A PRELIMINARY EVALUATION

OF SASSAQUIN POND

AND ITS WATERSHED

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A PRELIMINARY EVALUATION OF SASSAQUIN POND AND ITS WATERSHED

PREPARED FOR THE
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INTRODUCTION AND BACKGROUND

Sassaquin Pond is a 14.8 ha (36.6 ac) kettlehole pond located in northern New Bedford, Massachusetts (Figure 1). The Massachusetts Division of Fisheries and Wildlife surveyed the pond in 1962 and recommended fishery reclamation. Sassaquin Pond was subsequently treated with the fish toxicant rotenone and restocked with largemouth bass. In the late 1960's or early 1970's herbicide was applied to reduce growths of white and yellow water lilies. In 1974 and 1975 the area around Sassaquin Pond was hooked up to the City's sanitary sewer system. A ban on gasoline powered engines was also instituted in the 1970's. Residents have noticed a distinct improvement in summer pond appearance over the last decade, and logically attribute the improvement to sewering and banning power boats. There have been no other recorded management efforts directed at the pond, prior to this study, but an active and concerned pond association is seeking to protect the pond from potential future degradation.

The pond is used by area residents for swimming, fishing, and boating, although no gasoline powered engines are permitted. Electric engines are permitted, and sailing, rowing, and canoeing are popular. Residential density on the streets surrounding the pond is moderate to high, with relatively few building lots left available. The immediate shoreline slopes range from gradual to steep. Beyond the residential area which surrounds the pond there are swamp wetlands to the south, northwest, and far east. The Route 140 corridor passes to the west of the pond, and there is a vacant tract to the north. This vacant tract is largely owned by Parkwood Hospital. Large quantities of sand and gravel were removed from this area and used as fill when Route 140 was built. Much of this area is experiencing vegetative regrowth, but numerous open plots exist within it.

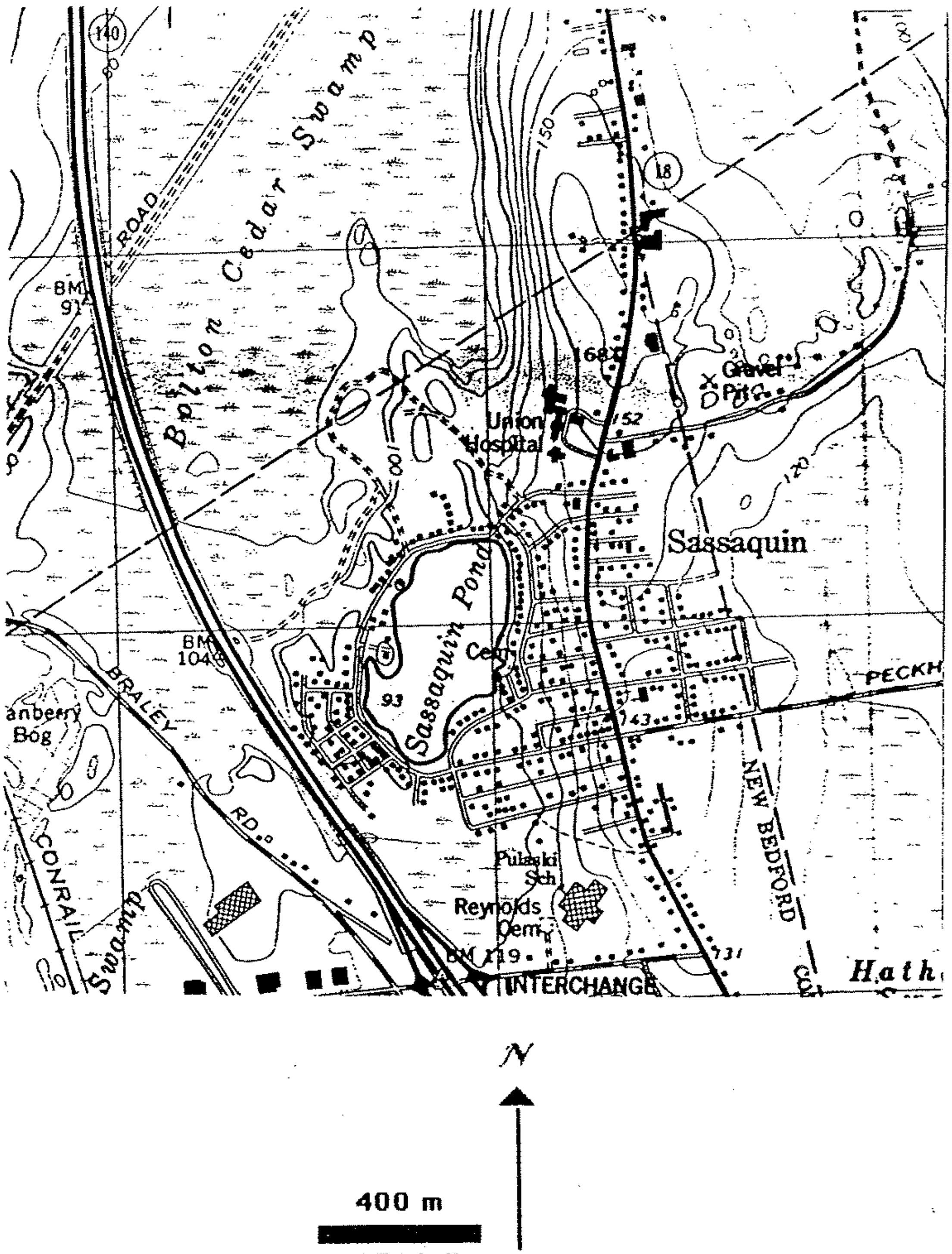
Soils in the area of Sassaquin Pond are primarily stony fine sandy loams of the Hinckley, Paxton, and Ridgebury series, with wetlands underlain by Freetown or Swansea mucks. Permeabilities range from 0.2 to 6.0 in/hr, and slopes range from 0 to 15%. Disturbed areas (e.g., urban complexes, udorthents) are common on the Soil Conservation Service map consulted (SCS 1981).

Prior to this study, virtually nothing was known about the extent of the hydrologic zone of contribution to Sassaquin Pond. Development pressure near the pond has been increasing, and there is justifiable concern over the future condition of this valuable water resource. Consequently, Baystate Environmental Consultants, Inc. (BEC) was retained by the City Planning Department to investigate the extent of the Sassaquin Pond watershed and evaluate existing and potential impacts on the pond.

FIGURE 1

SASSAQUIN POND STUDY AREA

(BASED ON USGS TOPOGRAPHIC MAP)



INVESTIGATIVE APPROACH

A general survey of pond and watershed features was conducted in September of 1987. A seepage survey was also conducted in that month. In October, 1987, six holes were drilled on the Parkwood Hospital property for the purpose of assessing the depth to ground water and associated soil features. Additional trips to review City maps and check salient features of the watershed were also made. Two storm drains were sampled during a storm event which coincided with a scheduled meeting between BEC and the New Bedford Conservation Commission. Although the sampling was not specifically part of the contract agreement, it was felt by BEC that storm water quality was a potentially important influence on Sassaquin Pond and warranted further investigation.

Once all data were collected, the hydrologic zone of contribution to Sassaquin Pond was estimated and a hydrologic budget was prepared. Considering the results of the limnological and watershed surveys, potential impacts of any future development in the vicinity of Sassaquin Pond could then be assessed. Management options were then reviewed and recommendations made.

FIELD SURVEY RESULTS

The bathymetry of Sassaquin Pond (Figure 2) is typical of kettlehole lakes, that is, those formed by stranded blocks of glacial ice. Sandy shelves drop off steeply in places to deeper bowls with deposits of organic muck which has accumulated over thousands of years. Sassaquin Pond reaches a maximum depth of 7.2 m (about 24 ft) in the north central portion of the pond. The mean depth is about 4.3 m (14 ft). The volume of the pond varies with water level, which has a vertical range of about 1.2 m (4 ft); on average, Sassaquin Pond holds 636,400 cu.m (168 million gallons) of water.

The bottom of Sassaquin Pond grades from cobble or gravel and sand near the edge to silty sand at intermediate depths and gyttja (muck) in the deeper portions of the pond. There are some muck patches near shore, particularly in cove areas, but most of the shoreline is either sandy shelf or moderately steep cobble slope. The sand and cobble areas are not very hospitable for plant growths, with lightly rooted, close cropped growths dominating the macrophyte community. Trails of bare sand were observed where there has been frequent boat traffic; these are particularly evident on the City Planning Department's aerial photos of Sassaquin Pond.

The pond has no permanent, natural inlets or outlets, but at least 15 pipes discharge into the pond and one overflow pipe outlets water to the south (Figure 3, Table 1). Five of these pipes are small subsoil drains intended to minimize ponding on private property during major storm events. As long as the associated lawns are not overfertilized, these drains represent no threat to Sassaquin Pond. Drain #10 has an unknown origin, but appears to emerge from the basement of a house on Tobey St. This pipe may serve something as innocuous as a sump pump or detrimental as a washing machine. Five more storm drains serve single catch basins or pairs of catch basins on Sassaquin Avenue. While the quality of water discharged by these drains is of concern, they are unlikely to be primary water sources.

The four remaining storm drains serve the residential area east of the pond. Drain #6 has been bypassed, its former drainage passing to Drain #7, but Drain #6 is still nominally active; it appears to function as an overflow pipe during times of elevated storm flow. Aside from residential side streets, parts of heavily developed Acushnet Avenue are served by Drains #1 and #7, the two largest contributors of storm water to the pond. Drain #5 serves Leroy Avenue, making it an intermediate level contributor.

