7.0 SEDIMENT CHARACTERISTICS AND DEPOSITION

Storm water characteristically transports a large amount of suspended sediment. Upon reaching the lake, the sediment particles settle and are deposited at or near their point of entry to the lake. These inflow areas may subsequently be colonized by aquatic macrophytes or even wetland plants.

Historically, Onota Lake has experienced such sediment deposition primarily at the northern end. A review of available literature along with bathymetric data (see Section 4) identified two major areas of sediment deposition to the east and west of Thomas Island. To further quantify the extent of the accumulated, unconsolidated sediment, measurements were conducted using a graduated sediment probe which was hand-driven through the loose material to the point of impenetrability. By conducting numerous measurements along a series of transects, sediment depth contours were established (Figure 7.1).

The sediment probes data indicate that appreciable (>0.3 meters) accumulation of sediment exists in the north basin. In the south basin, limited areas along the southwest shore were found to have deposits of organic sediments. These sediment deposits although sporatic were primarily confined to the shoreline parallel to Blythewood Drive and ranged from 0.3 to 1.0 meters in depth. The eastern and southern shore are very rocky and overlaid by sandy sediment. North of the sand bar, sediment deposits were characteristically organic and much less sandy. Deep deposits (1.8-2.0 meters) were recorded along the northwest shoreline. Deposits 1 to 1.2 meters deep were recorded to the north and west of Thomas Island and in Thomas Island Cove. The sediments in the cove included detrital material in the form of macrophyte tissue, deciduous tree leaves, and woody material.

One potential component of a lake restoration plan is the dredging of shallow, filled-in areas. Unconsolidated sediment depth measurements provide a good estimate of the volume of material which could be removed. Table 7.1 presents the surface areas and volumes associated with the 3 to 4 foot, the 2 foot, and the 1 foot sediment removal contours. These data are presented in English as opposed to metric values as this is the conventional method used to project spoil volume and dredging costs. The locations associated with this potential

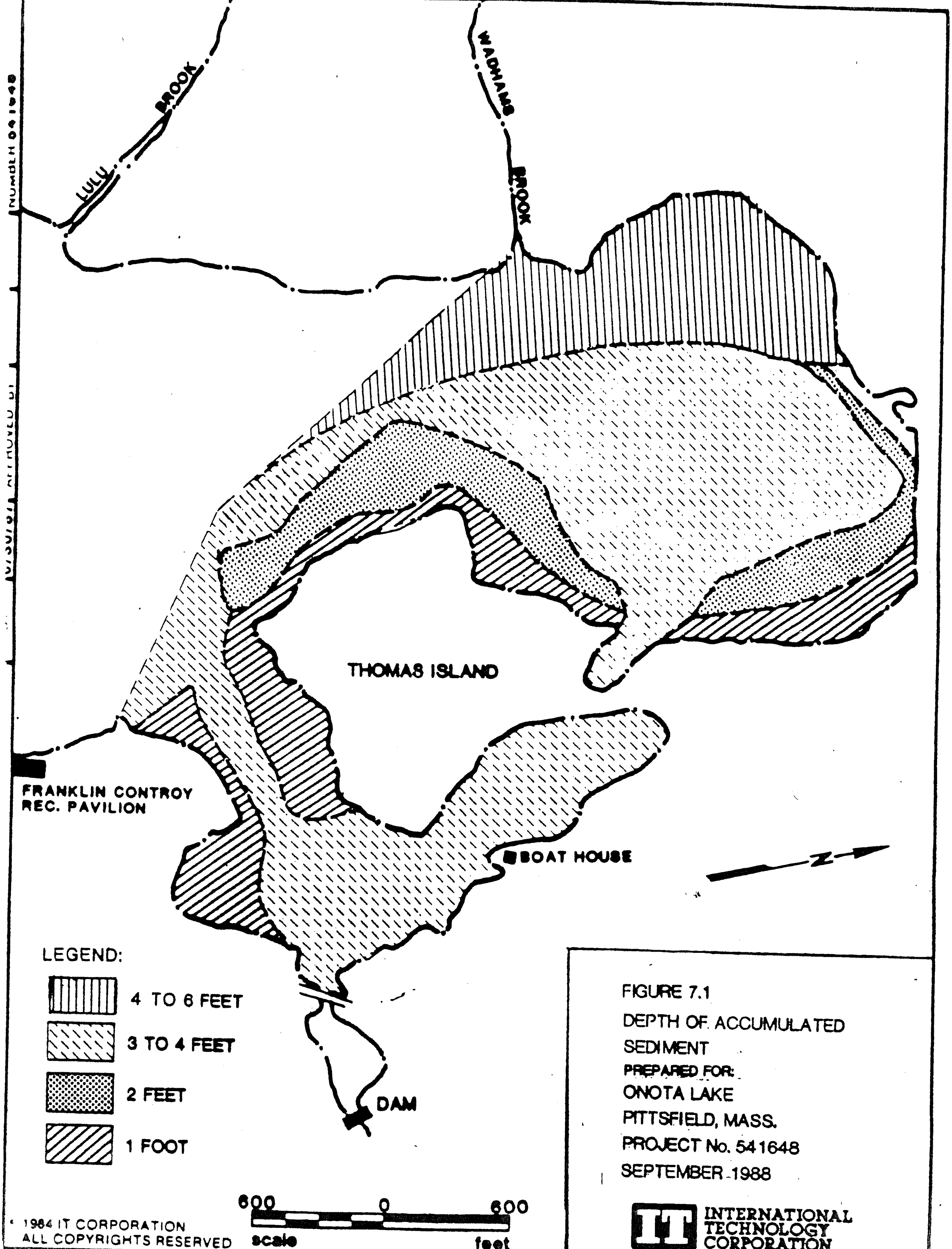

FIGURE 7.1
DEPTH OF ACCUMULATED SEDIMENT
PREPARED FOR:
ONOTA LAKE
PITTSFIELD, MASS.
PROJECT No. 541648
SEPTEMBER 1988

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dredging activity are depicted in Figure 7.2. Dredging of the North Basin appears potentially feasible from a cost/benefit viewpoint. This is the only area of the lake where considerable deposits of sediment occur. A total of 4.28×10^5 yd^3 (429,000 cubic yards) could possibly be removed from the Thomas Island section of the lake; 1.87×10^5 yd^3 from an area west of Thomas Island and 1.54×10^5 yd^3 from an area east of Thomas Island (Table 7.1). The feasibility of dredging will be reviewed in Section 11.0.

