9.4
05/15/86	3.8
05/29/86	5.9
06/19/86	35.3
07/17/86	8.2
07/31/86	63.5
08/14/86	69.5
08/28/86	74.8
09/16/86	91.0
10/22/86	47.9
11/19/86	7.8
02/05/87	16.7
MEAN	33.4
MAXIMUM	91.0
MINIMUM	3.8

BUTTONWOOD STORM DATA: 07/02/86

PARAMETER	UNITS	BU-1	BU-2S	BU-2B	BU-3	BU-4	BU-5	BU-6	BU-7
TALK	(mg/l)	6.2	21.0	13.0	25.0	3.0	2.3	2.3	6.2
TSS	(mg/l)	70.0	4.0	8.4	2.8	314.0	14.0	16.0	32.0
TDS	(mg/l)	56.0	89.0	61.0	91.0	4.0	15.0	4.0	64.0
AMM-N	(mg/l)	.06	.01	.05	.10	.11	.08	.07	.07
NITRATE-N	(mg/l)	.10	.02	.06	.09	.08	.06	.04	.08
CHLORIDE	(mg/l)	24.0	31.0	26.0	31.0	4.0	6.5	4.5	23.0
ORTHO-P	(ug/l)	80	50	51	62	130	75	38	71
TOTAL P	(ug/l)	150	120	130	120	260	98	51	150
KNITRO	(mg/l)	.33	.58	.71	.64	.40	.37	.22	.41
FEC.COLI	(#/100ml)	5900	100		100	TNTC	700	700	100
FEC.STREP	(#/100ml)	35100	2100		10500	50000	8200	7100	50000
TEMP	(Celsius)	16.5	20.7	18.2	20.8	17.5	17.5	18.0	17.0
DO	(mg/l)	7.5	7.6	5.2	3.2	8.7	7.7	8.4	7.2
PH	(S.U.)	5.7	7.2	6.8	6.9	5.6	5.5	5.5	5.7
COND	(umhos/cm)	125	152	186	200	24	34	24	121
FLOW	(cu.m/min)	28.8			.1	17.0	1.0	.1	.1

ADDITIONAL FLOW DATA: STATION	BU-8	BU-9	BU-10	BU-11	BU-12	BU-13
CU.M/MIN	.4	20.4	19.0	5.3	7.1	3.9

TOTAL RAINFALL = 5.4 CM (2.1 IN), DURATION = 14 HR.

BUTTONWOOD STORM DATA: 08/28/86

PARAMETER	UNITS	BU-1	BU-2S	BU-2B	BU-3	BU-4	BU-5	BU-6	BU-7	BU-8	BU-9	BU-10	BU-11	BU-12	BU-13
TALK	(mg/l)	29.6	18.2	18.2	19.7	12.9	1.8	1.8			26.3		18.6	11.8	
TSS	(mg/l)	28.0	3.0	2.0	1.0	16.0	60.0	47.0			15.0		5.0	4.0	
TDS	(mg/l)	151.0	64.0	68.0	68.0	79.0	9.0	33.0			145.0		227.0	49.0	
AMM-N	(mg/l)	2.10	.01	.01	.20	1.10	.23	.22			.12		.10	.13	
NITRATE-N	(mg/l)	1.21	.05	.03	.04	.78	.36	.37			1.17		.32	1.13	
CHLORIDE	(mg/l)	53.0	28.0	26.0	25.0	22.0	6.2	4.5			43.0		118.0	8.7	
ORTHO-P	(ug/l)	150	17	12	20	180	140	140			31		17	37	
TOTAL P	(ug/l)	300	119	125	91	270	108	110			44		65	54	
KNITRO	(mg/l)	3.60	1.30	1.50	1.40	3.00	.78	.91			.55		.69	.42	
FEC.COLI	(#/100ml)	1800	300		200	220	0	30			3000		1250	40	
FEC.STREP	(#/100ml)	100000	161		3300	100000	65000	43000			26000		5000	13000	
TEMP	(Celsius)	16.0	18.3	18.3	17.8	16.1	14.1				14.2		13.7	16.0	
DO	(mg/l)	7.7	8.3	7.7	3.3	7.7	9.7				7.9		8.8	7.8	
PH	(S.U.)	6.9	7.0	7.0	6.8	6.6	6.2	6.4			7.0		6.7	6.6	
COND	(umhos/cm)	220	98	108	103	100	22	26			195		315	66	
FLOW	(cu.m/min)	7.8			.2	6.3	.7	.2	0.0	0.0	.8	.5	.3	2.0	.8

TOTAL RAINFALL = 0.2 CM (0.08 IN), DURATION = 1 HR.

BUTTONWOOD STORM DATA: 09/16/86

PARAMETER	UNITS	BU-1	BU-2S	BU-2B	BU-3	BU-4	BU-5	BU-6	BU-7	BU-8	BU-9	BU-10	BU-11	BU-12	BU-13
TALK	(mg/l)	5.1	18.0	18.0	19.0	2.1	1.0	1.0		4.2	9.7	15.0	5.5	6.8	14.0
TSS	(mg/l)	179	4.4	19	18	94	24	60		34	52	84	124	80	47
TDS	(mg/l)	85	105	88	108	83	116	49		63	144	171	255	72	112
AMM-N	(mg/l)	.44	.01	.01	.21	.50	.41	.44		.44	.35	.20	.50	.68	.30
NITRATE-N	(mg/l)	.95	.04	.02	.15	.76	.69	.59		1.09	1.20	1.53	.93	1.25	.66
CHLORIDE	(mg/l)	16.0	28.0	29.0	29.0	15.0	4.9	6.6		5.8	38.0	42.0	106.0	11.0	22.0
TURBIDITY	(NTU)	17	9	11	9	21	7	7		9	10	14	25	4	2
ORTHO-P	(ug/l)	155	17	24	25	154	75	29		76	91	75	39	200	31
TOTAL P	(ug/l)	247	101	109	91	235	110	64		155	253	232	173	463	174
KNITRO	(mg/l)	2.40	1.17	1.27	1.05	1.55	.88	.84		1.29	2.17	2.66	2.00	1.42	1.17
FEC.COLI	(#/100ml)	900	36		1300	2200	1300	100		30000	18000	22000	15000	13000	8000
FEC.STREP	(#/100ml)	77000	7000		57000	64000	610	40		100000	107000	133000	126000	115000	113000
TEMP	(Celsius)	14.7	16.1	16.0	16.2										
DO	(mg/l)	7.4	8.3	7.2	2.3										
PH	(S.U.)	6.3	7.0	6.9	6.3	6.0	6.0	5.9		6.1	6.3	6.5	6.6	6.3	6.3
COND	(umhos/cm)	78	115	112	122	71	40	48		49	138	186	310	76	115
FLOW	(cu.m/min)	18.0			.2	10.8	.3	.2		.2	6.8	4.9	1.3	11.3	.5
O&G	(mg/l)	1.6	2.4	3.4	2.0	2.8	3.0	2.0		2.2	1.6	2.8	1.8	2.6	1.0
LEAD	(mg/l)	.2	.1	.1	.1	.1	.1	.1		.1	.1	.1	.2	.1	.1
CADMIUM	(mg/l)	.02	.02	.02	.02	.02	.02	.02		.02	.03	.03	.02	.08	.02
CHROMIUM	(mg/l)	.02	.02	.02	.02	.02	.02	.02		.02	.02	.02	.02	.02	.02
COPPER	(mg/l)	.04	.02	.02	.02	.03	.04	.03		.06	.03	.03	.04	.05	.03
IRON	(mg/l)	5.90	.39	.60	.83	2.70	.90	2.05		1.60	1.95	2.80	7.60	4.65	8.40
MANG.	(mg/l)	.22	.08	.08	.11	.15	.03	.05		.12	.30	.34	.72	.27	.52
ZINC	(mg/l)	.16	.02	.02	.02	.10	.16	.14		.13	.07	.04	.15	.17	.02

TOTAL RAINFALL = 1.9 CM (0.75 IN), DURATION = 2.5 HR.

BUTTONWOOD STORM DATA: 02/05/87

PARAMETER	UNITS	BU-4	BU-9	BU-12
TALK	(mg/l)	57.0	16.4	23.0
TSS	(mg/l)	12.0	.4	.8
TDS	(mg/l)	239.0	233.0	129.0
AMM-N	(mg/l)	5.50	.10	.10
NITRATE-N	(mg/l)	1.30	1.50	3.20
CHLORIDE	(mg/l)	92.0	138.0	42.0
ORTHO-P	(ug/l)	2160	10	13
TOTAL P	(ug/l)	2500	15	17
KNITRO	(mg/l)	20.00	.26	.32
FEC.COLI	(#/100ml)	6000	47	23
FEC.STREP	(#/100ml)	10000	97	37
TEMP	(Celsius)		-.8	-2.2
DO	(mg/l)		15.2	14.8
PH	(S.U.)	7.0	6.7	6.6
COND	(umhos/cm)	375	400	210
FLOW	(cu.m/min)	.1	1.6	.7

NOTE: THERE WAS NO PRECIPITATION ON THIS DATE, BUT SNOW MELT PROVIDED RUNOFF SUITABLE FOR SOME SAMPLING.

BUTTONWOOD STORM DATA: 04/28/87

PARAMETER	UNITS	BU-1*	BU-1	BU-3	BU-4A	BU-4B	BU-4C	BU-4D	BU-4E	BU-4	BU-5	BU-6	BU-8
TSS	(mg/l)	1	121	3	13	57	42	42	180	36	112	90	18
AMM-N	(mg/l)	.13	.30	.02	6.90	1.20	.14	.01	.04	2.20	.29	.27	.10
NITRATE-N	(mg/l)	1.23	.02	.24	.06	.05	.16	.13	.09	.23	.26	.17	1.67
CHLORIDE	(mg/l)	48.8	48.4	45.9	45.1	35.5	30.9	28.0	2.2	38.8	31.3	272.0	198.0
TURBIDITY	(NTU)	1.5	11.2	3.7	14.0	17.0	14.0	15.0	50.0	16.0	34.0	32.0	19.0
ORTHO-P	(ug/l)	38	126	24	193	344	179	79	88	558	25	47	20
TOTAL P	(ug/l)	160	320	110	2500	520	460	170	89	1500	130	180	100
KNITRO	(mg/l)	.60	1.37	.59	14.00	2.48	.73	.49	.34	4.05	.69	1.60	2.90
FEC.COLI	(#/100ml)	2300	200							6000	100		10
FEC.STREP	(#/100ml)	2900	3500	120							710	3700	50
PH	(S.U.)	6.9	7.4	7.1	7.0	6.8	6.7	6.7	5.9	6.9	6.7	6.6	6.9
COND	(umhos/cm)	210	190	178	270	187	133	112	24	195	120	135	590
FLOW	(cu.m/min)	.8	15.1	5.8	1.2	1.7	4.2	7.7	15.0	6.0	.7	.3	.5
O&G	(mg/l)		12.8	15.0						18.8	14.6	8.8	14.8
LEAD	(mg/l)		.1	.1						.1	.1	.1	.1
CADMIUM	(mg/l)		.02	.02						.02	.02	.02	.02
CHROMIUM	(mg/l)		.02	.02						.02	.02	.02	.02
COPPER	(mg/l)		.02	.02						.02	.03	.02	.02
IRON	(mg/l)		.57	.40						.87	1.60	3.75	2.60
MANG.	(mg/l)		.05	.07						.06	.04	.11	.89
ZINC	(mg/l)		.10	.03						.19	.30	.28	.07

NOTE: STATION 1* REPRESENTS STATION 1 IMMEDIATELY PRIOR TO THE STORM;
STATIONS 4A-4E AND 9A-9E REPRESENT DISCRETE SAMPLINGS;
ALL OTHER SAMPLES ARE COMPOSITES OVER A 6-HR PERIOD.

TOTAL RAINFALL = 4.5 CM (1.8 IN), DURATION = 12 HR.