FIGURE 2

SASSAQUIN POND BATHYMETRY

(Contour intervals given in meters)

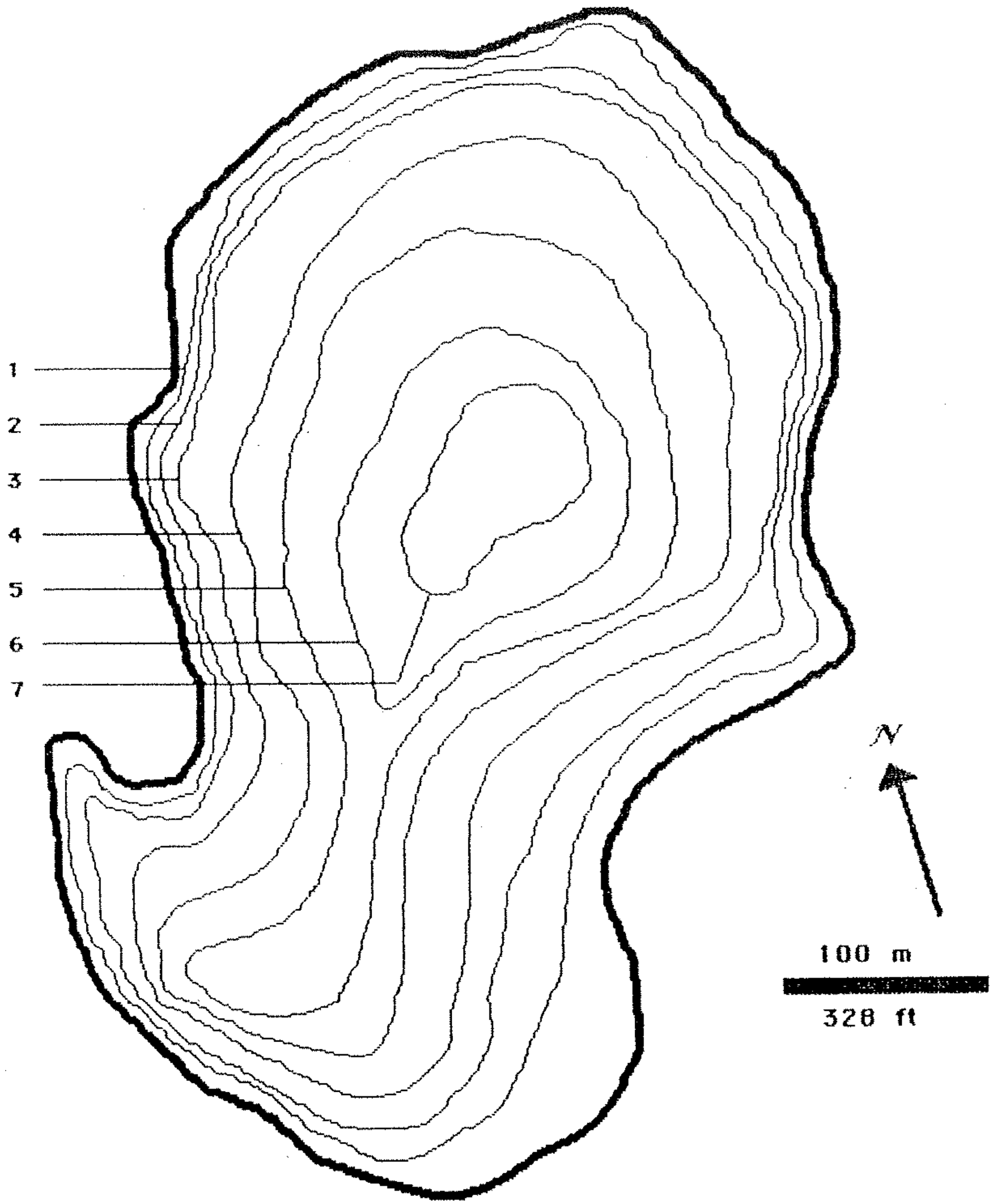
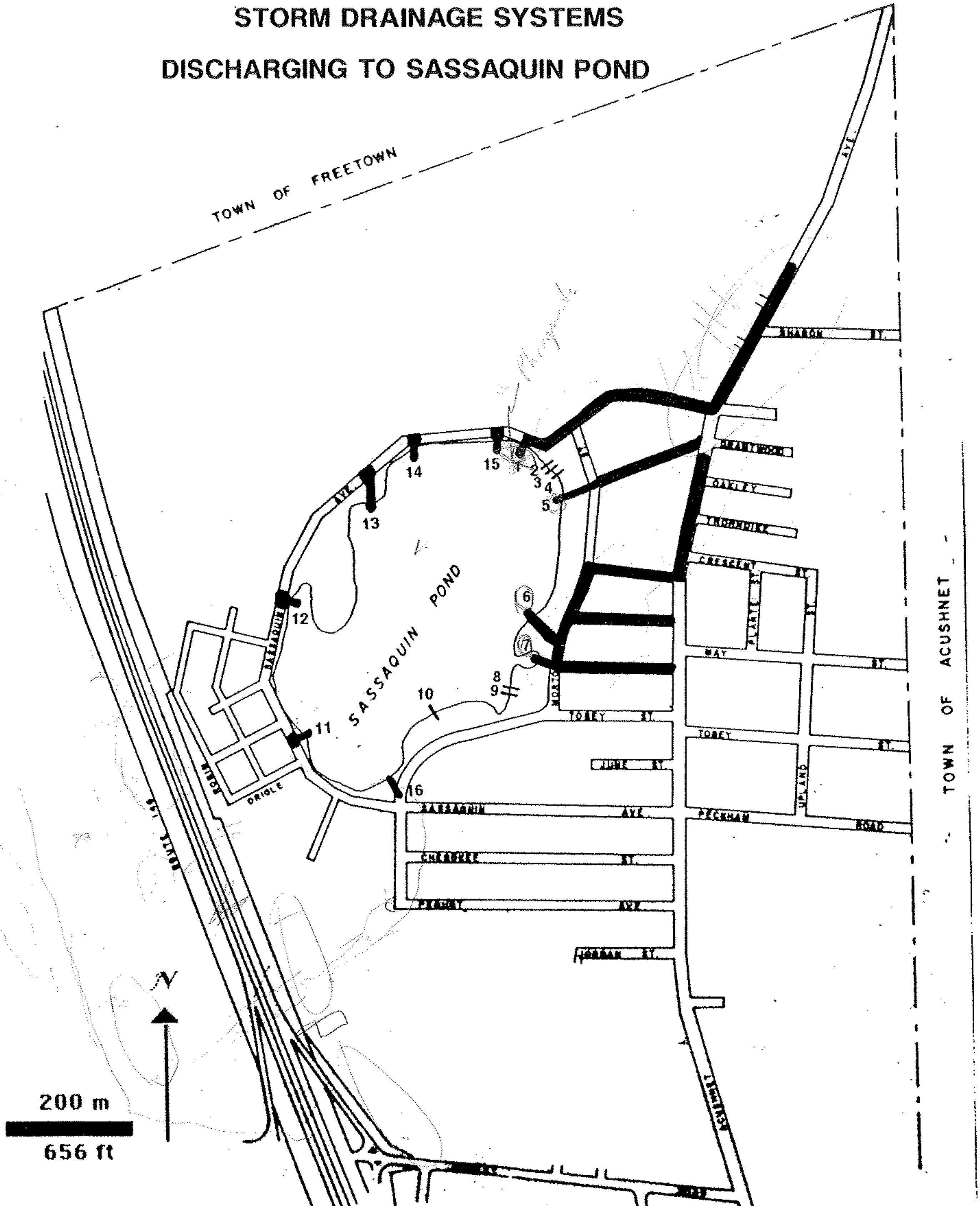


FIGURE 3

STORM DRAINAGE SYSTEMS DISCHARGING TO SASSAQUIN POND



(BASED ON CITY OF NEW BEDFORD ENGINEERING MAPS)

TABLE 1

DISCHARGE PIPE INVENTORY FOR SASSAQUIN POND, NEW BEDFORD

PIPE # (See Figure 3 for Location)	DESCRIPTION
1	24" drain serving portions of Sassaquin and Acushnet Avenues.
2-4	Tile drains from private residence.
5	12" drain serving Leroy Ave.
6	15" drain, partly buried and bypassed, but still active; linked to drain #7.
7	21" drain serving May, Ivers, Meadow, and part of Morton Ave.
8-9	Tile drains from private residence.
10	2" pipe (6" in some parts) from basement of private residence.
11-15	12" pipes, some with adjacent sluice channels, serving single or pairs of catchment basins along Sassaquin Ave.
16	16" overflow outlet pipe.

Due to the potential importance of storm water to the Sassaquin Pond system, samples were collected from Drains #1 and #14 on one date and analyzed for 11 parameters (Table 2). By nearly all standards, the quality of the water in both drainage systems was poor. The pH and buffering capacity of the water were low and concentrations of suspended solids, phosphorus, and fecal bacteria were high. The ammonia nitrogen level in Drain #1 was quite high as well, which in turn resulted in a high Kjeldahl nitrogen value. Chloride and oil and grease values were not especially high, but might very well rise under winter conditions. Although pollutant concentrations in precipitation or ground water were not assessed, those of the sampled storm waters are likely to be considerably higher, based on BEC experience elsewhere and our knowledge of water quality in southeastern Massachusetts.