An area to the northwest of the lake, in the Wadham Brook vicinity (Figure 7.1) with substantial accumulated sediment is not identified as a potential dredging area. This is due to its importance as a fish breeding/nursery area. Currently colonized by Nuphar advena, this area provides excellent fish habitat due to cover, the rich nature of the sediments and benthic invertebrate forage.

Analysis of the chemical composition of Onota Lake sediments was conducted for samples, collected with a modified K-B free-fall coring apparatus, from the two in-lake water quality monitoring stations (Figure 5.1). Samples were retrieved, transferred to plastic bottles and returned to the IT laboratory for analysis of:

Total nitrogen	Arsenic	Copper	Manganese
Total phosphate phosphorus	Cadmium	Iron	Zinc
Total organic carbon	Chromium	Lead	

The results of these analyses are presented in Table 7.2.

Lead and zinc are among the most prevalent toxic heavy metals found in storm-water runoff (Wilber and Hunter, 1975). Lakes with urbanized watersheds often display elevated levels of these metals in their sediment (Koppen and Souza, 1983). The concentrations of these metals in urban runoff have been quantitatively related to the levels of zinc in automobile tires (an average of 0.73 percent) and lead in gasoline. As a result of that analysis, it has been shown that the average deposition of these metals on road surfaces are 0.0030 g zinc/vehicle km and 0.0049 g lead/vehicle km (Christensen and Guinn, 1979). It would, therefore, be expected that surface runoff from roads would

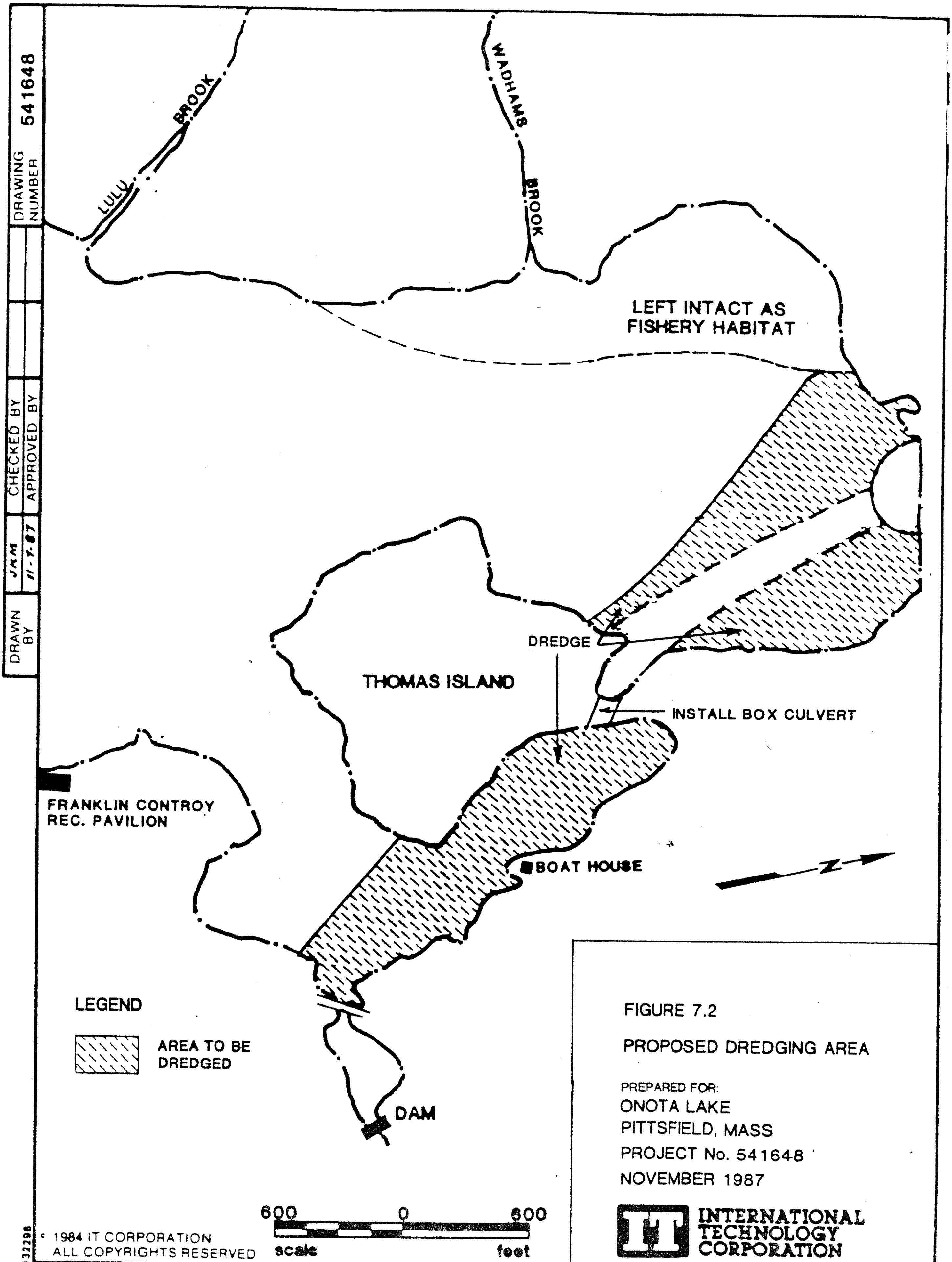

FIGURE 7.2

PROPOSED DREDGING AREA

PREPARED FOR:
ONOTA LAKE
PITTSFIELD, MASS
PROJECT No. 541648
NOVEMBER 1987

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have substantial levels of these metals. Both of these metals were detected in the Onota Lake sediment samples at concentrations considered fairly high. Comparison of the Onota Lake data with sediment data from a representative New Jersey lake with a substantially undeveloped watershed and no motorboat activity (PAS, 1987) reveals that lead and zinc sediment concentrations are an order of magnitude greater in Onota Lake than in the New Jersey lake.

Cadmium, like zinc, is a component of automobile tires (Owe, et. al., 1982) which may be transported into the lake with road surface runoff. The deterioration of galvanized pipe is another source of cadmium in the environment (APHA, 1983). Both cadmium and zinc were detected in low concentration in the sediments samples.