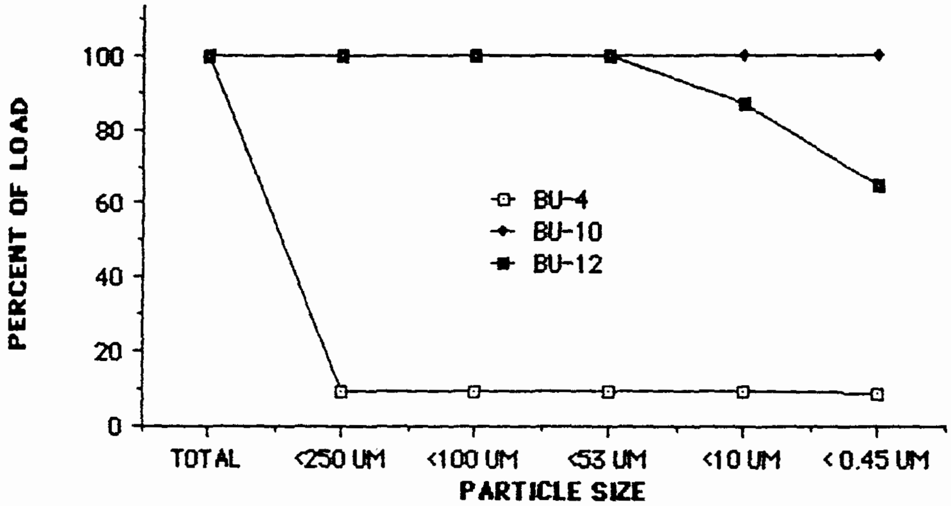
BUTTONWOOD STORM DATA: 04/28/87

PARAMETER	UNITS	BU-9A	BU-9B	BU-9C	BU-9D	BU-9E	BU-10	BU-11	BU-12	BU-13	BU-14	BU-15
TSS	(mg/l)	50	1	1	13	48	3	16	17	41	62	6
AMM-N	(mg/l)	.01	.01	.01	.01	.01	.01	.03	.08	.09	.27	.19
NITRATE-N	(mg/l)	1.08	1.18	.83	.95	.20	.88	.41	1.36	.58	.61	.22
CHLORIDE	(mg/l)	57.6	48.4	56.3	66.3	13.8	38.4	228.0	22.6	247.0	24.7	3.0
TURBIDITY	(NTU)	4.9	3.1	4.8	6.7	50.0	3.9	4.7	9.0	8.0	18.0	19.0
ORTHO-P	(ug/l)	20	10	20	16	38	10	10	20	17	29	39
TOTAL P	(ug/l)	39	19	49	49	94	41	46	105	77	129	110
KNITRO	(mg/l)	.39	.36	.43	.47	.44	.34	.30	.63	.45	.75	.25
FEC.COLI	(#/100ml)	1					300	100	100	200	700	
FEC.STREP	(#/100ml)	800					141	98	450	840	900	1700
PH	(S.U.)	6.9	6.8	6.8	6.7	6.1	6.7	6.7	6.8	6.4	6.5	6.5
COND	(umhos/cm	220	210	205	240	60	180	600	138	655	115	31
FLOW	(cu.m/min	2.4	2.7	5.1	8.8	28.9	7.6	6.8	6.6	2.0	.7	.7
O&G	(mg/l)	11.1					12.8	20.0	14.2	18.3	14.6	11.4
LEAD	(mg/l)	.1					.1	.1	.1	.1	0.0	0.0
CADMIUM	(mg/l)	.02					.02	.12	.02	.02	.02	.02
CHROMIUM	(mg/l)	.02					.02	.02	.02	.02	.02	.02
COPPER	(mg/l)	.02					.02	.02	.02	.02	.02	.02
IRON	(mg/l)	.76					.28	.10	.04	6.20	1.20	.79
MANG.	(mg/l)	.08					.08	.08	.10	.50	.06	.02
ZINC	(mg/l)	.05					.02	.10	.04	.06	.20	.13

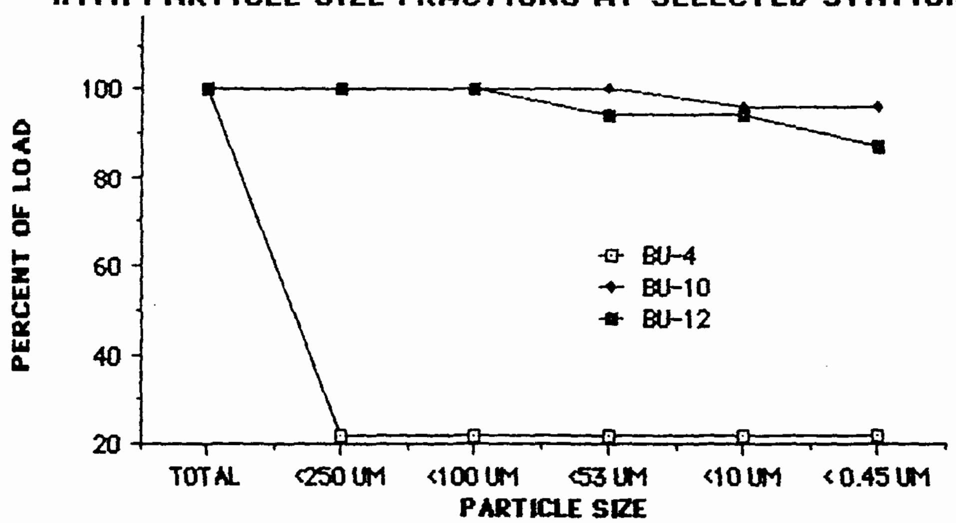
SIZE FRACTIONATION OF SELECTED POLLUTANT LOADS AT SELECTED STATIONS.
(BASED ON SAMPLES COLLECTED IN APRIL, 1987)

STATION	PARAMETER	VALUE (mg/l) PER SIZE FRACTION					
		TOTAL	<250 um	<100 um	<53 um	<10 um	<0.45 um
BU-4	TOTAL SUSPENDED SOLIDS	61.0	59.0	54.0	51.0	6.0	.1
	NITRATE NITROGEN	.23	.02	.03	.02	.04	.05
	TOTAL PHOSPHORUS	1.50	.19	.21	.11	.10	.11
	TOTAL KJELDAHL-NITROGEN	4.05	.22	.24	.30	.39	.34
BU-10	TOTAL SUSPENDED SOLIDS	10.5	9.3	10.0	8.0	5.0	3.0
	NITRATE NITROGEN	.88	.88	.89	.98	.94	.94
	TOTAL PHOSPHORUS	.04	.05	.04	.04	.05	.03
	TOTAL KJELDAHL-NITROGEN	.34	.42	.56	.46	.51	.56
BU-12	TOTAL SUSPENDED SOLIDS	17.0	16.0	20.0	14.0	11.0	1.0
	NITRATE NITROGEN	1.36	1.35	1.37	1.07	1.29	1.49
	TOTAL PHOSPHORUS	.10	.06	.09	.08	.08	.04
	TOTAL KJELDAHL-NITROGEN	.63	.60	.52	.68	.59	.44

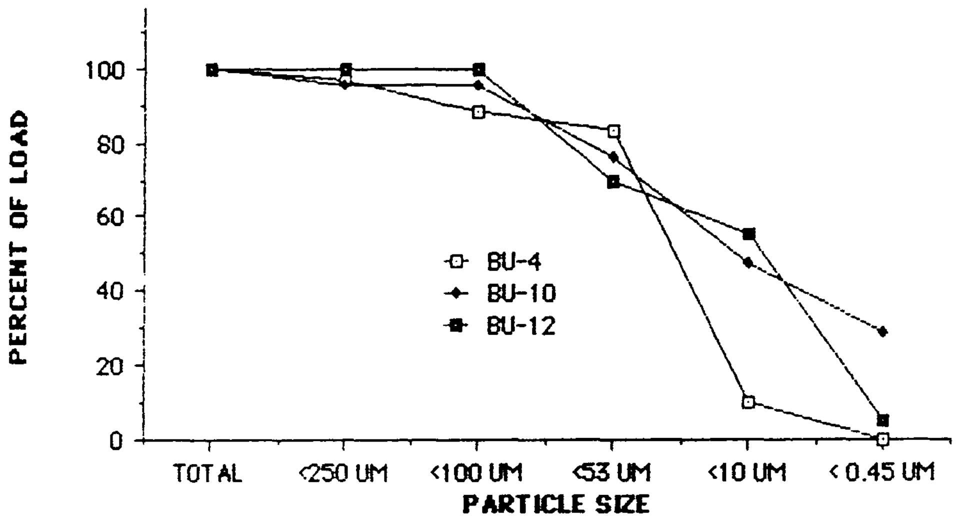
PERCENT OF TKN LOAD ASSOCIATED WITH PARTICLE SIZE FRACTIONS AT SELECTED STATIONS



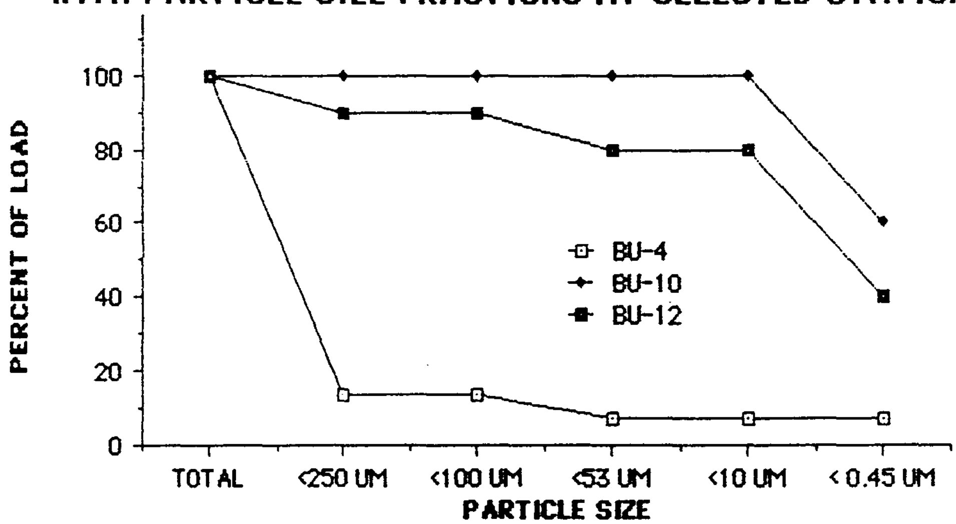
PERCENT OF NITRATE NITROGEN LOAD ASSOCIATED WITH PARTICLE SIZE FRACTIONS AT SELECTED STATIONS



PERCENT OF SUSPENDED SOLIDS LOAD ASSOCIATED WITH PARTICLE SIZE FRACTIONS AT SELECTED STATIONS



PERCENT OF TOTAL PHOSPHORUS LOAD ASSOCIATED WITH PARTICLE SIZE FRACTIONS AT SELECTED STATIONS



BUTTONWOOD POND ZOOPLANKTON

051586

TAXON	#/L	UG/L
COPEPODA		
Cyclops	0.1	.11
Diaptomus	0.2	.07
Nauplii	0.1	.19
CLADOCERA		
Bosmina	3.5	3.44
Daphnia catawba	0.2	.53
Sida	0.1	.18
TOTAL	4.2	4.54
COPEPODA	0.4	.38
CLADOCERA	3.8	4.16
MEAN LENGTH (MM)	0.4	

091586

TAXON	#/L	UG/L
COPEPODA		
Cyclops	0.1	.03
Diaptomus	0.1	.01
Nauplii	0.1	.08
CLADOCERA		
Bosmina	0.4	.39
Chydorus	8.0	7.84
Daphnia catawba	0.1	.03
Diaphanosoma	0.1	.05
TOTAL	8.9	8.45
COPEPODA	0.3	.13
CLADOCERA	8.6	8.32
MEAN LENGTH (MM)	0.3	

BUTTONWOOD POND PHYTOPLANKTON

031186

TAXON	CELLS/ML
CRYPTOPHYTA	
Cryptomonas	87
EUGLENOPHYTA	
Trachelomonas	63
PYRRHOPHYTA	
Peridinium	42
TOTAL	192
CRYPTOPHYTA	87
EUGLENOPHYTA	63
PYRRHOPHYTA	42
	UG/L
CRYPTOPHYTA	
Cryptomonas	17.4
EUGLENOPHYTA	
Trachelomonas	63
PYRRHOPHYTA	
Peridinium	126
TOTAL	206.4
CRYPTOPHYTA	17.4
EUGLENOPHYTA	63
PYRRHOPHYTA	126

040386

TAXON	CELLS/ML
BACILLARIOPHYTA	
Fragilaria	36
Melosira	15
Synedra	51
CHLOROPHYTA	
Pediastrum	48
Staurastrum	3
CRYPTOPHYTA	
Cryptomonas	184.5
CYANOPHYTA	
Chroococcus	12
EUGLENOPHYTA	
Euglena	3
TOTAL	352.5
BACILLARIOPHYTA	102
CHLOROPHYTA	51
CRYPTOPHYTA	184.5
CYANOPHYTA	12
EUGLENOPHYTA	3
	UG/L
BACILLARIOPHYTA	
Fragilaria	10.8
Melosira	36
Synedra	408
CHLOROPHYTA	
Pediastrum	9.6
Staurastrum	2.4
CRYPTOPHYTA	
Cryptomonas	184.5
CYANOPHYTA	
Chroococcus	.12
EUGLENOPHYTA	
Euglena	1.5
TOTAL	652.92
BACILLARIOPHYTA	454.8
CHLOROPHYTA	12
CRYPTOPHYTA	184.5
CYANOPHYTA	.12
EUGLENOPHYTA	1.5

041786

TAXON	CELLS/ML
BACILLARIOPHYTA	
Fragilaria	24
Synedra	138
CHLOROPHYTA	
Pediastrum	36
CRYPTOPHYTA	
Cryptomonas	147
CYANOPHYTA	
Chroococcus	42
PYRRHOPHYTA	
Peridinium	3
TOTAL	390
BACILLARIOPHYTA	162
CHLOROPHYTA	36
CRYPTOPHYTA	147
CYANOPHYTA	42
PYRRHOPHYTA	3
	UG/L
BACILLARIOPHYTA	
Fragilaria	7.2
Synedra	110.4
CHLOROPHYTA	
Pediastrum	7.2
CRYPTOPHYTA	
Cryptomonas	147
CYANOPHYTA	
Chroococcus	.42
PYRRHOPHYTA	
Peridinium	135
TOTAL	407.22
BACILLARIOPHYTA	117.6
CHLOROPHYTA	7.2
CRYPTOPHYTA	147
CYANOPHYTA	.42
PYRRHOPHYTA	135