A temperature/dissolved oxygen profile was established for the pond at its deepest point (Figure 4). Thermal stratification of the pond was minimal in early September, when stratification is usually most pronounced. Except near the bottom in the deepest part of Sassaquin Pond, it appears to be a thoroughly, continually mixed system. Although the oxygen level declined sharply below 6 m of water depth, the low oxygen values encountered near the bottom are of only minor concern. Since so little of the pond area is below 6 m of water (Figure 2), only a very small volume of water is affected (less than 3% of the total). Nearly all of the pond is suitable for fish habitat and for other forms of desirable aquatic life.

Fish encountered during the BEC survey included largemouth bass (dominant species), yellow perch, bluegill, pumpkinseed, and golden shiner. From discussions with fishermen and area residents it was determined that white perch, brown bullhead, black crappie, and american eel also inhabit the pond. Chain pickerel may also be present. Sassaquin Pond is a popular fishing area for residents of New Bedford and nearby communities.

The water was clear to slightly greenish, with a transparency (measured by Secchi disk) of 4.6 m (just over 15 ft). Phytoplankton are too small to be accurately assessed in the field and no samples were taken, but no evidence of nuisance blooms was uncovered. Zooplankton, which are small animals (mostly crustaceans) that consume algae or other zooplankton, were abundant. Large Daphnia and Leptodora (both cladocerans) were observed, as well as the copepods Diaptomus and Cyclops. A small cladoceran, possibly Bosmina, was also detected. Grazing pressure by these zooplankton may play an important role in keeping algal populations low and the water clear, and the abundance of zooplankton indicates an ample supply of fish food.

TABLE 2

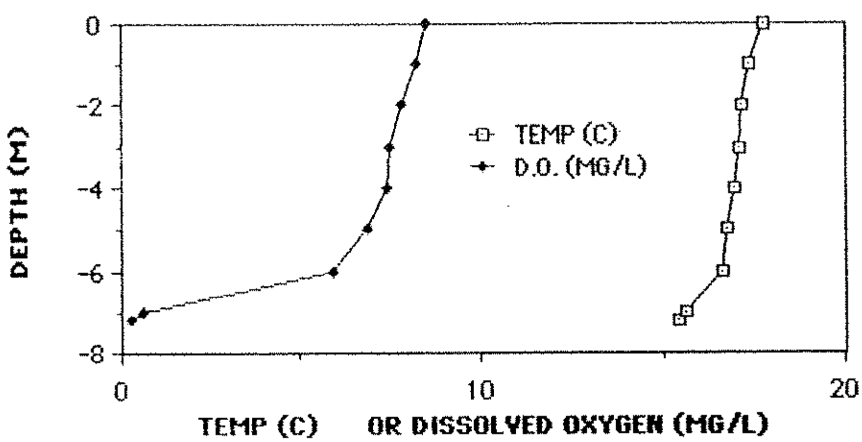
WATER QUALITY OF STORM DRAIN DISCHARGES SAMPLED ON 9/9/87

PARAMETER	DRAIN #1	DRAIN #14
pH (SU)	5.7	5.1
Total Alkalinity (mg/l)	5.5	1.7
Total Suspended Solids (mg/l)	29	13
Chloride (mg/l)	5.3	2.6
Oil and Grease (mg/l)	2.0	1.6
Ammonia Nitrogen (mg/l)	1.20	0.01
Nitrate Nitrogen (mg/l)	0.20	0.13
Total Kjeldahl Nitrogen (mg/l)	3.30	0.77
Total Phosphorus (mg/l)	0.26	0.24
Fecal Coliform (#/100 ml)	60,000	60,000
Fecal Streptococcus (#/100 ml)	100,000	100,000

FIGURE 4

TEMPERATURE-DISSOLVED OXYGEN PROFILE

FOR THE CENTER OF SASSAQUIN POND, 9/8/87



The macrophyte community of Sassaquin Pond was examined in the field and found to be relatively sparse. Patches of rooted aquatic vegetation rarely covered more than 30% of the sandy bottom. Eight species of rooted vascular plants were encountered in the pond, along with one aquatic moss and filamentous green algae mats. Two species of Eleocharis (spike rush) and Drepanocladus (the moss) were most frequently encountered. Less abundant but not uncommon were Gratiola, Myriophyllum, Nuphar, and the algal mats. Also present were Typha, Scirpus, and Phragmites. The plant community cannot be considered a nuisance to recreation in any way, and is not providing as much cover for fish as would typically be considered optimal.

A population of about 40 ducks was observed by BEC personnel, and local residents verified that this is about the average number of waterfowl at the pond at any time. Although waterfowl can contribute substantially to the nutrient loads to such a pond, the observed bird density is not high enough to represent a significant input to the system.

In order to directly quantify the ground water inflow to Sassaquin Pond, seepage meters (Figure 5) were placed in the pond over a two day period and seepage was monitored. The results (Table 3, Figure 6) indicate relatively low inflow over most of the area surveyed. Only two readings were negative, signifying outflow of ground water, and one zero value was obtained. This is a typical late summer or fall ground water flow pattern for a kettlehole pond; evaporation and low precipitation allow water levels to decline, increasing the hydraulic gradient, especially near shore. Water is then pulled into the pond from most or all of the land area immediately surrounding the pond. Steep slopes along much of the Sassaquin Pond shoreline aid this phenomenon. The actual seepage values are not high, however, suggesting only a limited ground water pool upon which the pond can draw or a ground water table with only a very slight slope.

Seepage values tended to reflect the steepness of the shoreline slopes with which they were associated, leading to higher values near the steepest slopes. Low values are linked to either flat areas adjacent to the shore or deep deposits of relatively impermeable muck, which inhibit seepage. It is not possible to accurately predict the overall direction of ground water flow from these data, but a slight indication of a northwesterly flow is given. Area topography suggests that ground water should flow approximately west, but local soil conditions and hydraulic gradients could affect the precise direction of flow. The collected data indicate that the entire nearshore area contributes to the ground water inputs to the

FIGURE 5

Seepage Meter Apparatus for Quantifying Ground Water Flow.