Chromium and manganese, components of automobile bumpers and trim (Sartor and Boyd, 1972), were detected at elevated concentrations, particularly at Station #2. The proximity of major roads to this shallow basin is likely a major cause of this metal contamination.

A common material in electrical and plumbing applications, as well as in various pesticides and herbicides, copper was detected in the lake sediment samples but at low concentrations. The measured values in the north and south basins (52 and 49 ppm respectively) are well within DEP limits stated in 310 CMR 32.00.

Arsenic compounds were often utilized as a pesticide in agricultural applications. Arsenic is very persistent and the historical use of arsenic based compounds may often be reflected in sediments even after a considerable amount of time. A concentration of 25 ppt arsenic is often used as an arbitrary environmental indicator of compromised conditions. The measured levels in Onota Lake (20 ppt) may require special attention be given to the method of sediment removal and disposal if dredging is conducted in the north basin. At a minimum, additional testing is recommended to better define the extent of arsenic contamination. Additional sediment analysis should include EP Toxicity testing to quantify the potential leachability of this material if distributed.

The most abundant metal measured in the sediment core samples was iron. However due to its ubiquitous nature in the environment, high levels of this metal are a natural occurrence.

Due to their role as nutrients that often accelerate the productivity of lake waters, both nitrogen and phosphorus are considered important components of lake sediments (Wetzel, 1983). Phosphorus, and to a lesser extent nitrogen, can be present in lake sediments at concentrations several orders of magnitude greater than in the water column. For the sediment samples analyzed from Onota Lake, the TP concentrations ranged from 2,800 to 3,700 mg/kg and TN concentrations from 9,900 to 16,000 mg/kg. Under anoxic, reducing conditions these nutrients can be liberated from the sediments and recycled to the overlying water. The internal recycling of total phosphorus from the sediments can have a marked influence on the productivity of the lake, particularly if it is a major component of the lake's total phosphorus budget.

Total organic carbon (TOC), a measure of the amount of carbon based material in the sediment, was high for samples from both the deep and shallow basin. TOC concentrations expressed in dry weight were 230,000 mg/kg and 290,000 mg/kg for the south and north basins respectively. Concentrations of this magnitude are common for lake sediments. Silt, algae and other organic materials settle at the bottom of the lake where they accumulate and lend a highly organic quality to the sediments. Sediments from the deep profundal area of a lake are rarely disturbed. As a result, over time, these sediments become characteristically organic.

In Section 10.0, detail is provided relative to the annual influx of sediment via each of the lake's main tributaries. Based on unit area loading estimates. (as developed in Section 10.1 - 10.6), the annual sediment influx per tributary is as follows:

Churchill Brook - 121,830 kg/yr
Daniels Brook - 255,270 kg/yr
Parker Brook - 275,935 kg/yr

Total annual sediment loading to the lake is calculated to be 1,080,118 kg.

TABLE 7.1
SURFACE AREA AND VOLUME OF MATERIAL TO BE DREDGED FROM ONOTA LAKE

Depth of Sediment Removal	Surface Area		Volume Dredged
West of Thomas Island			
3-4 foot	33.1 acres		1.87×10^5 yd^3
2 foot	14.0 acres		4.51×10^4 yd^3
1 foot	16.0 acres		2.58×10^4 yd^3
		Sum	2.58×10^5 yd^3
East of Thomas Island			
3-4 foot	27.3 acres		1.54×10^5 yd^3
2 foot	10.3 acres		1.55×10^4 yd^3
		Sum	1.70×10^5 yd^3
		TOTAL	4.28×10^5 yd^3

TABLE 7.2
ONOTA LAKE SEDIMENT
SAMPLE ANALYSES
OCTOBER 16, 1986

Parameter*	Station #1	Station #2
Total Nitrogen	9,900	16,000
TOC	230,000	290,000
Phosphate-P (Total)	2,800	3,700
Arsenic	20	12
Cadmium	1.4	0.83
Chromium	15	53
Copper	49	52
Iron	43,000	53,000
Lead	220	160
Manganese	690	1,600
Zinc	260	210

*Note: All results expressed as mg/kg dry wt.

8.0 WASTEWATER DISPOSAL PRACTICES

Properly operating onsite wastewater disposal systems usually contribute very little to the nutrient budget of lakes (Lee, et. al. 1978). In contrast, faulty systems contribute a significant nutrient load which can stimulate the development of aquatic primary producers to nuisance densities (Kerfoot, 1979). Total phosphorus loads associated with domestic wastewater (kitchen, toilet, bath and laundry) can be as much as 1.5 kg/capita/yr (Ligman, et. al, 1974). Faulty septic waste disposal systems located close to the shoreline could therefore have a serious impact on the trophic status of the lake.

In many lakefront developments, failing septic systems are often attributed to oversaturation of the leach field due to a seasonal elevation of water table height, hydraulic overloading of the system due to overcrowding of vacation homes and conversion of seasonal dwellings to permanent dwellings, or the formation of clogging mats in the leach field which significantly impair wastewater percolation. These problems are often compounded by installation of systems of improper design or capacity and by use of septic systems in areas with soils of poor absorption quality. All the above conditions reduce the ability of the soils to properly remove nutrients by sedimentation, absorption, filtration or biochemical oxidation (Otis, 1979). The area in immediate proximity to the lake's shoreline will also be more sensitive to these conditions due to water table height and limited soil depth available for bacterial degradation and soil absorption (Kerfoot, 1980). This may result in the discharge of waste-contaminated ground water plumes from these shoreline dwellings and the localized elevation of sediment-nutrient concentrations. In turn, by reducing or eliminating such discharges, noticeable improvements in water quality and substantial reduction in localized plant growth can be garnered (Otis, 1979).

Septic leachate entering the lake carries with it dissolved nitrate, ammonia, phosphate, and organic substances. These nutrients stimulate the growth of bacteria, algae and aquatic macrophytes, which in turn may effect the recreational and potable use of the water.

In order to determine the importance of septic systems on nutrient loading to the lake, a portable fluorescence - conductivity meter, commonly called a "septic snooper", was used to detect improper wastewater discharge. The discharge, referred to as a septic plume, is caused by the faulty operation of onsite disposal systems, and results from the active emergence of septic waste contaminated ground water into the lake (Kerfoot, 1980). Under such conditions the septic effluent has not had sufficient time to percolate through the soils, and is usually characterized by elevated organic and inorganic constituents.