050186

TAXON	CELLS/ML
BACILLARIOPHYTA	
Synedra	546
CHLOROPHYTA	
Chlamydomonas	163.8
CRYPTOPHYTA	
Cryptomonas	148.2
CYANOPHYTA	
Chroococcus	20.8
PYRRHOPHYTA	
Peridinium	5.2
TOTAL	884
BACILLARIOPHYTA	546
CHLOROPHYTA	163.8
CRYPTOPHYTA	148.2
CYANOPHYTA	20.8
PYRRHOPHYTA	5.2
	UG/L
BACILLARIOPHYTA	
Synedra	4368
CHLOROPHYTA	
Chlamydomonas	16.38
CRYPTOPHYTA	
Cryptomonas	29.64
CYANOPHYTA	
Chroococcus	.208
PYRRHOPHYTA	
Peridinium	15.6
TOTAL	4429.828
BACILLARIOPHYTA	4368
CHLOROPHYTA	16.38
CRYPTOPHYTA	29.64
CYANOPHYTA	.208
PYRRHOPHYTA	15.6

051586

TAXON	CELLS/ML
BACILLARIOPHYTA	
Synedra	21
CRYPTOPHYTA	
Cryptomonas	435
PYRRHOPHYTA	
Peridinium	3
TOTAL	459
BACILLARIOPHYTA	21
CRYPTOPHYTA	435
PYRRHOPHYTA	3
	UG/L
BACILLARIOPHYTA	
Synedra	168
CRYPTOPHYTA	
Cryptomonas	87
PYRRHOPHYTA	
Peridinium	135
TOTAL	390
BACILLARIOPHYTA	168
CRYPTOPHYTA	87
PYRRHOPHYTA	135

052986

TAXON	CELLS/ML
BACILLARIOPHYTA	
Synedra	19.2
CRYPTOPHYTA	
Cryptomonas	100.8
TOTAL	120
BACILLARIOPHYTA	19.2
CRYPTOPHYTA	100.8
	UG/L
BACILLARIOPHYTA	
Synedra	15.36
CRYPTOPHYTA	
Cryptomonas	20.16
TOTAL	35.52
BACILLARIOPHYTA	15.36
CRYPTOPHYTA	20.16

061986

TAXON	CELLS/ML
BACILLARIOPHYTA	
Synedra	8.8
CHLOROPHYTA	
Pediastrum	17.6
Sphaerocystis	74.8
CRYPTOPHYTA	
Cryptomonas	1298
CYANOPHYTA	
Chroococcus	26.4
TOTAL	1425.6
BACILLARIOPHYTA	8.8
CHLOROPHYTA	92.4
CRYPTOPHYTA	1298
CYANOPHYTA	26.4
	UG/L
BACILLARIOPHYTA	
Synedra	70.4
CHLOROPHYTA	
Pediastrum	3.52
Sphaerocystis	7.48
CRYPTOPHYTA	
Cryptomonas	1298
CYANOPHYTA	
Chroococcus	.264
TOTAL	1379.664
BACILLARIOPHYTA	70.4
CHLOROPHYTA	11
CRYPTOPHYTA	1298
CYANOPHYTA	.264

070286

TAXON	CELLS/ML
BACILLARIOPHYTA	
Melosira	24
Synedra	6
CHLOROPHYTA	
Pediastrum	48
Scenedesmus	36
Staurastrum	6
Volvox	1350
CRYPTOPHYTA	
Cryptomonas	1200
CYANOPHYTA	
Chroococcus	36
PYRRHOPHYTA	
Ceratium	156
TOTAL	2862
BACILLARIOPHYTA	30
CHLOROPHYTA	1440
CRYPTOPHYTA	1200
CYANOPHYTA	36
PYRRHOPHYTA	156
	UG/L
BACILLARIOPHYTA	
Melosira	7.2
Synedra	48
CHLOROPHYTA	
Pediastrum	9.6
Scenedesmus	3.6
Staurastrum	4.8
Volvox	135
CRYPTOPHYTA	
Cryptomonas	720
CYANOPHYTA	
Chroococcus	.36
PYRRHOPHYTA	
Ceratium	6240
TOTAL	7168.56
BACILLARIOPHYTA	55.2
CHLOROPHYTA	153
CRYPTOPHYTA	720
CYANOPHYTA	.36
PYRRHOPHYTA	6240

071786

TAXON	CELLS/ML
CHLOROPHYTA	
Chlamydomonas	399
Scenedesmus	33.6
Sphaerocystis	172.2
Staurastrum	25.2
CRYPTOPHYTA	
Cryptomonas	71.4
PYRRHOPHYTA	
Ceratium	119.7
TOTAL	821.1
CHLOROPHYTA	630
CRYPTOPHYTA	71.4
PYRRHOPHYTA	119.7
	UG/L
CHLOROPHYTA	
Chlamydomonas	39.9
Scenedesmus	3.36
Sphaerocystis	17.22
Staurastrum	20.16
CRYPTOPHYTA	
Cryptomonas	14.28
PYRRHOPHYTA	
Ceratium	4788
TOTAL	4882.92
CHLOROPHYTA	80.64
CRYPTOPHYTA	14.28
PYRRHOPHYTA	4788

073186

TAXON	CELLS/ML
BACILLARIOPHYTA	
Fragilaria	19.2
CHLOROPHYTA	
Pediastrum	51.2
Sphaerocystis	169.6
CRYPTOPHYTA	
Cryptomonas	76.8
CYANOPHYTA	
Chroococcus	28.8
PYRRHOPHYTA	
Ceratium	928
Peridinium	192
TOTAL	1465.6
BACILLARIOPHYTA	19.2
CHLOROPHYTA	220.8
CRYPTOPHYTA	76.8
CYANOPHYTA	28.8
PYRRHOPHYTA	1120
	UG/L
BACILLARIOPHYTA	
Fragilaria	5.76
CHLOROPHYTA	
Pediastrum	10.24
Sphaerocystis	16.96
CRYPTOPHYTA	
Cryptomonas	15.36
CYANOPHYTA	
Chroococcus	.288
PYRRHOPHYTA	
Ceratium	37120
Peridinium	576
TOTAL	37744.608
BACILLARIOPHYTA	5.76
CHLOROPHYTA	27.2
CRYPTOPHYTA	15.36
CYANOPHYTA	.288
PYRRHOPHYTA	37696

081486

TAXON	CELLS/ML
BACILLARIOPHYTA	
Synedra	296.4
CHLOROPHYTA	
Chlamydomonas	1950
CRYPTOPHYTA	
Cryptomonas	1560
CYANOPHYTA	
Anabaena	4680
Chroococcus	2288
PYRRHOPHYTA	
Ceratium	98.8
TOTAL	10873.2
BACILLARIOPHYTA	296.4
CHLOROPHYTA	1950
CRYPTOPHYTA	1560
CYANOPHYTA	6968
PYRRHOPHYTA	98.8
	UG/L
BACILLARIOPHYTA	
Synedra	2371.2
CHLOROPHYTA	
Chlamydomonas	195
CRYPTOPHYTA	
Cryptomonas	312
CYANOPHYTA	
Anabaena	14508
Chroococcus	22.88
PYRRHOPHYTA	
Ceratium	3952
TOTAL	21361.08
BACILLARIOPHYTA	2371.2
CHLOROPHYTA	195
CRYPTOPHYTA	312
CYANOPHYTA	14530.88
PYRRHOPHYTA	3952

[illegible]

TAXON	CELLS/ML
BACILLARIOPHYTA	
Synedra	365.2
CHLOROPHYTA	
Chlamydomonas	924
CRYPTOPHYTA	
Cryptomonas	396
CYANOPHYTA	
Anabaena	638
Chroococcus	1474
Microcystis	3960
EUGLENOPHYTA	
Euglena	50.6
PYRRHOPHYTA	
Ceratium	204.6
Peridinium	484
TOTAL	8496.4
BACILLARIOPHYTA	365.2
CHLOROPHYTA	924
CRYPTOPHYTA	396
CYANOPHYTA	6072
EUGLENOPHYTA	50.6
PYRRHOPHYTA	688.6
	UG/L
BACILLARIOPHYTA	
Synedra	292.16
CHLOROPHYTA	
Chlamydomonas	92.4
CRYPTOPHYTA	
Cryptomonas	79.2
CYANOPHYTA	
Anabaena	255.2
Chroococcus	14.74
Microcystis	118.8
EUGLENOPHYTA	
Euglena	25.3
PYRRHOPHYTA	
Ceratium	8184
Peridinium	1452
TOTAL	10513.8
BACILLARIOPHYTA	292.16
CHLOROPHYTA	92.4
CRYPTOPHYTA	79.2
CYANOPHYTA	388.74
EUGLENOPHYTA	25.3
PYRRHOPHYTA	9636

091686	
TAXON	CELLS/ML
BACILLARIOPHYTA	
Navicula	1.6
CHLOROPHYTA	
Kirchneriella	3520
Scenedesmus	25.6
CYANOPHYTA	
Anabaena	640
Chroococcus	1920
EUGLENOPHYTA	
Euglena	30.4
PYRRHOPHYTA	
Ceratium	51.2
TOTAL	6218.8
BACILLARIOPHYTA	1.6
CHLOROPHYTA	3575.6
CYANOPHYTA	2560
EUGLENOPHYTA	30.4
PYRRHOPHYTA	51.2
	UG/L
BACILLARIOPHYTA	
Navicula	80
CHLOROPHYTA	
Kirchneriella	352
Scenedesmus	2.56
CYANOPHYTA	
Anabaena	256
Chroococcus	19.2
EUGLENOPHYTA	
Euglena	15.2
PYRRHOPHYTA	
Ceratium	2048
TOTAL	2772.96
BACILLARIOPHYTA	80
CHLOROPHYTA	354.56
CYANOPHYTA	275.2
EUGLENOPHYTA	15.2
PYRRHOPHYTA	2048

112086	
TAXON	CELLS/ML
BACILLARIOPHYTA	
Synedra	7.2
CHLOROPHYTA	
Chlamydomonas	57.6
Chlorococcum	324
CHRYSOPHYTA	
Dinobryon	86.4
Synura	604.8
CRYPTOPHYTA	
Cryptomonas	149.4
CYANOPHYTA	
Anabaena	115.2
Chroococcus	75.6
PYRRHOPHYTA	
Peridinium	14.4
TOTAL	1434.6
BACILLARIOPHYTA	7.2
CHLOROPHYTA	381.6
CHRYSOPHYTA	691.2
CRYPTOPHYTA	149.4
CYANOPHYTA	190.8
PYRRHOPHYTA	14.4
	UG/L
BACILLARIOPHYTA	
Synedra	57.6
CHLOROPHYTA	
Chlamydomonas	5.76
Chlorococcum	1944
CHRYSOPHYTA	
Dinobryon	259.2
Synura	483.84
CRYPTOPHYTA	
Cryptomonas	29.88
CYANOPHYTA	
Anabaena	46.08
Chroococcus	.756
PYRRHOPHYTA	
Peridinium	43.2
TOTAL	2870.316
BACILLARIOPHYTA	57.6
CHLOROPHYTA	1949.76
CHRYSOPHYTA	743.04
CRYPTOPHYTA	29.88
CYANOPHYTA	46.836
PYRRHOPHYTA	43.2

020587	
TAXON	CELLS/ML
CHLOROPHYTA	
Closterium	1.3
CRYPTOPHYTA	
Cryptomonas	2080
CYANOPHYTA	
Chroococcus	62.4
TOTAL	2143.7
CHLOROPHYTA	1.3
CRYPTOPHYTA	2080
CYANOPHYTA	62.4
	UG/L
CHLOROPHYTA	
Closterium	130
CRYPTOPHYTA	
Cryptomonas	416
CYANOPHYTA	
Chroococcus	.624
TOTAL	546.624
CHLOROPHYTA	130
CRYPTOPHYTA	416
CYANOPHYTA	.624

APPENDIX C

CONVERSION FACTORS AND CALCULATION SHEETS

USEFUL CONVERSIONS

Multiply...	by...	to obtain...
Acre (ac)	0.4047	Hectare (ha)
Acre (ac)	43,560	Square Feet (sq.ft)
Acre (ac)	4,047	Square Meters (sq.m)
Acre (ac)	0.00156	Square Miles (sq.mi)
Acre Feet (af)	1613.3	Cubic Yards (cy)
Centimeters (cm)	0.3937	Inches (in)
Cubic Feet (cu.ft)	0.0283	Cubic Meters (cu.m)
Cubic Feet (cu.ft)	0.0370	Cubic Yards (cy)
Cubic Feet (cu.ft)	7.4805	Gallons (gal)
Cubic Feet (cu.ft)	28.32	Liters (l)
Cubic Feet/Second (cfs)	1.7	Cubic Meters/Minute (cu.m/min)
Cubic Feet/Second (cfs)	0.6463	Million Gallons/Day (mgd)
Feet (ft)	0.3048	Meters (m)
Feet (ft)	0.0001894	Mile (mi)
Kilograms (kg)	2.205	Pounds (lb)
Kilometers (km)	0.6214	Miles (mi)
Liters (l)	0.2642	Gallons (gal)
Liters (l)	1.057	Quarts (qt)
Meters (m)	1.094	Yards (yd)
Milligrams/Liter (mg/l)	1.0	Parts Per Million (ppm)
Micrograms/Liter (ug/l)	1.0	Parts Per Billion (ppb)
Square Kilometers (sq.km)	0.3861	Square Miles (sq.mi)
Square Meters (sq.m)	0.0001	Hectares (ha)

Flow Calculations - 10 Yr & 100 Yr Storms,
Buttonwood Pond Watershed

1. GEI has submitted estimates of 510 cfs and 1090 cfs for the peak flows associated with 10 yr and 100 yr storm events, respectively. While the exact calculations used have not been reviewed, a similar analysis by BEC (also using the SCS method) suggests that the GEI estimates properly use the SCS method and have chosen appropriate variable values for the Buttonwood Pond watershed. Reasonable assumptions lead to values similar to those submitted by GEI. The SCS method is considered to overestimate actual peak flows, however, based on the experience of BEC personnel.