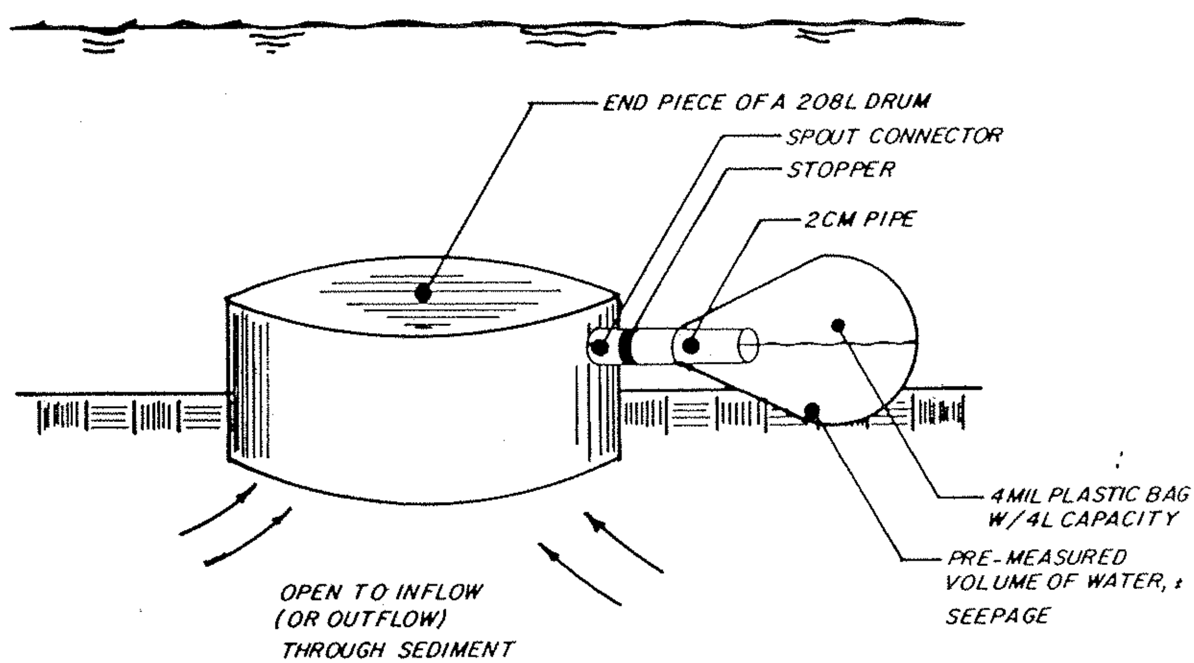


TABLE 3

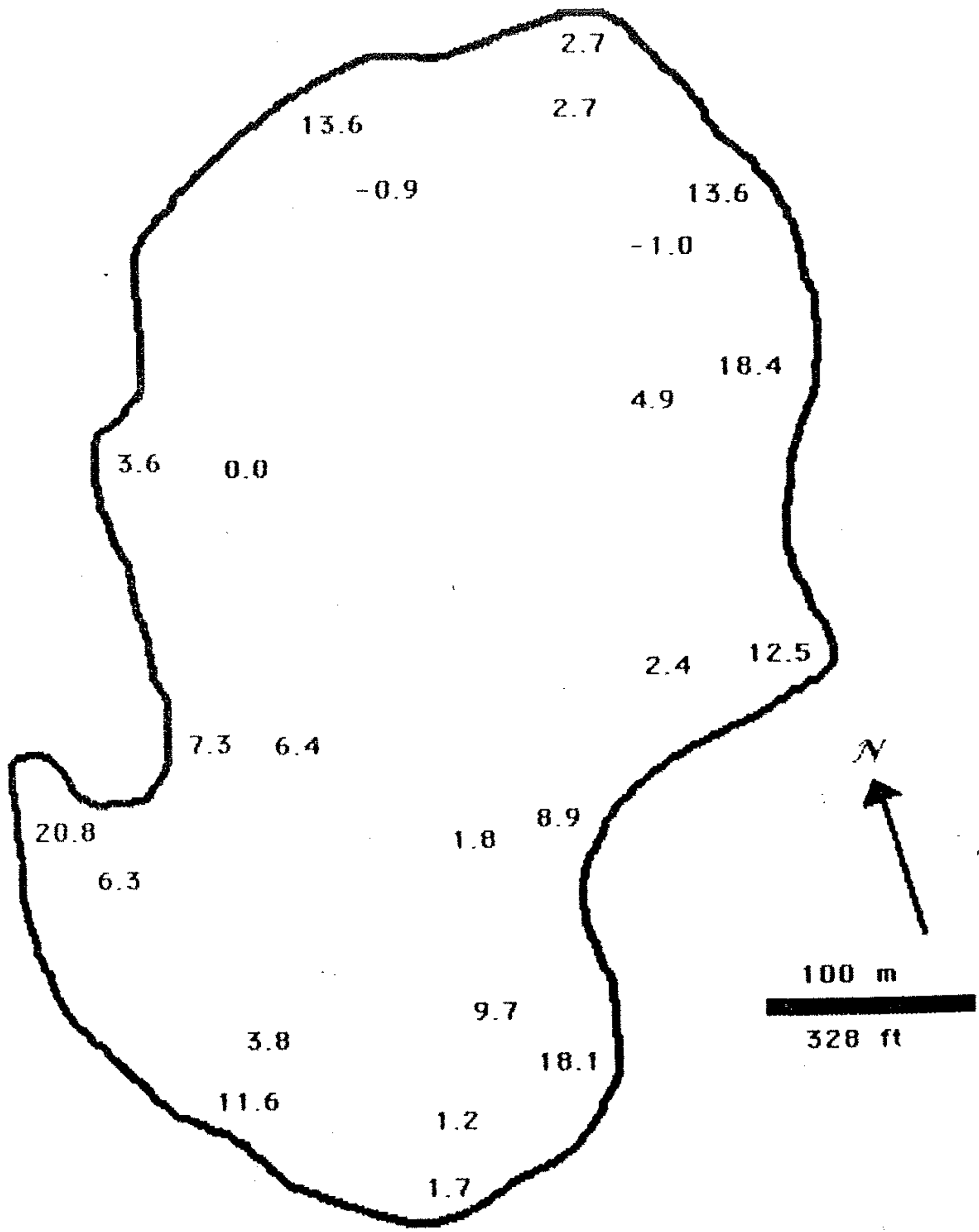
SASSAQUIN POND SEEPAGE MEASUREMENTS

Date	Meter #	Dist. from shore (M)	Seepage time (HR)	Volume change (L)	Seepage (L/SQ.M/D)
09/08/87	1	4.6	10.20	1.23	11.58
	2	8.5	10.20	.40	3.76
	3	1.8	5.30	1.15	20.83
	4	6.7	5.30	.35	6.34
	5	2.4	5.90	.45	7.32
	6	4.6	5.90	.39	6.35
	7	2.1	5.90	.22	3.58
	8	7.6	5.90	0.00	0.00
	9	3.0	5.10	.72	13.55
	10	6.7	5.10	-.05	-.94
	11	3.0	5.00	.14	2.69
	12	8.5	5.00	.14	2.69
09/09/87	13	7.9	5.00	.71	13.63
	14	3.7	5.00	-.05	-.96
	15	3.0	5.70	1.09	18.36
	16	10.7	5.70	.29	4.88
	17	3.7	5.70	.74	12.46
	18	13.7	5.70	.14	2.36
	19	4.3	5.80	.54	8.94
	20	17.1	5.80	.11	1.82
	21	4.6	9.50	1.79	18.09
	22	25.9	9.50	.96	9.70
	23	5.5	9.90	.17	1.65
	24	7.6	9.90	.12	1.16
MEAN					7.08
MEAN WITHOUT NEGATIVE VALUES					7.81

FIGURE 6

SASSAQUIN POND GROUND WATER SEEPAGE MEASUREMENTS

(Values given in liters/sq. meter/day)



pond, at least in late summer. There are therefore two ground water influences to be considered: localized inflow from the entire pond perimeter, and an overall, underlying direction of flow.

To better evaluate the overall direction of ground water flow, six holes were drilled with a power augur mounted on a truck. This operation was performed in October by Guild Drilling Company, under the direction of BEC personnel. The originally proposed design of four holes, one on each side of the pond, was modified to six holes, all to the north and west of the pond (Figure 7), as discussions with the New Bedford Conservation Commission indicated that this was the area of greatest concern. Additionally, area topography made prediction of flow direction on the east side of Sassaquin Pond relatively easy.

The locations of the bore holes were accurately marked on a topographic map provided by Tibbetts Engineering Corporation from photogrammetry by Teledyne Geotronics, Inc. Given a surface elevation at each bore hole and a depth to ground water measured in the field the day after each hole was drilled, the ground water elevation at each boring location was determined (Table 4). Relative to a pond surface elevation of 89.0 ft above MSL at the time of the drilling, much of the ground water table to the north and west of Sassaquin Pond is below the pond elevation. A westerly to slightly northwesterly direction of ground water flow is indicated, consistent with area surface topography. The slope of the water table is rather slight, however, at about 0.003 to 0.004 (3 to 4 ft per 1000 ft of horizontal distance).

While drilling was in progress, soil samples were taken at discrete intervals and examined for general characteristics. Relevant information is included in the boring logs filed by Guild Drilling Company (Appendix A). Sampled soils corresponded closely with the map provided by SCS (1981), except that more silt and clay were detected than expected at hole B-1, just behind Parkwood Hospital. Note that a monitoring well was installed at hole B-2, to allow further and future investigation of ground water depth and/or quality as warranted.

FIGURE 7

LOCATIONS OF BORE HOLES DRILLED TO INVESTIGATE WATER TABLE DEPTH

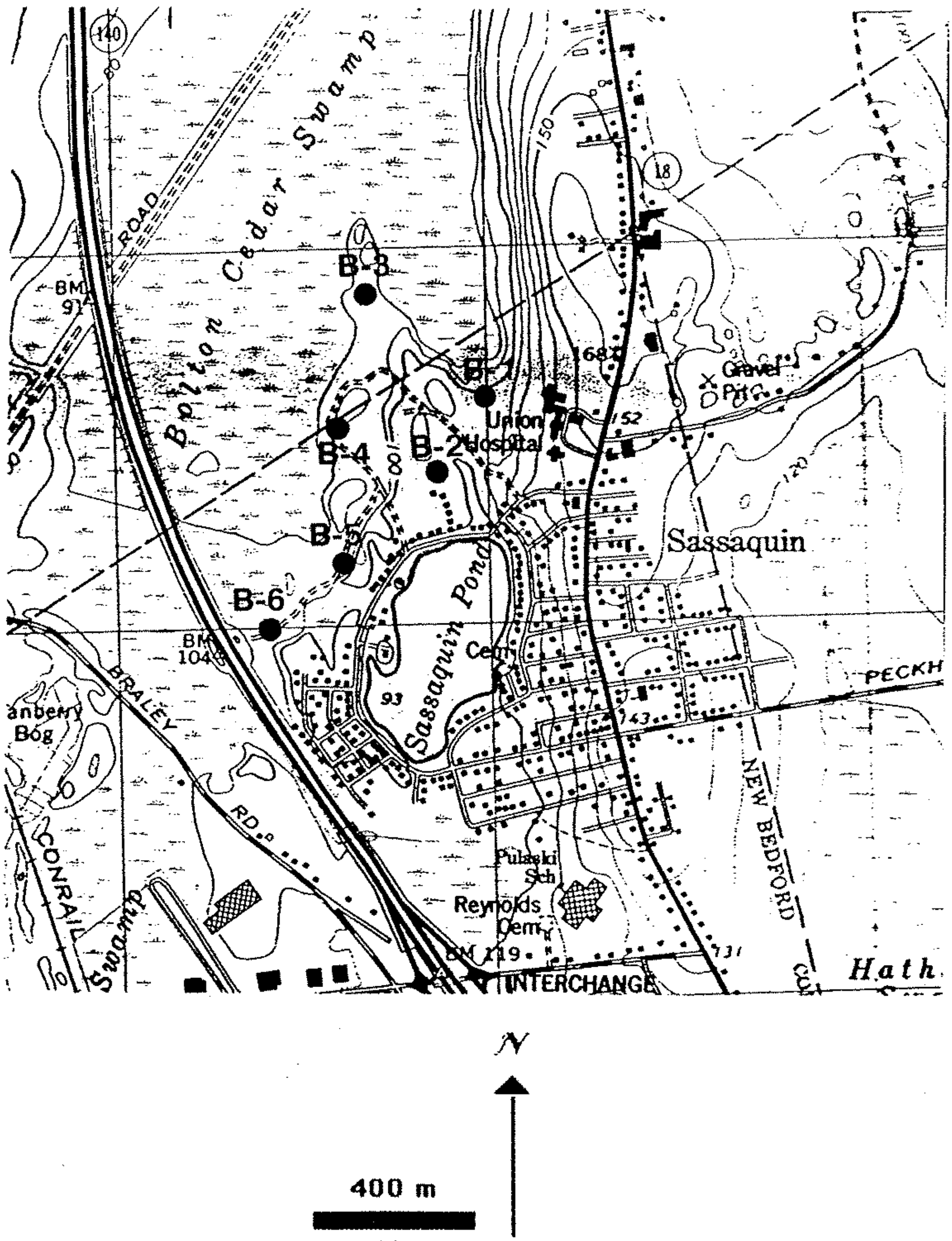


TABLE 4

DEPTH TO GROUND WATER IN BORE HOLES DRILLED ON 10/14/87

WELL # (See Figure 7 for Location)	DEPTH TO GROUND WATER (ft)	APPROXIMATE WELL ELEV. (ft above MSL)	GROUND WATER ELEV. (ft above MSL)
B-1	14.0	103.5	89.5
B-2	17.8	105.0	87.2
B-3	8.5	85.0	76.5
B-4	3.7	81.5	77.8
B-5	4.1	86.2	82.1
B-6	4.7	83.6	78.9