As water is pumped through the "septic snooper", conductance and fluorescence are monitored continuously. In principle, wastewater effluent is partly comprised of a mixture of near UV fluorescent organics derived from laundry whiteners, surfactants and natural degradation products, and conductive inorganics, such as chloride (Cl^-) and sodium (Na^+). By monitoring these parameters in the form of fluorescence and conductance, a leachate plume can be detected as it emanates from the shoreline. This results in three general conditions:

1. Elevated fluorescence
2. Elevated conductance
3. Elevated fluorescence and conductance

The third condition is indicative of septic contamination whereas the other two may indicate "grey water" contamination, ground water intrusion, or discharge from streams, bogs, or marshes. At those sites where both fluorescence and conductivity were elevated, water quality and bacteriological samples were collected. Analysis of these samples helped verify or refute the existence of a septic plume.

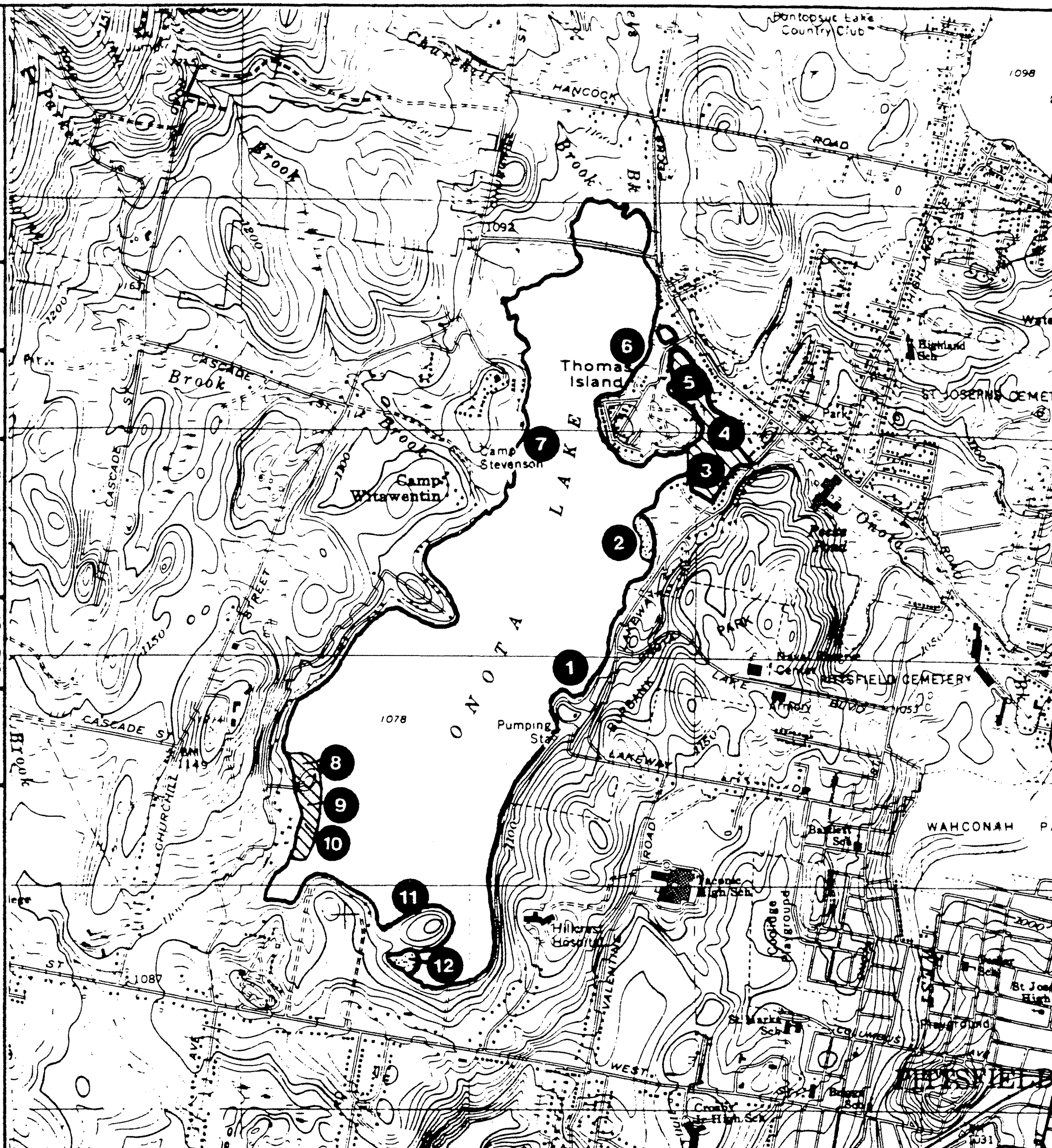
A septic leachate survey was conducted along the entire shoreline of Onota Lake on August 13 and 14, 1986. A number of septic leachate plumes were encountered in the survey of Onota Lake (Figure 8.1) The highest meter readings were located primarily along the Blythewood Drive shoreline and in the cove to the east of Thomas Island. The plume detected in both these areas was broad and non-distinct. More localized plumes were detected in the cove adjacent to the peninsula at the south end of the lake, and adjacent to the

Franklin H. Controy Recreation Pavilion. Both the Blythewood Drive and Thomas Island Cove plumes represented broad areas of diverse contamination, the latter condition being exacerbated by the restricted flow in the cove. The other two suspected plumes were more discrete in nature representing a more distinct source of septic leachate infiltration, perhaps indicative of individual septic failures encountered.

A number of water samples were collected to verify whether the observed readings were septic related. A total of 12 water samples were collected during the Septic Snooper Survey and analyzed for total coliform bacteria, fecal coliform bacteria, nitrate nitrogen, and chloride. The results of these analyses are presented in Table 8.1.

The parameter most substantially elevated in all samples was total coliform bacteria. While bacterial contamination is evident, it can not definitively be attributed to septic leachate as all August in-lake water quality samples displayed elevated total coliforms concentrations (see Section 5.1.10). The one exception was the sample collected from Thomas Island Cove. This sample result suggests the presence of sewage contamination. The homes in this area are serviced by city sewer rather than individual septic systems, therefore, the problem was not attributable to septic leachate intrusion. Further investigation of the problem following a discussion with Pittsfield DPW officials disclosed a break in the sewer line along Pecks Road.