2. Deductive calculation - 4.8" of rain (10 yr storm) on 506 ac of watershed (GEI value) assuming all of it reaches Buttonwood Pond in 24 hrs, yields a mean flow of 102 cfs. For the GEI peak flow estimate to be correct, the peak would have to be 5 x the mean. For the 100 yr storm (7" of rain) a mean of 149 cfs is anticipated. For the GEI peak flow to be correct, the peak would be 7.3 x the mean. While not impossible, these ratios of peak to mean seem high. A ratio less than 3:1 (peak to mean) seems more realistic, but this is an unsubstantiated estimate at this time.

3. Weiss Method (empirical formulas) applied to Buttonwood Pond.

   A = drainage area = 0.8 sq mi
   I = rainfall = 4.8" (10 yr) or 7" (100 yr)
   L = channel length = 1.6 mi
   Sm = channel slope = 31.3 f/mi
   %ASD Portion of area underlain by
   stratified drift = 0-20%

$$Q_{Peak\,10} = \frac{12.8\,(A)^{0.89} \times (I)^{1.6}}{\left(\frac{L}{\sqrt{S_m}}\right)^{0.06} \times (\%ASD+1)^{0.17}} = 83-139 \text{ cfs} \pm 44\%$$

$$Q_{Peak\,100} = \frac{73.5\,(A)^{0.91} \times (I)^{0.74}}{\left(\frac{L}{\sqrt{S_m}}\right)^{0.08} \times (\%ASD+1)^{0.18}} = 161-280 \text{ cfs} \pm 50\%$$

Given the nature of the Buttonwood Pond watershed, the best estimate probably lies near the upper limit of each range given. This suggests a 10 yr peak flow of not more than 200 cfs (probably not less than 150 cfs) and a 100 yr peak flow of not more than 420 cfs (probably not less than 300 cfs). BEC believes these to be realistic estimates of peak flows at the outlet of Buttonwood Pond.

Other Flow Calculations

1. Tibbetts Engineering Corp - Dec., 1970 Report

   Using formula Q = CxIxA, got 285 cfs as
   10 yr peak flow at
   Buttonwood Pond inlet.

2. Calculations by R. Garland (6/76) - Camp, Dresser & McKee

   Using SCS method and iterative calculations, got
   250 cfs as 10 yr peak flow at
   Buttonwood Pond inlet.

3. GHR Engineering Corp. - Spring 1980 report

   Using SCS method and iterative calculations, got
   440 cfs as 10 yr peak flow at
   Buttonwood Pond outlet (390 cfs @ Buttonwood Pond
   inlet).

These reports/calculations are available from the City of New Bedford, Dept. of Public Works, Cathy Burns' office. The Planning Dept. is also aware of them.

Summary - Flow Through Buttonwood Pond

Adjusting all values(in proportion to area represented) to the outlet of Buttonwood Pond, the following is obtained:

Source	Year	Method	Calculated Value for Peak Flow, 10 yr Storm Event
Tibbetts Engr. Corp.	1970	Rational (Q=CIA)	330 cfs
C.D.M.	1976	SCS	290 cfs
GHR Engr. Corp.	1980	SCS	440 cfs
GEI, Inc.	1986	SCS	510 cfs
BEC, Inc.	1986	Weiss (empirical)	150-200 cfs

The range is quite large, and is delineated by the recent GEI & BEC estimates. All estimates appear to make reasonable assumptions and use the associated models properly. The differences lie mainly in the failure of "desk-top" calculation methods based on general characteristics to accurately reflect specific circumstances in each watershed to which they are applied.

The watershed of Buttonwood Pond can be characterized as having slight slopes, poorly drained soils, and a moderate quantity of impervious surface. Storm drain systems speed delivery of water to the pond. Storage is minimal for low flows, but may be substantial for flows associated with the 10 yr. storm, as a consequence of back-up at culvert locations.

HYDROLOGIC BUDGET CALCULATIONS

Inflows:

Precipitation: 1.116 m/yr on 2.4 ha = 0.05 cu.m/min

Ground Water: Q = KIA
K = permeability = 0.2-6.0 in/hr (assume 6 in/hr)
I = slope = 0.001 ft/ft
A = seepage area = 128,500 SF (half of pond area)
Qmax = 1713 CF/d = 0.02 cfs = 0.03 cu.m/min

Surface Water Flows: Q = CIA = precip. x runoff coeff. x area

Drainage Area (see drainage figure)	C (m/yr)	I (%/100)	A (ha)	Q (cu.m/min)
1 (direct-pond)	1.116	0.2	7.2	0.03
2-6 (Bu-5,6,8,14,15)	1.116	0.6	8.9	0.11
7 (36 in drain)	1.116	0.6	35.4	0.45
8-10 (Bu Bk above Bu-9)	1.116	0.4	142.4	1.21
			Total	1.80

Note: Area 8-10 provides background flow. Using flow data @Bu-1 for dry periods (no precip. for >3 days), background flow = 0.7 cu.m/min.
Stormflow must then add 0.51 cu.m/min.

Outflows:

Evaporation: 0.69 m/yr from 2.4 ha = 0.03 cu.m/min

Ground Water:

When water level is below outlet level, downstream flow averages 0.15 cu.m/min (includes leakage thru dam). Assume GW contribution of 0.15 cu.m./min.

Outlet:

Due to use as storm water detention area, flow is spread out over time. Obs. mean = 1.24 cu.m/min. By subtraction, outlet flow = 1.7 cu.m/min. The latter is assumed.

BIRD COUNTS AND RELATED NUTRIENT LOADS AT BUTTONWOOD POND

			Nutrient Load			
			kg/bird/yr		kg/yr	
Bird	Mean	Range	TN	TP	TN	TP
Gulls	94	0-426	0.7	0.1	66	9.4
Ducks	76	21-165	1.0	0.2	76	15.2
Geese	4	0-10	4.0	0.5	16	2.0
Swans	<1	0-1	4.0	0.5	4	0.5
Pidgeons	12	0.54	0.7	0.1	8	1.2
Total	187	54-556			170	28.3

Does not include blackbirds or other small-bodied species.

NUTRIENT BUDGET CALCULATIONS

	kg/yr	
	N	P
Atmospheric Deposition:		
From export coefficients	41	1.0
Ground Water:		
From export coefficients	12	1.0
Buttonwood Bk background:		
0.7 cu.m/min w/TN @1.37 mg/l, TP @20 ug/l	504	7.4
Buttonwood Bk storm flow (@Bu-9):		
0.51 cu.m./min w/TN @1.85 mg/l, TP @116 ug/l	496	31.1
36" storm drain (Bu-4):		
0.45 cu.m/min w/TN @6.43 mg/l, TP @636 ug/l	1520	150.4
Other proximal storm drains (Bu-5,6,8,14,15):		
0.11 cu.m/min w/TN @2.20 mg/l, TP @120 ug/l	127	6.9
Direct Drainage:		
0.03 cu.m/min w/TN @1.37 mg/l, TP @20 ug/l (concs. assumed similar to Bu Bk background)	22	0.3
Bird Inputs:		
From bird count/loading calcs.	170	28.3
Internal Loading:		
A. Sediment release - no anoxia, no release assumed.		
B. Macrophyte pumping - TP only, Smith & Adams, 1986. 2.0 g TP/sq.m/yr, w/about 7500 sq.m involved	0	15.0
Total	2892	241.4

REMOVABLE SOFT SEDIMENT

15,222.8 sq.m @ 0.2 m deep	=	3044.6	cu.m
18,780.9 sq.m @ 0.4 m deep	=	7512.4	cu.m
534.1 sq.m @ 0.5 m deep	=	267.1	cu.m
Submerged sed. total	=	10,824.1	cu.m

13,869.1 sq.m @ 1.0 m deep = 13,869.1 cu.m
= filled pond area, now emergent "wetland"

Total removal soft sediment = 24,693.2, or about 25,000 cu.m

In addition, it would be desirable to remove about 0.3 m of sand below the silt layer, as this layer is mixed with some silt and contains some root masses.

25,000 sq.m @ 0.3 m deep = 7,500 cu.m, for a total excavation of about 32,500 cu.m = about 42,800 cy.

Calculations Related to the Existing Detention Basin

<u>Existing Capacity</u>:
Area of existing upstream detention basin = 58,500 SF = 1.34 ac
Depth = 4 to 6 ft, depending on how outlets are modified
Available volume = 234,000-351,000 cf

<u>Response to 10-yr Storm</u>:

$$Q_{10} = \frac{12.8\,(0.37\text{ sq. mi.})^{0.89} \times (4.8\text{ in})^{1.6}}{\left(\frac{0.5}{\sqrt{31.3\text{ ft/mi}}}\right)^{0.06} \times (0\text{ to }20\% + 1)^{0.17}} = 44.4\text{–}74.6\text{ cfs} \pm 44\%$$

Assume min = 44.4 cfs
Max = 107.5 cfs

Peak flows for 10-yr storm = 44.4-107.5 cfs (Weiss Method)
Critical velocity (Vc) for settling = Q/A = 0.0008-0.0018 ft/s
From a settling curve, this will allow settling
of particles w/diameter = 14-20 um
Detention time = 0.6-2.2 hr

<u>Response to 2-yr Storm</u>:

$$Q_{2} = \frac{8.1\,(0.37\text{ sq. mi.})^{0.88} \times (3.4\text{ in})^{1.74}}{\left(\frac{0.5}{\sqrt{31.3\text{ ft/mi}}}\right)^{0.05} \times (0\text{ to }20\% + 1)^{0.2}} = 17.3\text{–}31.9\text{ cfs} \pm 45\%$$

Assume min = 17.3 cfs
Max = 45.9 cfs

Peak flows for 2-yr storm = 17.3-45.9 cfs (Weiss Method)
Critical velocity (Vc) for settling = Q/A = 0.0003-0.0008 ft/s
From a settling curve, this will allow settling
of particles w/diameter = 8-14 um
Detention time = 1.4-5.6 hr

<u>Area Needed to Remove Particles of Specific Diameter</u>:

10 um:

A = Q/Vc	For 44.4 cfs, A = 74,000 SF = 1.7 ac
Vc = 0.0006	For 107.5 cfs, A = 179,167 SF = 4.1 ac
	For 17.3 cfs, A = 28,833 SF = 0.7 ac
	For 45.9 cfs, A = 76,500 SF = 1.8 ac

1 um:

Vc = 0.000005	For 44.4 cfs, A = 8,880,000 SF = 203.9 ac
	For 107.5 cfs, A = 21,500,000 SF = 493.6 ac
	For 17.3 cfs, A = 3,460,000 SF = 79.4 ac
	For 45.9 cfs, A = 9,180,000 SF = 210.7 ac

Flows Under Varying Rainfall Intensity
With a runoff coefficient of 0.5, a watershed of about 230 ac, and a 90 degree V-notch weir on a detention basin of 1.34 ac:

Rainfall (in/hr)	Runoff Generated (cf/hr)	Avg. Inflow (cfs)	Rise in Water Level (ft)	Resultant Outflow (cfs)
0.1	41800	12	0.7	1
0.2	83200	23	1.4	6
0.3	125000	35	2.1	17
0.4	166700	46	2.9	34
0.5	208400	58	3.6	60
0.6	250200	70	4.3	94
0.7	292000	81	5.0	138
0.8	333700	93	5.7	193
0.9	375100	104	6.4	259
1.0	416900	116	7.1	337

Note that inflow and outflow balance somewhere around the 0.6 in/hr mark; no overtopping of the basin will occur at rainfall intensities of less than 0.6 in/hr, if at least 4 ft of freeboard is available at storm initiation. Even with intensity at 1.0 in/hr, only 5 ft of freeboard is necessary to ensure no overtopping. Rainfall intensity of 0.6 in/hr occurs once or twice per year, while an intensity of 1.0 in/hr occurs only about once every two years (WPCF 1970).

COMPARISON OF FLOOD HAZARD BEFORE AND AFTER IMPLEMENTATION OF RECOMMENDED MANAGEMENT ACTIONS

Conditions	Before	After
Storage Capacity @ ST 12 (cf) (1.34 ac @ 4 ft deep)	0	234,000
Tolerable flow @ ST 1 (cfs) (6 ft x 1.7 ft x 5 ft/s)	50	50
Area of pond (ac)	6	8
Extra area covered around pond by 1 ft rise in water level (ac)	3	0.5
Storage at 1 ft rise in water level (cf) (pond area x 1 ft + extra area x avg. depth of coverage)	305,000	370,000
Outflow at 1 ft rise in water level (cfs) (15 ft crest with 1 ft head)	50	50
Tolerable flow at Hawthorne St. (cfs) (3 x 2 ft dia pipe & 1 x 3 ft dia pipe @ n = 0.013, slope = 0.004)	87	87
Time of travel (hr) to pond by 10 year storm runoff generated in area:		
1. (1000 ft/2 ft/s)	0.1	0.1
2. (700 ft/5 ft/s) + 0.1 hr	0.1	--
3. (500 ft/5 ft/s) + 0.1 hr	0.1	--
4. (700 ft/4 ft/s) + 0.1 hr	0.1	--
5. (1000 ft/5 ft/s) + 0.1 hr	0.2	--
6. (1000 ft/5 ft/s) + 0.1 hr	0.2	--
7. (3000 ft/5 ft/x) + 0.1 hr	0.3	--
8. (4500 ft/2 ft/s) + 0.1 hr	0.7	0.7
9. Assumed to be self-contained	--	--
10. (6000 ft/2 ft/s) + 0.3 hr + avg. det. (0 & >1.8)	1.1	>2.9

Time of travel through pond = volume/flow (depends avail. storage & inflow).