HYDROLOGIC EVALUATION

From the collected data it is possible to roughly delineate the hydrologic zone of contribution to Sassaquin Pond. This zone includes areas contributing surface flow and/or ground water inputs. Two zones have been mapped (Figures 8 and 9): the primary surface water/ground water contribution zone and the potential additional ground water contribution zone. The former is the minimum area contributing water to Sassaquin Pond, and is believed to be the best available delineation of the Sassaquin Pond watershed. The latter is the maximum contributing area, and is unlikely to affect the pond on a regular basis. The potential additional ground water contribution area is based upon the likely maximum ground water elevations and the minimum pond elevation, assuming a vertical fluctuation of 1.2 m (4 ft). As the ground water table and pond elevation are not independent, it is unlikely that the opposite extremes for each would be achieved simultaneously. This area should therefore be considered for potential impacts on the pond only if planned development will markedly affect the elevation of the ground water table or involves substantial routing of storm water runoff.

Impact assessment is greatly enhanced when all hydrologic inputs are known. Reasonable approximations of inputs from direct precipitation, runoff, and ground water seepage can be obtained from the collected data and a knowledge of historic trends for the New Bedford area. Calculations of inputs are shown on the accompanying Hydrologic Budget Calculation Sheet. An annual precipitation of 1.116 m as rain is applied (NOAA 1985). The primary zone of hydrologic contribution has an area of 30.0 ha (74.1 ac), and Sassaquin Pond has an area of 14.8 ha (36.6 ac). From the runoff curves given by Dunne and Leopold (1978), it is estimated that 50% of the precipitation falling on the primary zone of contribution is converted to runoff. Ground water seepage has been calculated from the direct measurements and from Darcy's formula (Dunne and Leopold 1978), with remarkable agreement.

The calculations result in an approximately equal split of the total water inflow to Sassaquin Pond among the three considered sources, with each contributing slightly more than 0.3 cu.m/min (80 gal/min. or 0.2 cfs). The total input of about 1 cu.m/min. is not large and is not evenly distributed over time. Given the extreme dependence of runoff on precipitation and a lesser but substantial link between seepage and precipitation, water inflow to the pond is likely to be highly erratic.

Outflow from the pond will be divided between evaporation and outward seepage; evaporation will be the dominant form of outflow during the summer, while seepage will provide the primary means for water removal during the remainder of the year. There

FIGURE 8

MINIMUM AND ESTIMATED MAXIMUM HYDROLOGIC ZONES OF CONTRIBUTION TO SASSAQUIN POND

(BASED ON USGS TOPOGRAPHIC MAP)

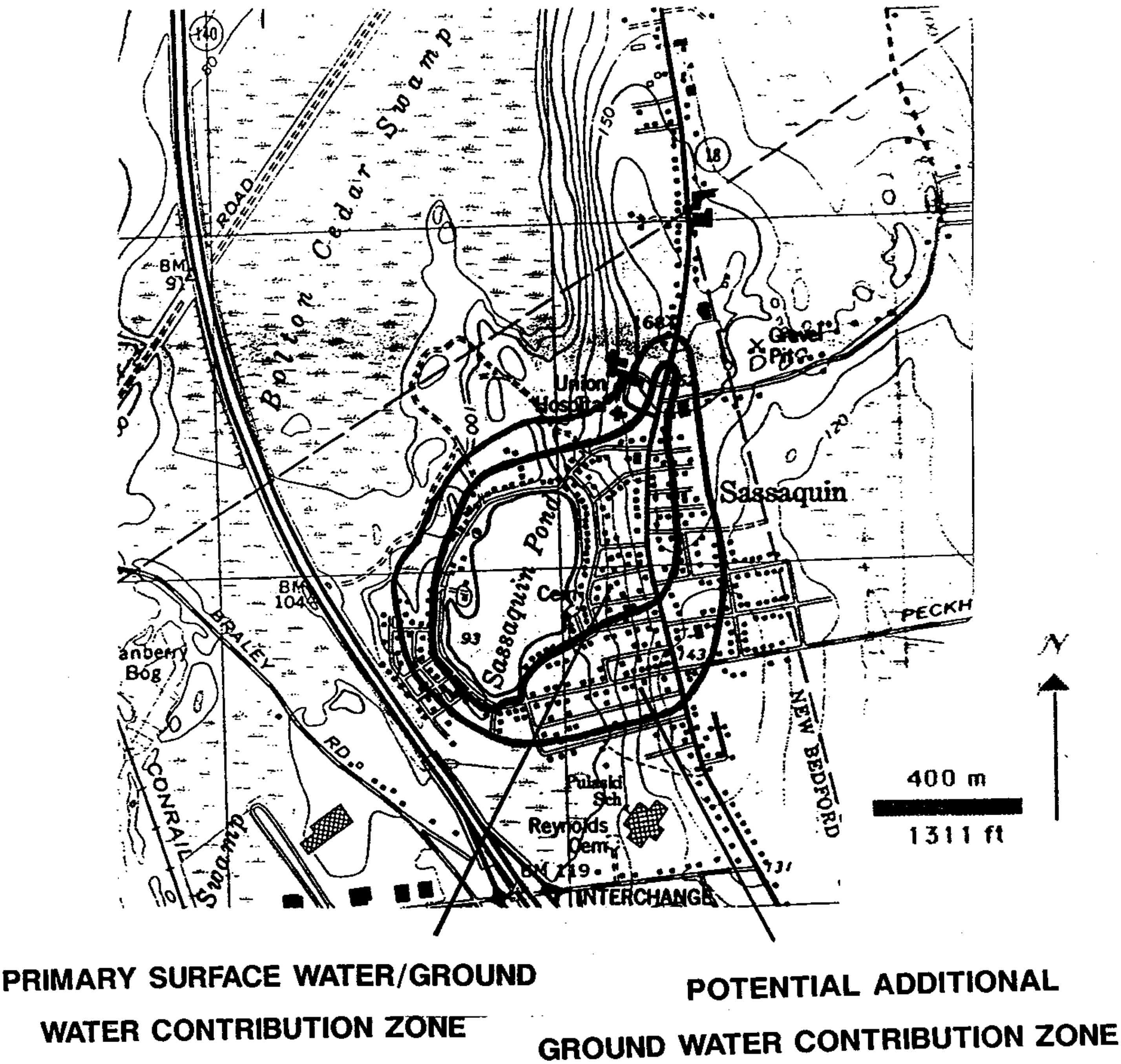
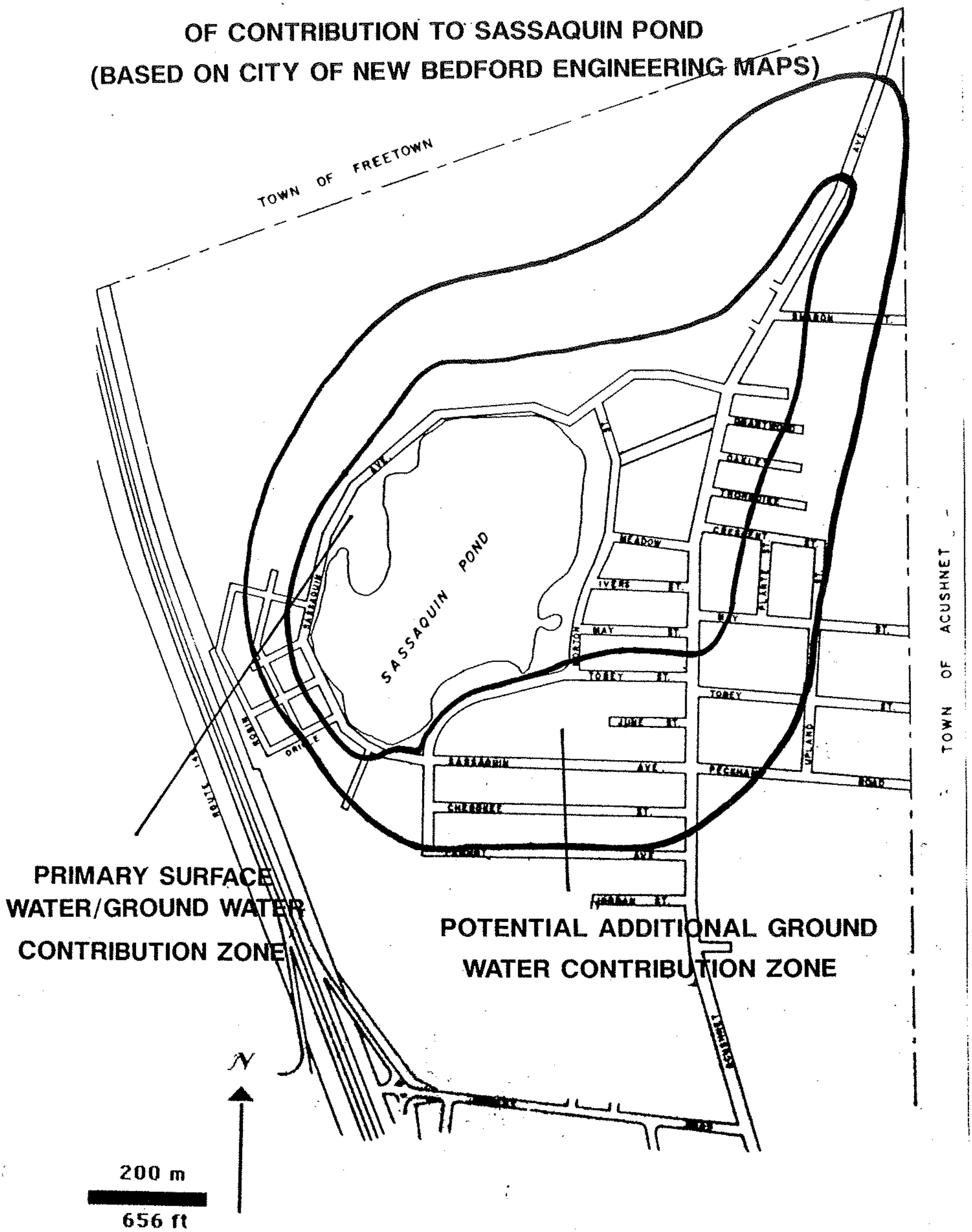