The broad plume along Blythewood Drive is indicative of general conditions of malfunctioning or improperly designed septic systems. It underscores the need for widespread system maintenance or sewering in this section of the watershed. Throughout this study and as documented in previous reports, the septic problem along Blythewood Drive has been identified as a problem requiring immediate attention. The contribution of septic loading to the total nitrogen and phosphorus budgets is small relative to non-point source inputs (Section 10). However, as this section of the lake becomes increasingly developed the contribution will become increasingly significant. This area represents one of the few sections of the watershed likely to be developed in the future. Immediate action is needed to protect the lake from future septic related perturbations.



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LEGEND:

1 SAMPLE LOCATION

AREA OF BROAD CONSISTENTLY HIGH READINGS

AREA OF MORE CONFINED HIGH READINGS

SOURCE:
U.S.G.S. 7.5' TOPOGRAPHIC QUADRANGLE

FIGURE 8.1
AREAS OF POTENTIAL SEPTIC LEACHATE EXCURSION INTO ONOTA LAKE

PREPARED FOR:
ONOTA LAKE PITTSFIELD, MASS.
PROJECT No. 541648
SEPTEMBER 1988

INTERNATIONAL TECHNOLOGY CORPORATION

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TABLE 8.1
RESULTS OF SEPTIC SNOOPER SAMPLE RESULTS
8/14/86, ONOTA LAKE

Parameter	Conc. 1	1	2	3	4	5	6	7	8	9	10	11	12
Fecal Coli	#col/100 ml	8	<4	104	24	8	8	.2	<4	8	<4	<4	*
Total Coli	#col/100 ml	340	TNTC	360	1340	540	1000	460	1300	TNTC	440	180	*
NO_3-N	mg/l	0.06	0.10	0.07	<0.01	0.12	0.03	<0.01	0.01	0.06	0.01	0.02	0.03
CL	mg/l	5.5	6.0	4.0	9.0	6.5	6.0	5.0	5.0	5.0	5.0	5.5	5.0

* TESTS NOT RUN, insufficient sample volume
II See Figure 8.1 for station location

Sewering of remaining areas which rely on the use of individual on-site septic systems is a major concern of residents and lake users. This is supported by the results of questionnaires and public comment at numerous lake restoration meetings. Individuals who live on Blythewood Drive are particularly anxious to have this area sewered. Although sewering will alleviate the identified problem of septic leachate contamination of the lake, it may encourage additional development. Heavy development of many of these areas could pose as great an impact to lake water quality as faulty septic systems. Areas such as Blythewood Drive have shallow soils, a high seasonal water table and relatively steep slopes. To combat intense development of such areas following sewering, stricter zoning and new ordinances (steep slope, sensitive environment, etc.) may be warranted. This is discussed further in Section II, the Restoration/Management Plan.

To further facilitate the examination of current wastewater disposal practices, a questionnaire was distributed to all residents living within 300 meters of the lakeshore (Table 8.2). Emphasis was placed on canvassing areas of the lake which are non-sewered. Three hundred-fourteen (314) questionnaires were distributed and ninety-five (95) were returned. Since the questionnaire also addressed recreational use of the lake, some questionnaires were distributed to residents living in areas of the watershed which are currently sewered.

The only densely populated area of the watershed not currently sewered is the Blythewood Drive section, located along the extreme southwest shoreline of the lake. There are approximately 30 dwellings along Blythewood Drive, most of which are within 100 feet of the shoreline. Thirty-three of the survey respondants used a septic system for wastewater treatment and disposal. The survey results suggest that 60% of these dwellings are utilized year round. Average occupancy appears to be 3-5 residents. Only 20% of those using a septic system had to alter their systems, but most alterations (63%) were due to malfunctioning disposal fields and pipes.

There were also reported problems with odor and sewage backup. A small number of residents on septic systems admitted to not having their tanks pumped at all. This could lead to odor and sewage backup, and insufficiently treated leachate reaching the lake. The majority of respondants however appeared conscious of the problems caused by faulty septic systems and reported their tanks pumped every one to two years.

TABLE 8.2

SUMMARY OF RESPONSES TO ONSITE WASTEWATER DISPOSAL SYSTEM

Number Distributed - 314
Number Returned - 95

TYPE OF ONSITE WASTEWATER DISPOSAL SYSTEM (PERCENT)	
Septic Tank	35%
Cess Pool	2%
Sewer	61%
No Response or Did Not Know	2%

ALTERATION OR IMPROVEMENT OF SYSTEM (PERCENT)	
None	32%
Altered/Improved	20%
No Response	48%

ALTERATION (PERCENT)	
Enlarge	26%
Malfunction	63%
Both	11%

TYPICAL PROBLEMS WITH SYSTEM (NUMBER)*	
None	40
Odor	5
Backup Into House	4
No Response	46

CAUSE OF PROBLEMS WITH SYSTEM (NUMBER)*	
High Water Table	6
Slowly Permeable Soils	5
Other	2
No Response	83

*Some responded to more than one category.

TABLE 8.2
SUMMARY OF RESPONSES TO ONSITE WASTEWATER
DISPOSAL SYSTEM (Continued)

Number Distributed - 314
Number Returned - 95

LOADS OF LAUNDRY PER WEEK (PERCENT)	
1-5	42%
6-10	12%
11-15	6%
16-20	3%

DETERGENTS USED (NUMBER)*			
LAUNDRY		DISH	
Tide	14	Dawn	4
Bold	1	Joy	2
Cheer	3	Ivory	9
Arm & Hammer	5	Palmolive	12
Oxydol	1	Cascade	4
Solo	2	#?	1
Wisk	14	Ajax	4
Dash	1	Dove	2
All	4	Octagon	1
Era	3	Sunlite	5
Fab	1	Calgon	3
Fresh Start	1	Electrosol	3
Cold Power	1	All	1
Ivory Snow	2	Any Brand	5
Ajax	2		
Any Brand	6		

*Some responded to more than one category.

9.0 HYDROLOGIC BUDGET

Tributary inflow, surface runoff, precipitation, evaporation, and ground water infiltration data were used to calculate the volume of water annually entering and leaving the lake. Hydrologic loading due to precipitation falling directly onto the lake, and normalized stream flows were calculated on the basis of the historical rainfall data. In this way, the hydrologic budget would be more amenable for use in the long term management of the lake. The methodology and results of the hydrologic budget are presented in detail in the following sections.