At desired max. 50 cfs flow, with volume at 20 ac ft, det. time = 4.8 hrs.

Time of travel from pond outlet to Hawthorne St. (1500/<6 ft/sec) = 0.1 hr.

For runoff piped to Hawthorne St. as part of project, time of travel from drains to outlet = pre-proj. travel time + (2500 ft/5 ft/s) = 0.2 to 0.4 hr.

Peak flows then depend upon the storm hydrograph and the additive effect of flows combining at specific points.

Assuming appropriate runoff coefficients (0.5 to 0.7), the 10-yr storm precipitation of 4.8 in/24 hrs, and times of travel as above, the following analysis is obtained.

For Avg. 10 yr storm flow: (Assumes Constant Hydrograph)		Before	After
Avg. flow at ST	12	23.4	23.4
	9	34.5	34.5
	5	0.2	0
	8	0.3	0.3
	4	12.3	0
	14	0.5	0
	1	48	35
(no storage assumed)	3	51.4	37.1
Hawthorne Street		53.9	53.9

For a 10 yr storm with the following hydrograph:

Hr.	1	2	3	4	5	6 thru 12	13 thru 24
In.	0.2	0.4	0.9	0.4	0.3	0.2	0.1

Peak flow at	Before (hr)	After (hr)
ST 12	104 (3) (leaving basin)	94 (4) (outflow @ 4.3 ft head)
9	126 (4) (area 10 @ hr 3 + area 8 @ hr 4)	110.7 (5) (ST 12 @ hr 4 + area 8 @ hr 5)
5	0.8 (3) (entering brook)	0 (diverted)
8	1.3 (3) (entering brook)	1.3 (3)
4	55.6 (3) (entering brook)	0 (diverted)
14	2.0 (3) (entering brook)	0 (diverted)
1	152.5 (4) (ST 9 @ hr 4 + Areas 4,5,6&7 @ hr 4)	111.1 (ST 9 @ hr 5 + ST 8 @ hr 5)
3	111.0 (5) (head created by ST 1 @ hr 4 + Areas 2 & 3 @ hr 4)	42.6 (6) (head created by ST 1 @ hr 5)
(Note: Water level rise @ ST 3)	(1.6 ft)	(0.9 ft)
Hawthorne St.	114.0 (5) (ST 3 @ hr 5 + direct runoff @ hr 5)	64.4 (3) (areas 2, 3, 4, 6 & 7 @ hr 3) [Note: 59.1 (6)]

APPENDIX D

ENVIRONMENTAL NOTIFICATION FORM

ENVIRONMENTAL NOTIFICATION FORM

I. SUMMARY

A. Project Identification

1. Project Name: Buttonwood Pond and Park
   Address/Location: c/o Office of Neighborhood
   City Hall, Williams Street
   City/Town: New Bedford, MA 02740
2. Project Proponent: same as above
   Address: ______
3. Est. Commencement: Late 1988. Est. Completion: 1991.
   Approx. Cost $ 1.3 million. Status of Project Design: 50 % Complete.
4. Amount (if any) of bordering vegetated wetlands, salt marsh, or tidelands to be dredged, filled, removed, or altered (other than by receipt of runoff) as a result of the project.
   11 acres 480,000 square feet.
5. This project is categorically included and therefore requires preparation of an EIR.
   Yes x No ______ ?

B. Narrative Project Description
Describe project and site.

The project involves three separate construction activities. The first is the modification of an existing detention basin between Rt. 140 and the Rockdale West development, to facilitate detention of storm water during typical storm events. The second action is the re-routing of a 36" storm drain which currently discharges into Buttonwood Brook just above the inlet to Buttonwood Pond. The re-routing will allow 4 other storm water discharge pipes to be diverted from the pond as well, as they can be tied into the re-routed line. This pipe will discharge into Buttonwood Brook below Buttonwood Park. The third activity involves the dredging of approximately 42,800 cubic yards of sediment from Buttonwood Pond, with deposition of the dredged material elsewhere within the park as part of a landscaping program. Pond banks will be stabilized and the outlet structure will be repaired.

Copies of the complete ENF may be obtained from (proponent or agent):
Name: Mr. Dana Souza Firm/Agency: Office of Neighborhoods
Address: City Hall, Williams Street Phone No. 617-999-2931
New Bedford, MA 02740

1986 THIS IS AN IMPORTANT NOTICE. COMMENT PERIOD IS LIMITED.
For Information, call (617) 727-5830

C. List the State or Federal agencies from which permits or other actions have been will be sought:

Agency Name	Permit	Date filed; file no.
See attached list (Table of Necessary Permits from Report)		No permit applications filed yet.

D. List any government agencies or programs from which the proponent will seek financial assistance for this project:

Agency Name	Funding Amount
MDEQE	Approx. $975,000
Possibly DEM, under Rivers and Harbors or Olmsted Parks Restoration	up to $329,000
Possibly EOEA, under Self Help or Conservation Fund	up to $329,000

E. Areas of potential impact (complete Sections II and III first, before completing this section).

1. Check all areas in which, in the proponent's judgment, an impact of this project may occur. Positive impacts, as well as adverse impacts, may be indicated.

	Construction Impacts	Long Term Impacts
Inland Wetlands	x	x
Coastal Wetlands/Beaches		
Tidelands		
Traffic	x	
Open Space/Recreation	x	x
Historical/Archaeological		
Fisheries/Wildlife	x	x
Vegetation/Trees	x	
Agricultural Lands		
Water Pollution	x	x
Water Supply/Use		
Solid Waste		
Hazardous Materials		
Air Pollution	x	
Noise	x	
Wind/Shadow		
Aesthetics	x	
Growth Impacts		
Community/Housing and the Built Environment		
Other (Specify)		

2. List the alternatives which have been considered.

No action
Additional upstream detention
Macrophyte harvesting
Bottom barriers
Street Sweeping

F. Has this project been filed with EOEA before? No x Yes ______ EOEA No. ______

G. WETLANDS AND WATERWAYS

1. Will an Order of Conditions under the Wetlands Protection Act (c.131s.40) or a License under the Waterways Act (c.91) be required?
   Yes x No ______
2. Has a local Order of Conditions been:
   a. issued? Date of issuance ______ ; DEQE File No. ______ .
   b. appealed? Yes ______ ; No x .
3. Will a variance from the Wetlands or Waterways Regulations be required? Yes ______ ; No ______ . Possibly. A determination must be made.

II. PROJECT DESCRIPTION

A. Map; site plan. Include an original 8½ x 11 inch or larger section of the most recent U.S.G.S. 7.5 minute series scale topographic map with the project area location and boundaries clearly shown. If available, attach a site plan of the proposed project.

See attached map; also, see figures in the BEC report

B. State total area of project: 526.3 acres. Includes pond watershed and park.
Estimate the number of acres (to the nearest 1/10 acre) directly affected that are currently:

1. Developed	346.9 acres	6. Tidelands	0 acres
2. Open Space/ Woodlands/Recreation	139.9 acres	7. Productive Resources	
		Agriculture	0 acres
3. Wetlands	11.5 acres	Forestry	0 acres
4. Floodplain	* acres	8. Other	28.0 acres
5. Coastal Area	0 acres		

* Much of the area is subject to flooding, but little or none of it is a designated flood plain.

C. Provide the following dimensions, if applicable:

	Existing	Increase	Total
Length in miles			
Number of Housing Units			
Number of Stories			
Gross Floor Area in square feet			
Number of parking spaces			
Total of Daily vehicle trips to and from site (Total Trip Ends)			
Estimated Average Daily Traffic on road(s) serving site			
1.			
2.			
3.			

N/A

D. TRAFFIC PLAN. If the proposed project will require any permit for access to local roads or state highways, attach a sketch showing the location and layout of the proposed driveway(s).

N/A

III. ASSESSMENT OF POTENTIAL ADVERSE ENVIRONMENTAL IMPACTS

Instructions: Explain direct and indirect adverse impacts, including those arising from general construction and operations. For every answer explain why significant adverse impact is considered likely or unlikely to result. Positive impact may also be listed and explained.

Also, state the *source* of information or other basis for the answers supplied. Such environmental information should be acquired at least in part by field inspection.

Unless stated otherwise, the source for all answers is: BEC, 1988. Diagnostic/ Feasibility Study for the Management of Buttonwood Pond.

A. Open Space and Recreation

1. Might the project affect the condition, use, or access to any open space and/or recreation area?

   Explanation and Source:

During construction certain areas will be temporarily less accessible. Afterword, all facilities will be improved (e.g. Buttonwood Pond, proposed containment area).

2. Is the project site within 500 feet of any public open space, recreation, or conservation land?

   Explanation and Source: The dredging and diversion elements of the project will take place within Buttonwood Park.

B. Historic and Archaeological Resources

1. Might any site or structure of historic significance be affected by the project? (Prior consultation with Massachusetts Historical Commission is advised.)

   Explanation and Source:

   None known (see MHC letter and Buttonwood Park Master Plan)

2. Might any archaeological site be affected by the project? (Prior consultation with Massachusetts Historical Commission is advised.)

   Explanation and Source:

   None known(see MHC letter and Buttonwood Park Master Plan)

C. Ecological Effects

1. Might the project significantly affect fisheries or wildlife, especially any rare or endangered species? (Prior consultation with the Massachusetts Natural Heritage Program is advised).

   Explanation and Source:

The project will affect fisheries and wildlife , as the pond will be drained for up to 1 year. Re-stocking and improved water quality will ultimately benefit fish and wildlife. No rare or endangered species known for this area. (see MNHP letter).

2. **Might the project significantly affect vegetation, especially any rare or endangered species of plant? (Prior consultation with the Massachusetts Natural Heritage Program is advised.)**

(Estimate approximate number of mature trees to be removed: ___10___)

Explanation and Source:

The project will alter the aquatic vegetation of Buttonwood Pond and the existing upstream detention basin (currently dry most of the time). Both areas will be positively affected in terms of most forms of aquatic life and recreational opportunities in Buttonwood Pond will be enhanced.

Up to 10 mature trees will be removed to allow construction of a containment area for dredged material. This area will be changed in accord with the Master Plan for the park.

3. **Agricultural Land. Has any portion of the site been in agricultural use within the last 15 years? If yes, specify use and acreage.**

Explanation and Source:

There are lands in the watershed which were agricultural about a decade ago, but none are active now and none are actually part of any construction site under the proposed project.

D. Water Quality and Quantity

1. **Might the project result in significant changes in drainage patterns?**

Explanation and Source:

The flow to Buttonwood Pond from five (5) storm drains will be routed to a point downstream of the pond, and the peak flow through the pond will be reduced. No water will be diverted away from the Buttonwood Brook system, however.

2. **Might the project result in the introduction of any pollutants, including sediments, into marine waters, surface fresh waters or ground water?**

Explanation and Source:

Construction activities during the project may cause very slight downstream siltation under extreme weather conditions, but a major reduction in pollution of Buttonwood Pond will result. A slight overall decrease in the pollutant load to Apponagansett Bay is also expected.

3. **Does the project involve any dredging? No ______ Yes ___X___ Volume ___42,800 cy___. If 10,000 cy or more, attach completed Standard Application Form for Water Quality Certification, Part I (314 CMR 9.02(3), 9.90, DEQE Division of Water Pollution Control).**

See attached form.

4. Will any part of the project be located in flowed or filled tidelands, Great Ponds, or other waterways? (Prior consultation with the DEQE and CZM is advised.)

Explanation and Source:

Buttonwood Pond is considered to be a Flowed Great Pond under the MDEQE listing, but is technically too small to qualify in its present state. The proposed project will restore Buttonwood Pond to Flowed Great Pond status. The project area does not come under CZM jurisdiction.

5. Will the project generate or convey sanitary sewage? No __X__ Yes ____
If Yes, Quantity: ________ gallons per day
Disposal by: (a) Onsite septic systems .... Yes ____ No ____
(b) Public sewerage systems (location; average and peak daily flows to treatment works) .... Yes ____ No ____

Explanation and Source:

6. Might the project result in an increase in paved or impervious surface over a sole source aquifer or an aquifer recognized as an important present or future source of water supply?

Explanation and Source:

No increase in impervious surfaces is anticipated.

7. Is the project in the watershed of any surface water body used as a drinking water supply?

Explanation and Source:

No.

8. Are there any public or private drinking water wells within a 1/2-mile radius of the proposed project?

Explanation and Source:

No.