FIGURE 9

MINIMUM AND ESTIMATED MAXIMUM HYDROLOGIC ZONES OF CONTRIBUTION TO SASSAQUIN POND (BASED ON CITY OF NEW BEDFORD ENGINEERING MAPS)



HYDROLOGIC BUDGET CALCULATION SHEET

Contribution of Precipitation:
1.116 m/yr falling directly on 14.8 ha (36.6 ac) of pond =
165,168 cu.m/yr, or .... 0.314 cu.m/min.

Contribution of Runoff:
1.116 m/yr falling on 30.0 ha (74.1 ac) of watershed, with
50% reaching the pond as runoff = 167,400 cu.m/yr, or 0.318 cu.m/min.

Contribution of Ground Water:
From seepage measurements:
Avg. of 7.08 l/sq.m/day from 50% of the pond area (7.4 ha) =
191,231 cu.m/yr, or .... 0.364 cu.m/min.
Probable range, assuming variable seepage and portion
of pond bottom contributing = 0.18 to 0.80 cu.m/min.
From Darcy's Formula:
Q = KIA,
where K = permeability = 0.2 to 6.0 in/hr
I = slope of water table = 0.003 to 0.004 ft/ft
A = area of seepage face = 645,000 to 1,075,000 sq.ft
Therefore, Q = seepage inflow = 282,510 to 18,834,000 cu.ft/yr,
or 8000 to 533,000 cu.m/yr,
or 0.02 to 1.0 cu.m/min.
with a mean of ..... 0.367 cu.m/min.

The agreement between the values derived by the two approaches to ground water seepage is most encouraging; a value of 0.365 cu.m/min. will be used in further calculations.

Based on the derived hydrologic input values, the following breakdown is offered:

Source	% of Total Input
Direct Precipitation	31.5
Surface Runoff	31.9
Ground Water Seepage	36.6
Total	100.0

is an overflow pipe at the southern end of the pond, but the water level is below the bottom lip of the pipe during most of the year. Given only slow means of outletting water and temporally erratic hydrologic inputs, the water level in Sassaquin Pond is likely to fluctuate noticably, especially on a seasonal basis.

The estimated hydrologic inputs suggest a mean detention time for water in the pond of 442 days, or 1.2 years. Annual fluctuations in precipitation suggest a range of slightly less than one year to almost a year and one half. All of these detention times are considered long for small water bodies, and indicate that pollutant loads will have sufficient time to realize their full impact once they have entered the pond. In many ponds with substantial throughflow there is insufficient time for entering pollutants to have as much impact as they would in a pond with a long detention time. Pollutants entering Sassaquin Pond are likely to remain there, eventually becoming sequestered in the bottom sediments.

IMPACT ASSESSMENT

While a detailed nutrient budget cannot be constructed from the available data, it is apparent that the primary force in the delivery of phosphorus, nitrogen, and other pollutants to Sassaquin Pond is the storm water drainage system around the pond. Runoff accounts for almost a third of the water entering the pond, and contains pollutant concentrations which are likely to be as much as an order of magnitude greater than those in precipitation or ground water. Since the sewering of the area around the pond, nutrient concentrations in the incoming ground water have probably declined substantially and should have approached relatively low background levels by this time. While the nutrient content of precipitation cannot be assumed to be negligible, values approaching those observed in the sampled storm waters have never been recorded in New England. Based on the data acquired during this study and a knowledge of water quality in southeastern Massachusetts, storm water inputs may account for as much as 70% of the loads of phosphorus, nitrogen, and other pollutants to Sassaquin Pond.

Given a mean pond depth of 4.3 m, a detention time of 1.2 yr, and the relationships established by Vollenweider (1968), Sassaquin Pond can be assigned a permissible phosphorus load of 0.2 g/sq.m/yr (about 30 kg/yr) and a critical load of 0.4 g/sq.m/yr (about 60 kg/yr). These loads can be used as preliminary guidelines for evaluating current pond status and potential future impacts. If the phosphorus load can be maintained below the permissible load level, it is likely that any algal blooms or other undesirable water quality episodes will occur only rarely. If the critical load level is reached, it is reasonable to assume that detectable deterioration of water quality and recreational utility will occur.

While there is currently no monitoring base upon which pond status can be evaluated, inference can be obtained from the Secchi disk transparency reading made on September 8, 1987. Using the relationship between phosphorus and water transparency established by Vollenweider (1982), an effective in-lake phosphorus concentration of 0.019 mg/l is predicted. Applying several load prediction models based on phosphorus concentration and system hydrology (Chapra 1975, Jones and Bachmann 1976, Kirchner and Dillon 1975, Larsen and Mercier 1975, Vollenweider 1975), a phosphorus load of 10 to 47 kg/yr is calculated for Sassaquin Pond, with a mean of 24 kg/yr. These loads are all below the critical load and all but one are below the permissible load, indicating that the pond is currently in an optimal condition for the variety of uses associated with it. This is a highly speculative analysis, however, and the implementation of a simple monitoring program for future reference is strongly recommended.

Within the primary zone of hydrologic contribution to Sassaquin Pond (Figures 8 and 9), further development (most likely additional housing) would have its greatest impact on the pond through the production of additional runoff during storm events. Both the quantity and quality of this runoff may impact the pond. As the percentage of urbanized land increases there is a roughly linear increase in the phosphorus export per unit area within a watershed (Walker 1987). Increased nutrient loading under apparent present conditions would be expected to translate into increased productivity and biomass at all levels of the food web. The input of additional nutrient rich water should be avoided, unless additional fish production is desired at the expense of water clarity.

As long as any development in the potential additional ground water contribution zone (Figures 8 and 9) is tied into the sanitary sewer system and is prohibited from discharging storm water directly into Sassaquin Pond, such development poses little threat to the pond. The only area which warrants scrutiny at this time is the land area to the southeast of the pond, between Pequot and Tobey Avenues. Excessive lawn fertilization or improper disposal of household chemicals (e.g., solvents, waste oil) could result in contamination of ground water which may reach the pond. Management of existing properties would be just as important as discouraging the development of new ones in this case.

MANAGEMENT OPTIONS

The number of actual techniques available for lake and watershed management is not overwhelming (Table 5). 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 Sassaquin Pond and its watershed suggests that none of the in-lake techniques are really applicable at this time. Of the watershed level techniques, several are applicable. These include: zoning/land use planning, storm water diversion, detention basin use, street sweeping, and restriction of lawn fertilization. The first involves a conscious effort to plan/restrict development to avoid pollutant loading. The latter four are directed primarily at minimizing the impact of storm water runoff. The last, restriction of lawn fertilization, will also serve to protect ground water quality.

It is not certain that lawn fertilization is a problem in the Sassaquin Pond watershed, but it could do no harm to inform residents of the potential impacts of lawn care. An informative pamphlet prepared by the Lake Cochituate Watershed Association (1984) is available from the Massachusetts Clean Lakes Program Office in Westborough, and could be distributed among watershed residents as an educational endeavor.

Diversion of storm water from Sassaquin Pond would be an expensive task requiring a serious engineering assessment, but could be accomplished if necessary. A partial diversion could be implemented, in which the three largest drain systems (#1, 5, and 6/7 on Figure 3) would be routed down Morton and Tobey Streets to the existing southbound drainage system at the south end of Tobey Street. This would be desirable in terms of the long range condition of Sassaquin Pond, but there is no evidence to demonstrate the necessity of such a diversion at this time.

Street sweeping, including cleaning of catch basins, would reduce the quantity of pollutants on the street which would be carried by runoff to the pond. The frequency and mode of sweeping (vaccuum rigs are preferable) necessary to cause a major reduction in pollutant loads is likely to be impractical for the City of New Bedford, however, unless a substantial monetary committment is made to the management of Sassaquin Pond. As with

TABLE 5

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 5 (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.

storm water diversion, there is currently no evidence to demonstrate a severe need for such a program. Routine sweeping and catch basin cleaning are still strongly encouraged, though.