9.1 PRECIPITATION/EVAPORATION

The NOAA thirty year average precipitation data, as recorded at the Stockbridge, Massachusetts monitoring station were compared to rain gage monitoring data recorded during 1986-1987 by LOPA volunteers. The NOAA data were disparate with the majority of the 1986-1987 rain gage data for those months where simultaneous collections were available for comparison (Table 9.1). Noticeable differences occurred in June, July and August, 1986 when unseasonably greater rainfall than the thirty-year average was measured (approximately 2 times greater than normal). In April and May, 1986 rainfall was significantly less than the thirty year average. The hydrologic load associated with precipitation onto the lake was calculated using the monthly 30 year average data for the annual contribution. The sum of the monthly averages was determined to be 1.11 m/yr (Table 9.1). Based on this value and a total lake area of $2.5 \times 10^6 m^2$, the annual contribution of precipitation falling directly on the lake would ge calculated as:

$$1.11 \text{ m/yr} \times 2.5 \times 10^6 m^2 = 2.78 \times 10^6 m^3/yr$$

Evaporative losses from the surface of the lake were determined using the isopleths developed by Hely, et. al. (1961). This method entails the use of USGS pan evaporation rates. Based on the geographical and limnological characteristics of Onota Lake, an evaporation coefficient of 75 cm/yr was selected. The hydrologic loss from the lake's surface caused by evaporation is calculated as:

$$0.75 \text{ m/yr} \times 2.50 \times 10^6 \text{ m}^2$$

$$= 1.88 \times 10^6 \text{ m}^3\text{/yr}$$

Net contribution of precipitation falling directly onto the lake's surface when corrected for evaporative losses would be 9.0×10^5 m^3/yr.

9.2 TRIBUTARY INFLOW

Hydrologic inputs from the ten sub-basins were determined using an empirical precipitation-stream discharge formula (Dunn and Leopold, 1978) and the thirty year average monthly precipitation data Table 9.2. The empirical stream discharge formula is given as:

$$Q = CIA\ (0.278)$$

where C = runoff coefficient

I = rainfall intensity (mm/hr)

A = area of sub basin (km_2)

Q = stream flow (m^3/sec)

This approach was necessitated as much of the surface inflow to the lake is from small streams, swales, and diffuse non-gaugable sources. The inflow data obtained by this method is a reasonable estimate, comparable, in terms of inherent error, with measured discharge methods (Scheider, et al., 1979). Inflow to the lake was calculated for each of the subbasins on a monthly basis (Table 9.3). Summation of the monthly inflow calculations was used to estimate tributary influx. These data were checked against those months when runoff was normal (as based on comparison of measured and historical rainfall). Agreement was deemed acceptable. Tributary inflow was calculated to be 5.50 X 10^6 m^3yr^{-1}.

9.3 OUTFLOW

Outfow from the lake were monitored routinely by LOPA volunteers. A staff gage was erected at the spillway and was calibrated on 13 dates by IT personnel (Table 9.4). The calibration points were utilized to develop an outflow regression equation (Table 9.5). The resulting regression equation, Y = 78.99 x -12.24, was used to calculate the annual outflow volume. A Spearman's correlation coefficient (r = 0.88) supported this methodology. The mean gage height as calculated from the data collected by IT personnel was 0.504 feet or 0.155 (Table 9.4). Applying this value to the equation results in a discharge of 27.07 ft^3/sec or 0.766 m^3/yr (Table 9.5). Using this value, the annual discharge volume was calculated to be:

$$27.07\ ft^3/sec \times 3.15 \times 10^7\ sec/yr$$

$$= 8.53 \times 10^8\ ft^3/yr$$

or

$$24.1 \times 10^6\ m^3/yr.$$

During the 1986 study year, a short term drawdown was conducted for dock/shoreline repair. The lake was drawn down approximately 3 feet (Sanginelli personal communication, 1990). This volume reduction was accounted for by calculating the total volume lost during drawdown which would have been last via the outflow. The volume lost during drawdown would be:

$$3\ feet \times 617\ acres$$

$$= 1851\ acre\text{-}feet$$

or

$$2.28 \times 10^6 m^3$$

Correcting for this excess release, the annual outflow volume was calculated as:

$$24.1 \times 10^6 m^3 - 2.28 \times 10^6 m^3$$

$$= 21.8 \times 10^6 m^3/yr$$

Based on this analysis outflow from Onota Lake totaled 21.8 X 10^6 m^3/yr.

9.4 GROUND WATER

There are two components to ground water inputs: that which feeds directly into the lake and that which seeps into tributaries which in turn feed the lake. Ground water which seeps directly into the lake may occur at discrete points (springs) and at diffuse sources along the shoreline or in the littoral zone. Ground water which seeps into tributaries constitutes part of the surficial aquifer. It represents precipitation which has infiltrated the overlying strata and has exceeded soil moisture needs and vegetative evapotranspiration loss. Such inputs are usually greatest during spring and fall because evaporation losses and water uptake by plants are low. Winter (1979) discusses the role of these different ground water flows and their interaction in a lake's hydrologic budget. In areas of considerable seeps and fractured bedrock geology, such as the Berkshires, an appreciable amount of this recharge feeds tributaries (Posten, 1982). To account for this potential component of the hydrologic budget, the ground water runoff methodology of Posten (1982) was applied to those sub-basins which drain to Onota Lake via a stream. For those sub-basins where drainage to the lake is via surface runoff, ground water contributions to the lake were assumed to result from seepage along the shoreline or nearshore littoral areas. It was also assumed that ground water recharge would occur primarily only during those months when soil moisture needs were low, plant uptake minimal and evaporation inconsequential, typically November through April (Dunne and Leopold, 1978). This assumption seems to apply to streams in the Onota Lake watershed. In 1986, even with the unseasonably large amount of rain, stream flow in three of the four monitored tributaries was low from June through August. Based on a rate of 7.2 X 10^2 $m^3/d/km^2$, applied to sub-basins III, IV, V, VI, VII, and VIII for 210 days (November through April), a recharge value of 5.16 X 10^6 m^3/yr was obtained. This represents the volume of ground water which seeps into the lake's tributaries (Table 9.6).