9. Does the operation of the project result in any increased consumption of water?
   Approximate consumption ________ gallons per day. Likely water source(s) ________
   Explanation and Source:

   No

E. Solid Waste and Hazardous Materials
1. Estimate types and approximate amounts of waste materials generated, e.g., industrial, domestic, hospital, sewage sludge, construction debris from demolished structures. How where will such waste be disposed of?
   Explanation and Source:

   Excavated sediment will be dried in a containment area adjacent to the pond and will be spread in the park as part of a landscaping program.

2. Might the project involve the generation, use, transportation, storage, release, or disposal of potentially hazardous materials?
   Explanation and Source:

   No.

3. Has the site previously been used for the use, generation, transportation, storage, release, or disposal of potentially hazardous materials?
   Explanation and Source:

   Not as far as can be ascertained. Parts of Buttonwood Park have been used as fill and refuse disposal sites in the last century, but no historical or archaeological significance has been accorded these areas.

F. Energy Use and Air Quality
1. Will space heating be provided for the project? If so, describe the type, energy source, and approximate energy consumption.
   Explanation and Source:

   No.

2. Will the project require process heat or steam? If so, describe the proposed system, the fuel type, and approximate fuel usage.

   Explanation and Source:

No.

3. Does the project include industrial processes that will release air contaminants to the atmosphere? If so, describe the process (type, material released, and quantity released).

   Explanation and Source:

Only emissions from engines powering construction equipment are expected.

4. Are there any other sources of air contamination associated with the project (e.g. automobile traffic, aircraft traffic, volatile organic compound storage, construction dust)?

   Explanation and Source:

Only emissions from engines powering construction equipment are expected.

5. Are there any sensitive receptors (e.g. hospitals, schools, residential areas) which would be affected by air contamination caused by the project?

   Explanation and Source:

There are residential areas nearby, but air contamination resulting from this project will not be detectable above the existing background levels.

G. Noise

1. Might the project result in the generation of noise?

   (Include any source of noise during construction or operation, e.g., engine exhaust, pile driving, traffic.)

   Explanation and Source:

Construction activities will generate noise through the operation of vehicles and power equipment.

2. Are there any sensitive receptors (e.g., hospitals, schools, residential areas) which would be affected by any noise caused by the project?

Explanation and Source:

Residential areas nearby will experience a slight, possibly undetectable increase in noise.

3. Is the project a sensitive receptor, sited in an area of significant ambient noise?

Explanation and Source:

Yes. Traffic on roads around and through the project area is extensive.

H. Wind and Shadow

1. Might the project cause wind and shadow impacts on adjacent properties?

Explanation and Source:

No.

I. Aesthetics

1. Are there any proposed structures which might be considered incompatible with existing adjacent structures in the vicinity in terms of size, physical proportion and scale, or significant differences in land use?

Explanation and Source:

The containment area may present some temporary incompatibilty in land use within the park, but no long range incompatibility will occur.

2. Might the project impair visual access to waterfront or other scenic areas?

Explanation and Source:

During dredging, the aesthetic appeal and public access to Buttonwood Pond will be reduced, but long term aesthetics and access will increase.

IV. CONSISTENCY WITH PRESENT PLANNING

Discuss consistency with current federal, state and local land use, transportation, open space, recreation and environmental plans and policies. Consult with local or regional planning authorities where appropriate.

The proposed project is consistent with all local and regional ordinances and plans. It is intended to reduce flooding, improve water quality, and increase recreational utility in the Buttonwood Pond/Park area. The proposed project will meet all requirements of the DEQE Clean Lakes Program and Buttonwood Park Master Plan before implementation.

V. FINDINGS AND CERTIFICATION

A. The public notice of environmental review has been/will be published in the following newspaper(s):

-(NAME) ______________________ (Date) ______________________

______________________ ______________________

______________________ ______________________

B. This form has been circulated to all agencies and persons as required by 301 CMR 11.24.

______	______________________	______	Kenneth J. Wagner (signature)
Date	Signature of Responsible Officer or Project Proponent	Date	Signature of person preparing ENF (if different from above)
	______________________		Kenneth J. Wagner
	Name (print or type)		Name (print or type)
	Address ______________________		BEC Address 296 N. Main Street, East Longmeadow, MA 01028
	Telephone Number ______________		Telephone Number 413-525-3822

DIVISION OF WATER POLLUTION CONTROL
ONE WINTER STREET
BOSTON, MASSACHUSETTS 02108

APPLICATION for WATER QUALITY CERTIFICATION
for Stream Crossing and Fill in Wetlands

Location (town) New Bedford
Project Name Buttonwood Pond
Applicant Office of Neighborhoods

Address of applicant: Office of Neighborhoods, City Hall, Williams Street,
Name and address of authorized agent if any: New Bedford, MA Attn: D.Souza

1. DEQE file number: ____________ issued by ____________ regional DEQE office.

2. Submit a copy of the Order of Conditions.

3. a) Indicate the status of this project with respect to MEPA
   In review
   b) Give EOEA number and date of MEPA decision, if any

4. Briefly describe a) the overall scope of the project See ENF

   b) the scope of work in the wetlands Dredging of up to 4 acre

5. Submit a USGS quad sheet showing the location of the project.
   See ENF and BEC report

6. a) Provide a plan view of the whole project site showing all wetland areas
   See BEC report
   b) Provide a plan view clearly indicating, as appropriate to the proposed work:

   (1) all areas where alteration of wetlands will occur

   (2) areas where wetlands compensation will be provided / See BEC report

   (3) width and depth of waters within any construction site

   c) Please do not send any full sized plans which have not been requested per 6(a) and (b).

7. Name all downstream surface waters within a 2 mile radius of the project site.
   Only Buttonwood Brook, with several branches.

8. If fill is to be placed in wetland areas:

   a) What volume of fill will be placed? Up to 1000 cy — Possibly up to 1000 cy for bank stabilization.

   b) What material(s) will fill consist of? Sand/loam (probably dried dredged soil)

   c) What is the total area of wetland filled? Less than 1500 sq.yards

   d) Explain measures to be taken to control the discharge of pollutants (including oils, silt, and any other pollutants present) to waters and wetlands on site or adjacent to the project site. See BEC report.

   e) How much wetland compensation area will be provided? None planned
   (indicate type of wetland i.e. marsh, pond, etc.)

9. If construction will occur in the water, provide the following information:

a) Name of water body or waterway: Buttonwood Brook and Pond

b) During what month(s) is the work to occur? Summer through Fall

c) What is the duration of actual work in the waterway? Detention= 12 days
Diversion= 4 days
Dredging = 4 months

d) During construction what is the expected width, depth, and flow in waterway? Channel will not be altered, but pond will be drained.
Average: 6'x1' @ 0.6 to 30 cfs

e) What is the nature of the affected sediments? Primarily eroded topsoil with debris
Indicate the basis for your answer. Soil samples/analysis and visual obs.

f) If fill is to be placed in the waterway, what volume of fill will be placed? None in channel, up to 1000 cy along pond shore.

g) Is fill temporary or permanent? Permanent

h) What material will be used as fill? Probably dried material dredged from the pond.

i) Are temporary siltation basins or permanent detention basins planned? (If yes, enclose plan showing location and dimensions) Yes, see BEC report

j) How will turbidity in the waterway be controlled during the placing and removal of fill? (Please explain on a separate page).
Downstream (immediate) detention

k) List the construction steps plannded for any work in the waterway (please use a separate page).

Please return to: Department of Environmental Quality Engineering
Division of Water Pollution Control - Permits
One Winter Street
Boston, MA 02108

(date) (signature of applicant or authorized agent)

4-87

Response to 9K: Construction Sequence:

Detention Work:
1. Clear dry portion of existing basin, excavate approx. 4400 cy, haul to landfill as cover.

2. Channel flow out one of the two outlets from the basin, construct stop-log or cement weir at the other.

3. Repeat step #2 for the opposite outlets.

Diversion Work:
1. Draw down Buttonwood Pond and close pond drain, creating a detention basin.

2. Route 48 inch storm drain pipe across channel of Buttonwood Brook in a 5 ft by 5 ft by 20 ft excavated trench.

3. Cover pipe with stone/gravel, allow sand and silt in upstream channel to fill in any remaining openings.

4. Excavate and install storm drainage pipe with tie-ins in non-wetland areas.

Dredging Work:
1. Construct containment area adjacent to pond, using berms.

2. Draw down Buttonwood Pond and maintain drawdown.

3. Place haybales or sandbags and filter fabric around area to be dredged; work in approximately 1 acre parcels.

4. Excavate to desired grade, deposit dredged material in containment area using conventional equipment (backhoes, front end loaders, dump trucks).

5. Stabilize shoreline with enkamat, filter fabric, and appropriate cover. Seed or plant as designated.

6. Make necessary repairs to outlet structure.

7. Remove erosion control devices, refill pond.

Note: Extreme storm events may necessitate the use of Buttonwood Pond for detention. Work schedule will minimize impairment of dredging program; dredging during late summer and fall recommended.

APPENDIX E

COMMENTS BY INTERESTED PARTIES

MASSACHUSETTS ★ HISTORICAL ★ COMMISSION ★
A CommonWealth to Keep

April 25, 1988

Kenneth J. Wagner, Ph.D.
Baystate Environmental Consultants, Inc.
296 North Main Street
East Longmeadow, MA 01028

RE: Buttonwood Pond, New Bedford, Massachusetts

Dear Dr. Wagner:

Thank you for supplying the Massachusetts Historical Commission with information concerning the proposed Buttonwood Pond management plan.

After review of MHC files and the materials you submitted, it has been determined that this project is unlikely to affect significant historic or archaeological resources. No further review is required in compliance Massachusetts General Laws, Chapter 9, Sections 26C and 27C, as amended by Chapter 152 of the Acts of 1982 (950CMR 71).

If you have any questions, please feel free to contact Peter Mills at this office.

Sincerely,

Brona Simon

Brona Simon
State Archaeologist
Director, Technical Services Division
Massachusetts Historical Commission

Massachusetts Historical Commission, Valerie A. Talmage, *Executive Director, State Historic Preservation Officer*
80 Boylston Street, Boston, Massachusetts 02116 (617) 727-8470
Office of the Secretary of State, Michael J. Connolly, *Secretary*

Massachusetts
Natural Heritage
Program

10 May 1988

Mr. Kenneth J. Wagner
Baystate Environmental Consultants
296 North Main Street
East Longmeadow, MA 01028

Re: Buttonwood Pond
Fall River

Dear Mr. Kenneth J. Wagner:

Thank you for contacting the Natural Heritage and Endangered Species Program regarding rare plants, animals, and natural communities in the vicinity of Buttonwood Pond, as described in your 21 March 1988 letter.

At this time, we are not aware of any rare plants or animals or natural communities in the area of the proposed project.

The Natural Heritage database is continually being updated and expanded, therefore this review may require reconsideration if more information about the site becomes available.

Sincerely,

Jay Copeland
Environmental Reviewer

JC:jc

cc: town and chrono files

Division of Fisheries and Wildlife 100 Cambridge Street, Boston, Mass. 02202 (617) 727-9194,-3151

Commonwealth of Massachusetts

Division of Fisheries & Wildlife

Richard Cronin, *Director*

June 2, 1988

Dr. Ken Wagner
Baystate Environmental Consultants, Inc.
296 North Main Street
East Longmeadow, MA 01028

RE: Buttonwood Pond Diagnostic/Feasibility Report

Dear Dr. Wagner:

The Division of Fisheries and Wildlife has completed its review of the "Diagnostic/Feasibility Study for the Management of Buttonwood Pond, New Bedford, Massachusetts" as you requested in your 30 March transmittal to this office. As noted in the report, information concerning the fishery of this small pond is lacking.

With respect to the recommended management approach, as outlined on page 103, we offer the following comments:

- rerouting of the storm water drainage systems - data documenting the fish resources of Buttonwood Brook is also lacking. Based upon geographical and physical features of the drainage, a warmwater fish population (also influenced by the upstream pond) is presumed. This agency does not stock Buttonwood Brook with trout. Diversion of storm water to the brook should not have major impacts to the fish populations, assuming that such storm water does not contain major and excessive pollutants.

- alteration of the existing detention basin serving Drainage Area 10 - we have no particular concerns or comments relative to this action

- dredging of the bottom of the open water zone and possible dredging of the emergent wetland zone - a dredging of the pond's bottom in the open water zone done with the pond in a dry or drained condition will, of course, necessitate the elimination of the fish population. It is very doubtful that this agency would conduct a salvage operation of the fish population prior to or during the water draining. The logistics of such a procedure make it unfeasible.

Field Headquarters
Westborough, Massachusetts 01581 (617) 366-4470
An Agency of the Department of Fisheries, Wildlife & Environmental Law Enforcement

As the water is lowered the majority of fishes will simply wash downstream. Unfortunately, inspection of the U.S.G.S. topographical maps for the area south of the pond indicates that Buttonwood Brook simply flows south with no impounded areas along its course prior to emptying into Apponagannestt Bay. Such impounded areas, could provide alternate lentic (pond) habitat, similar to that which the displaced fishes of Buttonwood Pond could utilize.

At this time, the Division cannot make a commitment to restock Buttonwood Pond so that a viable fish population can become established. We do not culture the common warm water fish species such as bluegills, pumpkinseeds, largemouth bass, chain pickerel, yellow perch, brown bullhead, golden shiner, or white sucker which are very likely, the species found in Buttonwood Pond. The prospects of procuring stocks of such species from other local ponds can be explored. There is also the likelihood that some fish will enter the pond via inlets, however, the lack of impoundments upstream of the pond (as acknowledged in the study) will limit natural reintroduction. In any event, a period of some three to five years will probably be necessary for the fish population to recover to something similar to pre-project level.