There are relatively few undeveloped lots in the primary hydrologic zone of contribution to Sassaquin Pond where a detention basin could be placed, but the use of detention basins for storm water purification prior to discharge to the pond should be considered for all future development projects within the primary or potential additional zones of contribution. Although the developable land within the potential additional zone of contribution is unlikely to have a major impact on Sassaquin Pond, the use of detention basins in association with new construction projects is currently considered to be the environmentally responsible approach and is required by many municipalities. The major obstacle to the required use of detention basins is that they preclude most single lot projects, both physically and financially. This may be a desirable end, but it is difficult to socially justify such measures in areas where past development has not been subjected to such restrictions.

Zoning and land use planning are highly desirable when contemplating large scale development, but are difficult to apply fairly when retrofitting a partially developed area. In the experience of BEC with development projects in environmentally sensitive areas, a residential lot size of one acre has never been found to lead to detectable water quality degradation. In the absence of on-site waste water disposal systems (as with the Sassaquin Pond area, where homes are sewered), it may be possible to allow one half acre lots without significant impact to water quality. House density in the primary watershed of Sassaquin Pond is currently approximately 2 houses/ac, or one half acre per house. This suggests that further development within the primary watershed should be discouraged, but without further evidence of resultant impacts a building moratorium will be most unpopular.

BEC is currently studying three kettlehole ponds in Springfield, MA, which are very similar to Sassaquin Pond. The results of a year long investigation are not yet completely tabulated, but it appears at this time that storm water runoff routed directly to the ponds is by far the most detrimental influence on these water bodies. The pond with the greatest storm water contribution exhibits the poorest water quality, while lesser storm water inputs and indirect entry (via wetlands) has been observed to yield detectably higher water quality. The watersheds of all three ponds are highly developed, with large commercial parking lots and housing densities of up to 6 homes/ac. Nearly all homes in the watersheds of these ponds are sewered. Where storm water influence has been minimized, the water is suitable for contact recreation (i.e., swimming). Based on this comparison, management of Sassaquin Pond should center on controlling storm water inputs.

RECOMMENDATIONS

Within the limitations of this cursory study of Sassaquin Pond and its watershed, the following recommendations are offered:

1. Establish a simple monitoring program to gather baseline water quality data for Sassaquin Pond. Include analyses of phosphorus, nitrogen, suspended solids, conductivity, pH, temperature, dissolved oxygen, and water clarity for the pond and several storm drain inlets on a quarterly basis. Also arrange to have ground water quality near the pond assessed on two occasions.

2. Distribute educational literature regarding the impacts of residential practices (such as lawn care) on water quality and general pond condition to residents of the Sassaquin Pond watershed.

3. Consider diverting storm water currently entering Sassaquin Pond through drains #1, 5, 6 and 7 (Figure 3) southward along Morton and Tobey Streets to the Tobey Street drainage system, which discharges to the south, away from the pond.

4. Carefully evaluate proposed development projects within the primary hydrologic zone of contribution to Sassaquin Pond for potential impact on storm water runoff and ground water quality. Potential impacts should be minimized, although not necessarily eliminated, through design modifications prior to project approval.

5. Evaluate potential development projects in the potential additional ground water contribution zone for possible effects on ground water elevation and quality. Only a predicted major impact should be considered just cause for delaying or witholding approval based on ground water considerations. Do not allow any additional direct routing of runoff to the pond from this zone.

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APPENDIX A

BORING LOGS FOR DRILLING PERFORMED ON 10/14/87

GUILD DRILLING CO., INC.

100 WATER STREET EAST PROVIDENCE, R. I.

SHEET 1 OF 1
DATE
HOLE NO. B-1
LINE & STA.
OFFSET
SURF. ELEV.

TO Baystate Environmental
ADDRESS East Longmeadow, Mass.
PROJECT NAME Ground Water Study
LOCATION New Bedford, Mass.
REPORT SENT TO Above
PROJ. NO.
SAMPLES SENT TO Taken At Site
OUR JOB NO. 88-299

GROUND WATER OBSERVATIONS		CASING	SAMPLER	CORE BAR.
At 14' after ___ Hours	Type	Hollow	S/S	
	Size I.D.	Stem-Auger	1-3/8"	
At ___ after ___ Hours	Hammer Wt.		140#	BIT
	Hammer Fall		30"	

	Date	Time
START	10-14-87	a.m. p.m.
COMPLETE	10-14-87	a.m. p.m.
TOTAL HRS.		

BORING FOREMAN D. Holley
INSPECTOR
SOILS ENGR.

LOCATION OF BORING:

DEPTH	Casing Blows per foot	Sample Depths From - To	Type of Sample	Blows per 6" on Sampler From 0-6	To 6-12	12-18	Moisture Density or Consist.	Strata Change Elev.	SOIL IDENTIFICATION Remarks include color, gradation, Type of soil etc. Rock-color, type, condition, hardness, Drilling time, seams and etc.	SAMPLE No.	Pen	Rec
		0'-2'	Auger Sample						Brown coarse to fine SAND, some fine to coarse Gravel, Cobbles, little Silt	1	24"	-
		5'-6'6"	D	31	55	47				2	18"	16"
								9'				
		10'-11'6"	D	25	32	34			Gray coarse to fine SAND & Silt, trace of fine Gravel	3	18"	16"
								13'				
		15'-16'6"	D	5	7	6		16'6"	Brown SILT, trace of fine Sand, trace of Clay	4	18"	18"
									Bottom of Boring 16'6"			

GROUND SURFACE TO 15' USED HSA "CASING: THEN S/S

Sample Type
D=Dry C=Cored W=Washed
UP=Undisturbed Piston
TP=Test Pit A=Auger V=Vane Test
UT=Undisturbed Thinwall

Proportions Used	
trace	0 to 10%
little	10 to 20%
some	20 to 35%
and	35 to 50%

140 lb Wt. x 30" fall on 2" O.D. Sampler

Cohesionless Density		Cohesive Consistency			
0-10	Loose	0-4	Soft	30 +	Hard
10-30	Med. Dense	4-8	M/Stiff		
30-50	Dense	8-15	Stiff		
50 +	Very Dense	15-30	V-Stiff		

SUMMARY:
Earth Boring 16'6'
Rock Coring -0-
Samples 4

HOLE NO.

GUILD DRILLING CO., INC.

100 WATER STREET EAST PROVIDENCE, R. I.

TO Baystate Environmental
ADDRESS East Longmeadow, Mass.
PROJECT NAME Ground Water Study
LOCATION New Bedford, Mass.
REPORT SENT TO Above
PROJ. NO.
SAMPLES SENT TO Taken At Site
OUR JOB NO. 88-299

SHEET 1 OF 1
DATE
HOLE NO. B-2
LINE & STA.
OFFSET
SURF. ELEV.

GROUND WATER OBSERVATIONS	
At 17'10"	after ___ Hours
At ___	after ___ Hours

	CASING	SAMPLER	CORE BAR.
Type	Hollow	S/S	
Size I.D.	Stem-Auger	1-3/8"	
Hammer Wt		140#	BIT
Hammer Fall		30"	

	Date	Time
START	10-14-87	a.m. p.m.
COMPLETE	10-14-87	a.m. p.m.
TOTAL HRS.		
BORING FOREMAN	D. Holley	
INSPECTOR		
SOILS ENGR.		

LOCATION OF BORING

DEPTH	Casing Blows per foot	Sample Depths From - To	Type of Sample	Blows per 6" on Sampler From 0-6	To 6-12	12-18	Moisture Density or Consist.	Strata Change Elev.	SOIL IDENTIFICATION Remarks include color, gradation, Type of soil etc. Rock-color, type, condition, hardness, Drilling time, seams and etc.	SAMPLE No	Pen	Rec
		0'-2'	Auger Sample						Brown coarse to fine SAND & Gravel, Cobbles, Boulders, some Silt	1	24"	-
		5'-6'6"	D	14	16	11				2	18"	12"
		10'-11'6"	D	40	43	32				3	18"	14"
		15'-16'6"	D	22	28	28				4	18"	16"
								20'				
									Bottom of Boring 20' Installed Monitor Well 10'-Slotted 10'-Solid 250# of Ottawa Sand 1 - Guard Pipe 1 - Padlock 1 - Bag of Cement 1 - Plug			

GROUND SURFACE TO 20' USED HSA "CASING: THEN S/S to Well

Sample Type
D=Dry C=Cored W=Washed
UP=Undisturbed Piston
TP=Test Pit A=Auger V=Vane Test
UT=Undisturbed Thinwall

Proportions Used	
trace	0 to 10%
little	10 to 20%
some	20 to 35%
and	35 to 50%

140 lb Wt. x 30" fall on 2" O.D. Sampler

Cohesionless Density		Cohesive Consistency		
0-10	Loose	0-4	Soft	30 + Hard
10-30	Med. Dense	4-8	M/Stiff	
30-50	Dense	8-15	Stiff	
50 +	Very Dense	15-30	V-Stiff	

SUMMARY
Earth Boring 20'
Rock Coring -0-
Samples 4

HOLE NO. B-2

GUILD DRILLING CO., INC.

100 WATER STREET EAST PROVIDENCE, R. I.

SHEET 1 OF 1
DATE B-3
HOLE NO.
LINE & STA.
OFFSET
SURF. ELEV.