Ground water contributions resulting from diffuse seepage into the littoral area of the lake and discrete springs were estimated as the difference between total inflow and total outflow. Based on this approach, direct ground water influx to the lake is calculated to be 3.60 x 10^6 M^3. Unconfirmed reports suggest there is substantial spring activity in the lake's south basin. Attempts were made to quantify this on two occasions late September, and mid-N ovember, 1986. Seepage meters constructed from 20 gallon metal trash cans (Lee, 1977) were driven into the substrate at three locations suggested to IT personnel where spring activity was suspected. The three monitored stations were along the southeast shoreline, within 50 feet of shore. The substrate was coarse sand to gravel and water depth ranged from 6 to 10 feet. After 24 hours the meters were inspected by divers and on both dates very little, if any, influx of water had occurred.

An additional evaluation of the ground water loading estimate was developed through comparison of the Onota Lake estimate and a ground water influx value mathematically generated for Lake Buel, Montery/New Marlborough, Massachusetts (IEP, 1982). Lake Buel and Onota Lake are in the same physiographic province, of the same geological history and share similar soil types. The shoreline of Lake Buel is approximately 17,400 feet, which is 0.455 the length of Onota. The ground water favorability study and permeability analysis of Lake Buel revealed annual ground water inflow to amount to 3.2 to 3.8 X $10^6 m^3$. As Onota's shoreline is 2.2 times that of Lake Beul, an annual ground water inflow of 7.04 to 8.4 X 10^6 m^3 would be predicted using the same approach as in the Lake Beul study. The predicted Onota Lake ground water contribution from direct seepage (3.6) is 8.7 X $10^6 m^3$yr. This value is similar to that obtained using the Lake Buel methodology. As such, the ground water influx to Onota Lake as computed in this study was deemed reasonable.

9.6 HYDROLOGIC BUDGET

Summing the various components of the hydrologic budget yields an annual net water balance of 4.8 X $10^6 m^3$/yr (Table 9.7). Given a lake volume of 15.98 X 10^6 m^3, the annual flushing rate is 1.28 times/year. The inverse of the flushing rate, residence time is 0.78 years.

Areal water load (qs) is an important function in the determination of phosphorus retention. The ratio of annual lake inflow to lake surface area (Q/SA) is used to compute a qs. For Onota Lake, qs was calculated to be 6.8 m/yr.

TABLE 9.1

NOAA AVERAGE AND MEASURED PRECIPITATION

RECORDED FOR ONOTA LAKE

MONTH	TOTAL MONTHLY PRECIPITATION 30 YEAR MONTHLY AVERAGE (NOAA DATA) (INCHES)	AS MEASURED DURING STUDY (INCHES)
JAN	3.17	--
FEB	2.71	--
MARCH	3.51	--
APRIL	3.94	0.25
MAY	3.77	1.87
JUNE	3.69	7.83
JULY	3.89	8.28
AUG	4.27	6.33
SEPT	3.95	2.14
OCT	3.40	3.18
NOV	3.81	--
DEC	3.62	--

TABLE 9.3
VOLUME OF PRECIPITATION AND VOLUME OF EVAPORATIVE WATER LOSS FROM THE SURFACE OF ONOTA LAKE

Surface area of lake....................................	$2.5 \times 10^6 m^2$
Precipitation on lake's surface*..........................	$2.75 \times 10^6 m^3$
Evaporative loss**..	$1.875 \times 10^6 m^3$
ANNUAL TOTAL NET GAIN DUE TO DIRECT PRECIPITATION	$0.875 \times 10^6 m^3$

* Based on historical thirty year average rainfall data

** Based on a pan evaporation coefficient of 0.75 m/yr

TABLE 9.2

TRIBUTARY AND SURFACE RUNOFF

CONTRIBUTIONS TO THE ANNUAL HYDROLOGIC BUDGET

OF LAKE ONOTA*

MONTHLY RUNOFF VOLUMES IN M^3

SUB-BASIN**	RUNOFF COEF	JAN	FEB	MARCH	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	
I	0.5	7.31×10^5	6.92×10^5	8.1×10^5	7.8×10^4	7.45×10^4	7.3×10^4	7.7×10^4	8.4×10^4	7.8×10^4	6.75×10^4	7.55×10^4	7.15×10^4	
II	0.4	3.25×10^5	3.85×10^5	3.60×10^5	3.46×10^4	3.32×10^4	3.24×10^4	3.42×10^4	3.74×10^4	3.46×10^4	2.99×10^4	3.35×10^4	3.18×10^4	
III	0.3	7.29×10^4	6.90×10^4	8.08×10^4	7.77×10^3	7.44×10^3	7.29×10^3	7.68×10^3	8.4×10^3	7.77×10^3	6.72×10^3	7.53×10^3	7.14×10^3	
	IV	0.3	7.55×10^4	7.12×10^4	8.33×10^4	8.01×10^3	7.68×10^3	7.50×10^3	7.92×10^3	8.64×10^3	8.01×10^3	6.93×10^3	7.74×10^3	7.35×10^3
V	0.2	1.43×10^5	1.36×10^5	1.59×10^5	1.53×10^4	1.47×10^4	1.43×10^4	1.51×10^4	1.65×10^4	1.53×10^4	1.32×10^4	1.48×10^4	1.41×10^4	
VI	0.25	2.02×10^6	1.92×10^6	2.24×10^6	2.16×10^5	2.07×10^5	2.02×10^5	2.14×10^5	2.34×10^5	2.16×10^5	1.87×10^4	2.09×10^5	2.00×10^5	
VII	0.25	7.27×10^5	6.88×10^5	8.06×10^5	7.75×10^4	7.42×10^4	7.25×10^4	7.65×10^4	8.38×10^4	7.75×10^4	6.7×10^4	7.4×10^4	7.12×10^4	
VIII	0.25	1.49×10^6	1.40×10^6	1.42×10^5	1.59×10^5	1.52×10^5	1.49×10^5	1.57×10^5	1.72×10^5	1.59×10^5	1.37×10^5	1.54×10^5	1.46×10^5	
IX	0.6	3.39×10^5	3.21×10^5	3.23×10^4	3.62×10^4	3.47×10^4	3.39×10^4	3.58×10^4	3.91×10^4	3.62×10^4	3.13×10^4	3.50×10^4	3.32×10^4	
X	0.6	4.33×10^5	4.09×10^5	4.12×10^4	4.61×10^4	4.42×10^4	4.32×10^4	4.56×10^4	4.98×10^4	4.61×10^4	3.98×10^4	4.46×10^4	4.26×10^4	
TOTAL		6.35×10^6	6.09×10^6	6.06×10^5	6.78×10^5	6.50×10^5	6.35×10^5	6.71×10^5	7.34×10^5	6.78×10^5	4.15×10^5	6.56×10^5	6.25×10^5	

* Calculated using rational formula (Dunne and Leopold, 1978), based on 30 year ave rainfall.