We view the reduction and possible elimination of the emergent wetland area with concern. The Division encourages a course of action which will maximize the retention of diverse habitats for fish and wildlife. A small urban pond, capable of sustaining a multitude of fish and wildlife species, seems more valuable than a larger pond with simply more open water area. Is the emergent wetland area (or islands) utilized by waterfowl for nesting areas? What about other common wildlife forms such as muskrat, turtles, frogs and snakes?

- <u>grading and stabilization of the shoreline</u> - if #1 is implemented, evaluated and deemed successful, particularly in promoting a more stable water level, is this action really necessary? As a component of the fish and wildlife habitat of the pond, how does the existing natural shoreline compare to what will result from a grading and revegetating program? Will it be as diverse, less diverse, no change? How will it affect access for shore fishing?

  Since the granite blocks along Court Street have been in place for many years, we have no objection to their repair/replacement.

o <u>watershed education program</u> - MDFW supports this action

Thank you for submitting this report to the Division of Fisheries and Wildlife for review. If you have any questions concerning any of these comments please contact me at the above address or by phone at (617) 366-4479.

Sincerely,

Robert P. Madore

Robert P. Madore
Aquatic Biologist II

cc. MDWPC - Clean Lakes
EOEA - Mepa Unit
MDFW - Southeast District

APPENDIX F

GLOSSARY

GENERAL AQUATIC GLOSSARY

Abiotic - Pertaining to any non-biological factor or influence, such as geological or meteorological characteristics.

Acid precipitation - Atmospheric deposition (rain, snow, dryfall) of free or combined acidic ions, especially the nitrates, sulfates and oxides of nitrogen and sulfur fumes from industrial smoke stacks.

Adsorption - External attachment to particles, the process by which a molecule becomes attached to the surface of a particle.

Algae - Aquatic single-celled, colonial, or multi-celled plants, containing chlorophyll and lacking roots, stems, and leaves.

Alkalinity - A reference to the carbonate and bicarbonate concentration in water. Its relative concentration is indicative of the nature of the rocks within a drainage basin. Lakes in sedimentary carbonate rocks are high in dissolved carbonates (hard-water lakes) whereas lakes in granite or igneous rocks are low in dissolved carbonate (soft-water lakes).

Ammonia Nitrogen - A form of nitrogen present in sewage and is also generated from the decomposition of organic nitrogen. It can also be formed when nitrites and nitrates are reduced. Ammonia is particularly important since it has high oxygen and chemical demands, is toxic to fish in un-ionized form and is an important aquatic plant nutrient because it is readily available.

Anadromous - An adjective used to describe types of fish which spawn in freshwater rivers but spend most of their adult lives in the ocean. Before spawning, anadromous adult fish ascend the rivers from the sea.

Anoxic - Without oxygen.

Aphotic Zone - Dark zone, below the depth to which light penetrates. Generally equated with the zone in which most photosynthetic algae cannot survive, due to light deficiency.

Aquifer - Any geological formation that contains water, especially one that supplies wells and springs; can be a sand and gravel aquifer or a bedrock aquifer.

Artesian - The occurrence of groundwater under sufficient pressure to rise above the upper surface of the aquifer.

Assimilative Capacity - Ability to incorporate inputs into the system. With lakes, the ability to absorb nutrients or other potential pollutants without showing extremely adverse effects.

Attenuation - The process whereby the magnitude of an event is reduced, as the reduction and spreading out of the impact of storm effects or the removal of certain contaminants as water moves through soil.

Background Value - Value for a parameter that represents the conditions in a system prior to a given influence in space or time.

Bathymetry - The measurement of depths of water in oceans, seas, or lakes or the information derived from such measurements.

Benthic Deposits - Bottom accumulations which may contain bottom-dwelling organisms and/or contaminants in a lake, harbor, or stream bed.

Benthos - Bottom-dwelling organisms living on, within or attached to the sediment. The phytobenthos includes the aquatic macrophytes and bottom-dwelling algae. The zoobenthos (benthic fauna) includes a variety of invertebrate animals, particularly larval forms and molluscs.

Benthic - Living or occupying space at the bottom of a water body, on or in the sediment.

Best Management Practices - (BMP's) State-of-the-art techniques and procedures used in an operation such as farming or waste disposal in order to minimize pollution or waste.

Bio-available - Able to be taken up by living organisms, usually refers to plant uptake of nutrients.

Biocide - Any agent, usually a chemical, which kills living organisms.

Biological Oxygen Demand - The BOD is an indirect measure of the organic content of water. Water high in organic content will consume more oxygen due to the decomposition activity of bacteria in the water than water low in organic content. It is routinely measured for wastewater effluents. Oxygen consumption is proportional to the organic matter in the sample.

Biota - Plant (flora) and animal (fauna) life.

Biotic - Pertaining to biological factors or influences, concerning biological activity.

Bloom - Excessively large standing crop of algae, usually visible to the naked eye.

Bulk Sediment Analysis - Analysis of soil material or surface deposits to determine the size and relative amounts of particles composing the material.

CFS - Cubic feet per second, a measure of flow.

Chlorophyll - Major light gathering pigment of all photosynthetic organisms imparting the characteristic color of green plants. Its relative measurement in natural waters is indicative of the concentration of algae in the water.

Chlorophyte - Green algae, algae of the division Chlorophyta.

Chrysophyte - Golden or golden-brown algae, algae of the division Chrysophyta.

Color - Color is determined by visual comparison of a sample with known concentrations of colored solutions and is expressed in standard units of color. Certain waste discharges may turn water to colors which cannot be defined by this method; in such cases, the color is expressed qualitatively rather than numerically. Color in lake waters is related to solids, including algal cell concentration and dissolved substances.

Combined Sewer - A sewer intended to serve as both a santiary sewer and a storm sewer. It receives both sewage and surface runoff.

Composite Sample - A number of individual samples collected over time or space and composited into one representative sample.

Concentration - The quantity of a given constituent in a unit of volume or weight of water.

Conductivity - The measure of the total ionic concentration of water. Water with high total dissolved solids (TDS) level would have a high conductance. A conductivity meter tests the flow of electrons through the water which is heightened in the presence of electrolytes (TDS).

Confluence - Meeting point of two rivers or streams.

Conservative Substance - Non-interacting substance, undergoing no kinetic reaction; chlorides and sodium are approximate examples.

Cosmetic - Acting upon symptoms or given conditions without correcting the actual cause of the symptoms or conditions.

Cryptophyte - Small, flagellated algae of variable pigment composition, algae of the division Cryptophyta, which is often placed under other taxonomic divisions.

Cyanophyte - Bluegreen algae, algae of the division Cyanophyta, actually a set of pigmented bacteria.

Decomposition - The metabolic breakdown of organic matter, releasing energy and simple organic and inorganic compounds which may be utilized by the decomposers themselves (the bacteria and fungi).

Deoxygenation - Depletion of oxygen in an area, used often to describe possible hypolimnetic conditions, process leading to anoxia.

Diatom - Specific type of chrysophyte, having a siliceous frustule (shell) and often elaborate ornamentation, commonly found in great variety in fresh or saltwaters. Often placed in its own division, the Bacillariophyta.

Dinoflagellate - Unicellular algae, usually motile, having pigments similar to diatoms and certain unique features. More commonly found in saltwater. Algae of the division Pyrrhophyta.

Discharge Measurement - The volume of water which passes a given location in a given time period, usually measured in cubic feet per second (cfs) or cubic meters per minute (m^3/min).

Dissolved Oxygen (D.O.) - Refers to the uncombined oxygen in water which is available to aquatic life. Temperature affects the amount of oxygen which water can contain. Biological activity also controls the oxygen level. D.O. levels are generally highest during the afternoon and lowest just before sunrise.

Diurnal - Varying over the day, from day time to night.

Domestic Wastewater - Water and dissolved or particulate substances after use in any of a variety of household tasks, including sanitary systems and washing operations.

Drainage Basin - A geographical area or region which is so sloped and contoured that surface runoff from streams and other natural watercourses is carried away by a single drainage system by gravity to a common outlet. Also referred to as a watershed or drainage area. The definition can also be applied to subsurface flow in groundwater.

Dystrophic - Trophic state of a lake in which large quantities of nutrients may be present, but are generally unavailable (due to organic binding or other causes) for primary production. Often associated with acid bogs.

Ecosystem - A dynamic association or interaction between communities of living organisms and their physical evironment. Boundaries are arbitrary and must be stated or implied.

Elutriate - Elutriate refers to the washings of a sample of material.

Epilimnion - Upper layer of a stratified lake. Layer that is mixed by wind and has a higher average temperature than the hypolimnion. Roughly approximates the euphotic zone.

Erosion - The removal of soil from the land surface, typically by runoff water.

Eskar - A winding, narrow ridge of sand or gravel deposited by a stream flowing under glacial ice.

Euglenoid - Algae similar to green algae in pigment composition, but with certain unique features related to food storage and cell wall structure. Algae of the division Euglenophyta.

Eutrophic - High nutrient, high productivity trophic state generally associated with unbalanced ecological conditions and poor water quality.

Eutrophication - Process by which a body of water ages, most often passing from a low nutrient concentration, low productivity state to a high nutrient concentration, high productivity stage. Eutrophication is a long-term natural process, but it can be greatly accelerated by man's activities. Eutrophication as a result of man's activities is termed cultural eutrophication.

Evapotranspiration - Process by which water is lost to the atmosphere from plants.

Fauna - A general term referring to all animals.

Fecal Coliform Bacteria - Bacteria of the coli group that are present in the intestines or feces of warm-blooded animals. They are often used as indicators of the sanitary quality of the water. In the laboratory they are defined as all organisms which produce blue colonies within 24 hours when incubated at $44.5^{\circ}C \pm 0.2^{\circ}C$ on M-FC medium (nutrient medium for bacterial growth). Their concentrations are expressed as number of colonies per 100 ml of sample.

Fecal Streptococci Bacteria - Bacteria of the Streptococci group found in intestines of warm-blooded animals. Their presence in water is considered to verify fecal pollution. They are characterized as gram positive, cocciod bacteria which are capable of growth in brain-heart infusion broth. In the laboratory they are defined as all the organisms which produce red or pink colonies within 48 hours at $35^{o}C \pm 1.0^{o}C$ on KF medium (nutrient medium for bacterial growth). Their concentrations are expressed as number of colonies per 100 ml of sample.

Flora - A general term referring to all plants.

Food Chain - A linear characterization of energy and chemical flow through organisms such that the biota can be separated into functional units with nutritional interdependence. Can be expanded to a more detailed characterization with multiple linkage, called a food web.

French (or Pit) Drain - Water outlet which allows fairly rapid removal of water from surface, but then allows subsurface percolation. Generally consists of sand and gravel layers under grating or similar structure, at lowest point of a sloped area. Water runs quickly through the coarse layers, then percolates through soil, often without the use of pipes. The intent is the purification of most percolating waters.

Grain Size Analysis - A soil or sediment sorting procedure which divides the particles into groups depending on size so that their relative amounts may be determined. Data from grain size analyses are useful in determining the origin of sediments and their behavior in suspension.

Groundwater - Water in the soil or underlying strata, subsurface water.

Hardness - A physical-chemical characteristic of water that is commonly recognized by the increased quantity of soap required to produce lather. It is attributable to the presence of alkaline earths (principally calcium and magnesium) and is expressed as equivalent calcium carbonate ($CaCO_3$).

Humus - Humic substances form much of the organic matter of sediments and water. They consist of amorphous brown or black colored organic complexes.

Hydraulic Detention Time - Lake water retention time, amount of time that a random water molecule spends in a water body; time that it takes for water to pass from an inlet to an outlet of a water body.

Hydraulic Dredging - Process of sediment removal using a floating dredge to draw mud or saturated sand through a pipe to be deposited elsewhere.

Hydrologic Cycle - The circuit of water movement from the atmosphere to the earth and return to the atmosphere through various stages or processes such as precipitation, interception, runoff, infiltration, percolation, storage, evaporation, and transpiration.

Hypolimnion - Lower layer of a stratified lake. Layer that is mainly without light, generally equated with the aphotic zone, and has a lower average temperature than the epilimnion.

Impervious - Not permitting penetration or percolation of water.

Intermittant - Non-continuous, generally referring to the occasional flow through a set drainage path. Flow of a discontinuous nature.

Kame - A short, steep ridge or hill of stratified sand or gravel deposited in contact with glacial ice.

Kjeldahl Nitrogen - The total amount of organic nitrogen and ammonia in a sample, as determined by the Kjeldahl method, which involves digesting the sample with sulfuric acid, transforming the nitrogen into ammonia, and measuring it.

Leachate - Water and dissolved or particulate substances moving out of a specified area, usually a landfill, by a completely or partially subsurface route.

Leaching - Process whereby nutrients and other substances are removed from matter (usually soil or vegetation) by water. Most often this is a chemical replacement action, prompted by the quality of the water.

Lentic - Standing, having low net directional motion. Refers to lakes and impoundments.

Limiting Nutrient - That nutrient of which there is the least quantity, in relation to its importance to plants. The limiting nutrient will be the first essential compound to disappear from a productive system, and will cause cessation of productivity at that time. The chemical form in which the nutrient occurs and the nutritional requirements of the plants involved are important here.