TO Baystate Environmental
ADDRESS East Longmeadow, Mass.
PROJECT NAME Ground Water Study
LOCATION New Bedford, Mass.
REPORT SENT TO Above
PROJ. NO.
SAMPLES SENT TO Taken At Site
OUR JOB NO. 88-299

GROUND WATER OBSERVATIONS
At 8'6" after ____ Hours
At ____ after ____ Hours

	CASING	SAMPLER	CORE BAR.
Type	Hollow	S/S	
Size I.D.	Stem-Auger	1-3/8"	
Hammer Wt.		140#	BIT
Hammer Fall		30"	

	Date	Time
START	10-14-87	a.m. p.m.
COMPLETE	10-14-87	a.m. p.m.

TOTAL HRS.
BORING FOREMAN D. Holley
INSPECTOR
SOILS ENGR.

LOCATION OF BORING:

DEPTH	Casing Blows per foot	Sample Depths From - To	Type of Sample	Blows per 6" on Sampler From 0-6	6-12	To 12-18	Moisture Density or Consist.	Strata Change Elev.	SOIL IDENTIFICATION Remarks include color, gradation, Type of soil etc. Rock-color, type, condition, hardness, Drilling time, seams and etc.	SAMPLE No	Pen	Rec
		0'-2'	Auger Sample						Brown coarse to fine Gravel, trace of Silt	1	24"	-
		5'-6'6"	D	13	22	27				2	18"	15"
		10'-11'6"	D	6	15	18		11'6"		3	18"	16"
									Bottom of Boring 11'6"			

GROUND SURFACE TO 10' USED HSA "CASING: THEN S/S 11'6"

Sample Type
D=Dry C=Cored W=Washed
UP=Undisturbed Piston
TP=Test Pit A=Auger V=Vane Test
UT=Undisturbed Thinwall

Proportions Used
trace 0 to 10%
little 10 to 20%
some 20 to 35%
and 35 to 50%

140 lb Wt. x 30" fall on 2" O.D. Sampler

Cohesionless Density		Cohesive Consistency		
0-10	Loose	0-4	Soft	30 + Hard
10-30	Med. Dense	4-8	M/Stiff	
30-50	Dense	8-15	Stiff	
50 +	Very Dense	15-30	V. Stiff	

SUMMARY:
Earth Boring 11'6"
Rock Coring -0-
Samples 3

HOLE NO. B-3

GUILD DRILLING CO., INC.

100 WATER STREET EAST PROVIDENCE, R. I.

SHEET 1 OF 1
DATE
HOLE NO. B-4
LINE & STA.
OFFSET
SURF. ELEV.

TO Baystate Environmental
ADDRESS East Longmeadow, Mass.
PROJECT NAME Ground Water Study
LOCATION New Bedford, Mass.
REPORT SENT TO Above
PROJ. NO.
SAMPLES SENT TO Taken At Site
OUR JOB NO. 88-299

GROUND WATER OBSERVATIONS
At 3'7" after ___ Hours
At ___ after ___ Hours

	CASING	SAMPLER	CORE BAR.
Type	Hollow	S/S	
Size I.D.	Stem-Auger	1-3/8"	
Hammer Wt		140#	BIT
Hammer Fall		30"	

	Date	Time
START	10-14-87	a.m. p.m.
COMPLETE	10-14-87	a.m. p.m.
TOTAL HRS.		

BORING FOREMAN D. Holley
INSPECTOR
SOILS ENGR.

LOCATION OF BORING:

DEPTH	Casing Blows per foot	Sample Depths From - To	Type of Sample	Blows per 6" on Sampler From 0-6	6-12	To 12-18	Moisture Density or Consist.	Strata Change Elev.	SOIL IDENTIFICATION Remarks include color, gradation, Type of soil etc. Rock-color, type, condition, hardness, Drilling time, seams and etc.	SAMPLE No	Pen	Rec
		0'-2'	Auger Sample						Brown coarse to fine Sand, & Silt, some coarse to fine Gravel, Cobbles	1	24"	-
		5'-6'6"	D	15	17	22		6'6"		2	18"	16"
									Bottom of Boring 6'6"			

GROUND SURFACE TO 5' USED HSA "CASING: THEN S/S 6'6"

Sample Type
D=Dry C=Cored W=Washed
UP=Undisturbed Piston
TP=Test Pit A=Auger V=Vane Test
UT=Undisturbed Thinwall

Proportions Used
trace 0 to 10%
little 10 to 20%
some 20 to 35%
and 35 to 50%

140 lb Wt. x 30" fall on 2" O.D. Sampler

Cohesionless Density		Cohesive Consistency	
0-10	Loose	0-4	Soft
10-30	Med. Dense	4-8	M/Stiff
30-50	Dense	8-15	Stiff
50 +	Very Dense	15-30	V-Stiff
		30 +	Hard

SUMMARY
Earth Boring 6'6"
Rock Coring -0-
Samples 2

HOLE NO. B-4

GUILD DRILLING CO., INC.

100 WATER STREET EAST PROVIDENCE, R. I.

SHEET 1 OF 1
DATE
HOLE NO. B-5
LINE & STA.
OFFSET
SURF. ELEV.

TO Baystate Environmental
ADDRESS East Longmeadow, Mass.
PROJECT NAME Ground Water Study
LOCATION New Bedford, Mass.
REPORT SENT TO Above
PROJ. NO.
SAMPLES SENT TO Taken At Site
OUR JOB NO. 88-299

GROUND WATER OBSERVATIONS
At 4'1" after ____ Hours
At ____ after ____ Hours

	CASING	SAMPLER	CORE BAR.
Type	Hollow	S/S	
Size I.D.	Stem-Auger	1-3/8"	
Hammer Wt.		140#	BIT
Hammer Fall		30"	

	Date	Time
START	10-14-87	a.m. p.m.
COMPLETE	10-14-87	a.m. p.m.
TOTAL HRS.		

BORING FOREMAN D. Holley
INSPECTOR
SOILS ENGR.

LOCATION OF BORING:

DEPTH	Casing Blows per foot	Sample Depths From - To	Type of Sample	Blows per 6" on Sampler From To 0-6	6-12	12-18	Moisture Density or Consist.	Strata Change Elev.	SOIL IDENTIFICATION Remarks include color, gradation, Type of soil etc. Rock-color, type, condition, hardness, Drilling time, seams and etc.	SAMPLE No	Pen	Rec
		0'-2'	Auger Sample						Brown Gray coarse to fine SAND & Silt, some fine to coarse Gravel, Cobbles	1	24"	24'
		5'-6'6"	D	71	75	39		6'6"		2	18"	16"
									Bottom of Boring 6'6"			

GROUND SURFACE TO 5' USED HSA "CASING: THEN S/S 6'6"

Sample Type
D=Dry C=Cored W=Washed
UP=Undisturbed Piston
TP=Test Pit A=Auger V=Vane Test
UT=Undisturbed Thinwall

Proportions Used	
trace	0 to 10%
little	10 to 20%
some	20 to 35%
and	35 to 50%

140 lb Wt. x 30" fall on 2" O.D. Sampler

Cohesionless Density		Cohesive Consistency		
0-10	Loose	0-4	Soft	30 + Hard
10-30	Med. Dense	4-8	M/Stiff	
30-50	Dense	8-15	Stiff	
50 +	Very Dense	15-30	V-Stiff	

SUMMARY:
Earth Boring 6'6"
Rock Coring -0-
Samples 2
HOLE NO.

GUILD DRILLING CO., INC.

100 WATER STREET EAST PROVIDENCE, R. I.

SHEET 1 OF 1
DATE
HOLE NO. B-6
LINE & STA.
OFFSET
SURF. ELEV.

TO Baystate Environmental
ADDRESS East Longmeadow, Mass.
PROJECT NAME Ground Water Study
LOCATION New Bedford, Mass.
REPORT SENT TO Above
PROJ. NO.
SAMPLES SENT TO Taken At Site
OUR JOB NO. 88-299

GROUND WATER OBSERVATIONS
At 4'8" after ____ Hours
At ____ after ____ Hours

	CASING	SAMPLER	CORE BAR.
Type	Hollow	S/S	
Size I D	Stem-Auger	1-3/8"	
Hammer Wt		140#	BIT
Hammer Fall		30"	

	Date	Time
START	10-14-87	a.m. p.m.
COMPLETE	10-14-87	a.m. p.m.
TOTAL HRS.		

BORING FOREMAN D. Holley
INSPECTOR
SOILS ENGR.

LOCATION OF BORING:

DEPTH	Casing Blows per foot	Sample Depths From - To	Type of Sample	Blows per 6" on Sampler From 0-6	6-12	To 12-18	Moisture Density or Consist.	Strata Change Elev.	SOIL IDENTIFICATION Remarks include color, gradation, Type of soil etc. Rock-color, type, condition, hardness, Drilling time, seams and etc	SAMPLE No	Pen	Rec
		0'-2'	Auger Sample						Brown Gray coarse to fine SAND & Silt, some coarse to fine Gravel, Cobbles	1	24"	-
		5'-6'2"	D	15	30	50/2"		6'2"		2	14"	14"
									Bottom of Boring 6'2" (Refusal)			

GROUND SURFACE TO 5' USED HSA "CASING: THEN S/S to Refusal

Sample Type
D=Dry C=Cored W=Washed
UP=Undisturbed Piston
TP=Test Pit A=Auger V=Vane Test

Proportions Used	
trace	0 to 10%
little	10 to 20%
some	20 to 35%

140 lb Wt. x 30" fall on 2" O.D. Sampler

Cohesionless Density		Cohesive Consistency			
0-10	Loose	0-4	Soft	30 +	Hard
10-30	Med. Dense	4-8	M/Stiff		
30-50	Dense	8-15	Stiff		

SUMMARY:
Earth Boring 6'2"
Rock Coring -0-
Samples 2

HOLE NO.