Limnology - The comprehensive study of lakes, encompassing physical, chemical and biological lake conditions.

Littoral Zone - Shallow zone occurring at the edge of aquatic ecosystems, extending from the shoreline outward to a point where rooted aquatic plants are no longer found.

Loading - Inputs into a receiving water that may exert a detrimental effect on some subsequent use of that water.

Lotic - Flowing, moving. Refers to streams or rivers.

Macrofauna - A general term which refers to animals which can be seen with the naked eye.

Macrophyte - Higher plant, macroscopic plant, plant of higher taxonomic position than algae, usually a vascular plant. Aquatic macrophytes are those macrophytes that live completely or partially in water. May also include algal mats under some definitions.

Mesotrophic - An intermediate trophic state, with variable but moderate nutrient concentrations and productivity.

Metalimnion - The middle layer of a stratified lake, constituting the transition layer between the epilimnion and hypolimnion and containing the thermocline.

Mixis - The state of being mixed, or the process of mixing in a lake.

MGD - Million gallons per day, a measure of flow.

Micrograms per Liter (ug/l) - A unit expressing the concentration of chemical constituents in solution as mass (micrograms) of solute per unit volume (liter) of water. One thousand micrograms per liter is equivalent to one milligram per liter.

Nitrate - A form of nitrogen that is important since it is the end product in the aerobic decomposition of nitrogenous matter. Nitrogen in this form is stable and readily available to plants.

Nitrite - A form of nitrogen that is the oxidation product of ammonia. It has a fairly low oxygen demand and is rapidly converted to nitrate. The presence of nitrite nitrogen usually indicates that active decomposition is taking place (i.e., fresh contamination).

Nitrogen - A macronutrient which occurs in the forms of organic nitrogen, ammonia nitrogen, nitrite nitrogen and nitrate nitrogen. Form of nitrogen is related to a successive decomposition reaction, each dependent on the preceding one, and the progress of decomposition can be determined in terms of the relative amounts of these four forms of nitrogen.

Nitrogen fixation - The process by which certain bacteria and bluegreen algae make organic nitrogen compounds (initially NH_4^+) from elemental nitrogen (N_2) taken from the atmosphere or dissolved in the water.

Non-point Source - A diffuse source of loading, possibly localized but not distinctly definable in terms of location. Includes runoff from all land types.

Nutrients - Are compounds which act as fertilizers for aquatic organisms. Small amounts are necessary to the ecological balance of a waterbody, but excessive amounts can upset the balance by causing excessive growths of algae and other aquatic plants. Sewage discharged to a waterbody usually contains large amounts of carbon, nitrogen, and phosphorus. The concentration of carbonaceous matter is reflected in the B.O.D. test. Additional tests are run to determine the concentrations of nitrogen and phosphorus. Storm water runoff often contributes substantial nutrient loadings to receiving waters.

Oligotrophic - Low nutrient concentration, low productivity trophic state, often associated with very good water quality, but not necessarily the most desirable stage, since often only minimal aquatic life can be supported.

Organic - Containing a substantial percentage of carbon derived from living organisms; of a living organism.

Outwash - Sand and gravel deposited by meltwater streams in front of glacial ice.

Overturn - The vertical mixing of major layers of water caused by seasonal changes in temperature. In temperate climate zones overturn typically occurs in spring and fall.

Oxygen Deficit - A situation in lakes where respiratory demands for oxygen become greater than its production via photosynthesis or its input from the drainage basin, leading to a decline in oxygen content.

Periphyton - Attached forms of plants and animals, growing on a substrate.

pH - A hydrogen concentration scale from 0 (acidic) to 14 (basic) used to characterize water solutions. Pure water is neutral at pH 7.0.

Phosphorus - A macronutrient which appears in waterbodies in combined forms known as ortho- and poly-phosphates and organic phosphorus. Phosphorus may enter a waterbody in agricultural runoff where fertilizers are used. Storm water runoff from highly urbanized areas, septic system leachate, and lake bottom sediments also contribute phosphorus. A critical plant nutrient which is often targeted for control in eutrophication prevention plans.

Photic Zone - Illuminated zone, surface to depth beyond which light no longer penetrates. Generally equated with the zone in which photosynthetic algae can survive and grow, due to adequate light supply.

Photosynthesis - Process by which primary producers make organic molecules (generally glucose) from inorganic ingredients, using light as an energy source. Oxygen is evolved by the process as a byproduct.

Phytoplankton - Algae which are suspended, floating or moving only slightly under their own power in the water column. Often this is the dominant algal form in standing waters.

Plankton - The community of suspended, floating, or weakly swimming organisms that live in the open water of lakes and rivers.

Point Source - A specific source of loading, accurately definable in terms of location. Includes effluents or channeled discharges that enter natural waters at a specific point.

Pollution - Undesirable alteration of the physical, chemical or biological properties of water, addition of any substance into water by human activity that adversely affects its quality. Prevalent examples are thermal, heavy metal and nutrient pollution.

Potable - Usable for drinking purposes, fit for human consumption.

Primary Productivity (Production) - Conversion of inorganic matter to organic matter by photosynthesizing organisms. The creation of biomass by plants.

Riffle Zone - Stretch of a stream or river along which morphological and flow conditions are such that rough motion of the water surface results. Usually a shallow rocky area with rapid flow and little sediment accumulation.

Riparian - Of, or related to, or bordering a watercourse.

Runoff - Water and its various dissolved substances or particulates that flows at or near the surface of land in an unchanneled path toward channeled and usually recognized waterways (such as a stream or river).

Saturation Zone - Volume of soil in which all pore spaces are filled with water; the volume below the water table.

Secchi Disk Transparency - An approximate evaluation of the transparency of water to light. It is the point at which a black and white disk lowered into the water is no longer visible.

Secondary Productivity - The growth and reproduction (creation of biomass) by herbivorous (plant-eating) organisms. The second level of the trophic system.

Sedimentation - The process of settling and deposition of suspended matter carried by water, sewage, or other liquids, by gravity. It is usually accomplished by reducing the velocity of the liquid below the point at which it can transport the suspended material.

Sewage (Wastewater) - The waterborne, human and animal wastes from residences, industrial/commercial establishments or other places, together with such ground or surface water as may be present.

Specific Conductance - Yields a measure of a water sample's capacity to convey an electric current. It is dependent on temperature and the concentration of ionized substances in the water. Distilled water exhibits specific conductance of 0.5 to 2.0 micromhos per centimeter, while natural waters show values from 50 to 500 micromhos per centimeter. In typical New England lakes, Specific Conductance usually ranges from 100-300 micromhos per cm. The specific conductance yields a generalized measure of the inorganic dissolved load of the water.

Stagnant - Motionless, having minimal circulation or flow.

Standing Crop - Current quantity of organisms, biomass on hand. The amount of live organic matter in a given area at any point in time.

Storm Sewer - A pipe or ditch which carries storm water and surface water, street wash and other wash waters or drainage, but excludes sewage and industrial wastes.

Stratification - Process whereby a lake becomes separated into two relatively distinct layers as the result of temperature and density differences. Further differentation of the layers usually occurs as the result of chemical and biological processes. In most lakes, seasonal changes in temperature will reverse this process after some time, resulting in the mixing of the two layers.

Stratified Drift - Sand, gravel or other materials deposited by a glacier or its meltwater in a layered manner, according to particle size.

Substrate - The base of material on which an organism lives, such as cobble, gravel, sand, muck, etc.

Succession - The natural process by which land and vegetation patterns change, proceeding in a direction determined by the forces acting on the system.

Surface Water - Refers to lakes, bays, sounds, ponds, reservoirs, springs, rivers, streams, creeks, estuaries, marshes, inlets, canals, oceans and all other natural or artificial, inland or coastal, fresh or salt, public or private waters at ground level.

Suspended Solids - Those which can be removed by passing the water through a filter. The remaining solids are called dissolved solids. Suspended solids loadings are generally high in stream systems which are actively eroding a watershed. Excessive storm water runoff often results in high suspended solids loads to lakes. Many other pollutants such as phosphorus are often associated with suspended solids loadings.

Taxon (Taxa) - Any hierarchical division of a recognized classification system, such as a genus or species.

Taxonomy - The division of biology concerned with the classification and naming of organisms. The classification of organisms is based upon a hierarchical scheme beginning with Kingdom and progressing to the Species level or even lower.

Thermocline - Boundary level between the epilimnion and hypolimnion of a stratified lake, variable in thickness, and generally approximating the maximum depth of light penetration and mixing by wind.

Till - Unstratified, unsorted sand, gravel, or other material deposited by a glacier or its meltwater.

Trophic Level - The position in the food chain determined by the number of energy transfer steps to that level; 1 = producer; 2 = herbivore; 3, 4, 5 = carnivore.

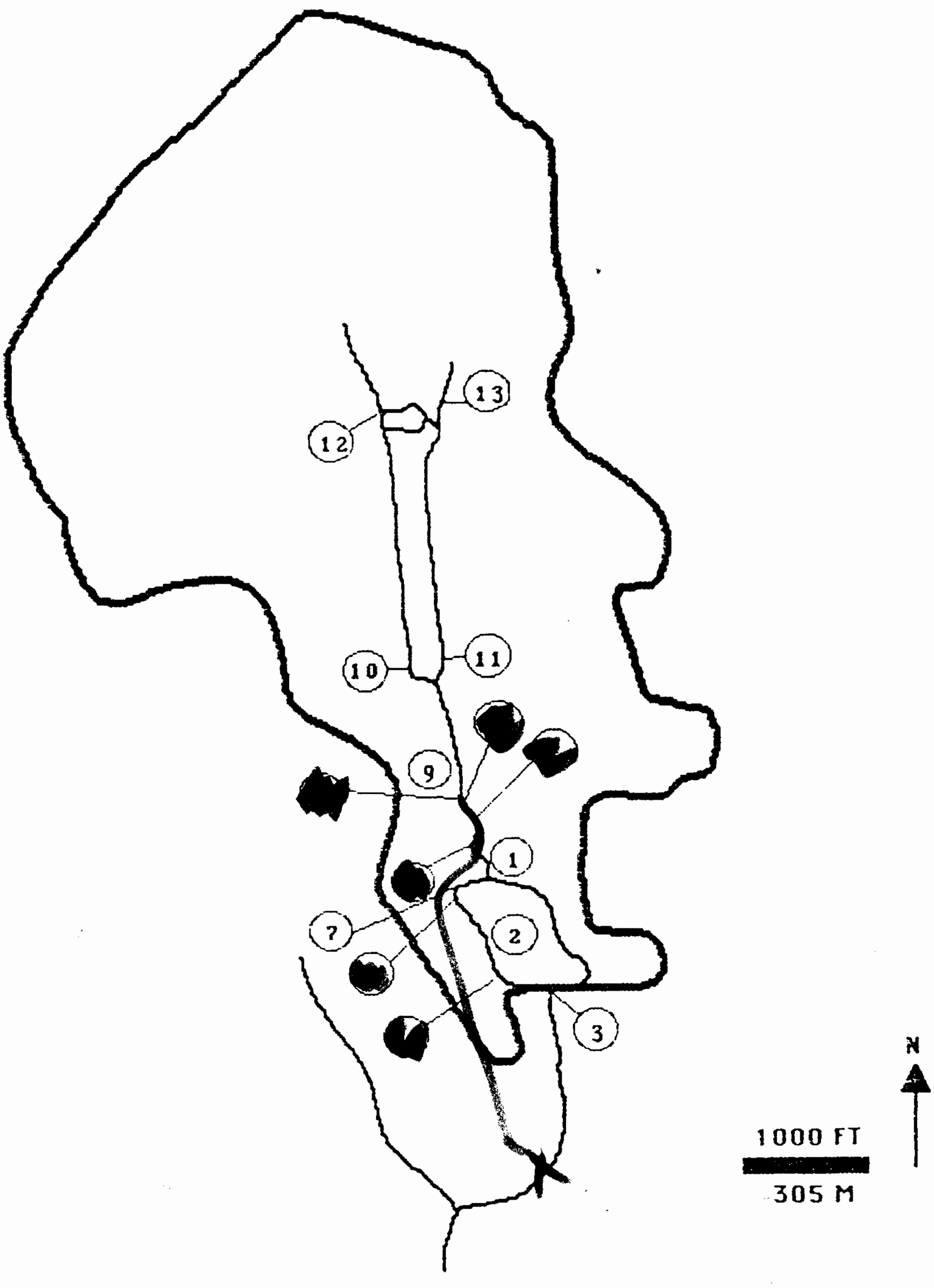
Trophic State - The stage or condition of an aquatic system, characterized by biological, chemical and physical parameters.

Turbidity - The measure of the clarity of a water sample. It is expressed in Nephelometric Turbidity Units which are related to the scattering and absorption of light by the water sample.

Volatile Solids - That portion of a sample which can be burned off, consisting of organic matter, including oils and grease.

FIGURE 1

SAMPLING STATION LAYOUT IN THE BUTTONWOOD POND WATERSHED



Water Quality - A term used to describe the chemical, physical, and biological characteristics of water, usually with respect to its suitability for a particular purpose or use.

Watershed - Drainage basin, the area from which an aquatic system receives water.

Zone of Contribution - Area or volume of soil from which water is drawn into a well.

Zooplankton - Microscopic animals suspended in the water; protozoa, rotifers, cladocera, copepods and other small invertebrates.