** Refer to figure 4.1 for location of sub-basins.

TABLE 9.4
FLOW/STAFF GAGE RELATIONSHIP
FOR THE OUTFALL (SPILLWAY) OF
ONOTA LAKE

Calibration (Date)	Flow (ft^3/s)	Staff Gage Height (ft)
4-8-86	84.1	0.85
5-6-86	11.5	0.26
6-3-86	11.9	0.15
6-24-86	29.2	0.62
7-22-86	7.4	0.20
8-13-86	26.0	0.52
9-9-86	2.3	0.15
9-24-86	15.6	0.41
10-16-86	18.6	0.50
11-13-86	73.4	1.05
12-16-86	23.8	0.60
1-20-87	25.7	0.66
2-18-87	26.2	0.58

N = 13

* 0.155

5D+/- = 0.0834

TABLE 9.5

RESULT OF LINEAR REGRESSION

CONDUCTED ON FLOW/STAFF GAGE

DATA RECORDED AT ONOTA LAKE

OUTFALL (SPILLWAY)

Y = 78.99 x -12.42

Staff* Gage Ht X value	Flow** Predicted Y	Population 95% C.L.***		Individual 95% C.L.	
0.2000	3.3759	-7.8798	14.6316	-25.3379	32.0897
0.3000	11.2750	1.9723	20.5776	-16.7309	39.2809
0.4000	19.1740	11.2870	27.0611	-8.3940	46.7421
0.5000	27.0731	19.7459	34.4003	-0.3400	54.4862
0.6000	34.9722	27.1627	42.7817	7.4262	62.5181
0.7000	42.8713	33.7003	52.0422	14.9088	70.8337
0.8000	50.7703	39.6779	61.8627	22.1202	79.4205
0.9000	58.6694	45.3355	72.0034	29.0791	88.2597
1.0000	66.5685	50.8089	82.3281	35.8089	97.3281
1.1000	74.4676	56.1714	92.7638	42.3344	106.6008
1.2000	82.3666	61.4631	103.2701	48.6806	116.0527
1.3000	90.2657	66.7077	113.8237	54.8712	125.6602
1.4000	98.1648	71.9194	124.4101	60.9276	135.4020
1.5000	106.0639	77.1074	135.0203	66.8686	145.2591
1.6000	113.9629	82.2778	145.6481	72.7108	155.2151
1.7000	121.8620	87.4347	156.2894	78.4681	165.2560
1.8000	129.7611	92.5811	166.9411	84.1525	175.3697
1.9000	137.6602	97.7192	177.6011	89.7742	185.5462
2.0000	145.5593	102.8507	188.2678	95.3416	195.7769
2.1000	153.4583	107.9766	198.9400	100.8620	206.0547
2.2000	161.3574	113.0981	209.6167	106.3415	216.3733
2.3000	169.2565	118.2157	220.2972	111.7852	226.7278
2.4000	177.1556	123.3302	230.9809	117.1975	237.1136

* Height of water at outfall in feet

** Flow in ft^3/s

*** Confidence limits of predicted flow

TABLE 9.6

GROUND WATER RECHARGE TO

TRIBUTARIES OF ONOTA LAKE

Sub* Basin	Sub-Basin Area (km^2)	Ground water** Loading $10^2 m^3/d/km^2$	Number*** Of Days	Recharge Vol. X $10^4 m^3/yr$
III	2.59	7.20	210	0.392
IV	2.67	7.20	210	0.404
V	7.65	7.20	210	1.16
VI	8.65	7.20	210	1.31
VII	3.10	7.20	210	0.464
VIII	6.35	7.20	210	0.960
			TOTAL	4.69 X $10^4 m^3/yr$

* Applied only to those sub-basins with a runoff coefficient (R) < 0.4, in those sub-basins with R >0.4, the % impervious area is probably too great to allow for significant infiltration.

** Posten, 1982

*** November - April (210 days), that time of year when there exists enough soil moisture to allow for recharge.

TABLE 9.7

HYDROLOGIC BUDGET OF ONOTA LAKE

Inputs

	$10^6 m^3/yr$
• Tributary and Surface Runoff Inputs	7.36
• Precipitation directly on lake surface corrected for evaporation	0.875
• Ground water recharge and subsequent * influx of surplus to tributaries	0.0469
• Direct seepage of ground water to ** lake.	8.70
TOTAL INPUT BUDGET	17.0

Outputs

• Total Annual Outflow	21.8
	-4.8***

* Represents ground water recharge which occurs only during those periods when soil moisture demands exceeded. Based on loading coefficient established by Posten (1982).

** Difference between outflow and inflow.

*** Represents the net loss of water volume annually

10.0 NUTRIENT LOADING AND LAKE TROPHIC STATE ANALYSIS

10.1 SEDIMENT/NUTRIENT BUDGET

An important step in the development of a successful lake restoration action plan is the accurate calculation of the sediment and nutrient budgets. These data provide insight relevant to the trophic dynamics of the lake. The nutrient budget is the quantification of the various sources of nitrogen and phosphorus. The amount of phosphorus and nitrogen annually contributed to the lake is referred to as the annual load. The magnitude of the annual load will greatly influence the productivity of the lake. The nutrient budget therefore is an important determinant of lake trophic state. The sediment budget provides an estimate of the annual influx of eroded soils, occurring naturally and as a result of human activity. Nutrients display a high affinity to soil particles, particularly phosphorus which adsorbs to the surface of particulate material. As well as serving as a source or vehicle for nutrients, sediment contributions may increase turbidity, decrease flood storage volume, create deltas which are in turn colonized by macrophytes and alter flow and flushing patterns in lakes.

Nutrients and sediments may be of natural sources, anthropogenic sources, or natural sources exacerbated by human activity. In any case, it is important that all major sources be identified and accurately quantified. It is also important that the nature of sediment and nutrient influx, whether point, non-point or internal, be established. Such data are provided through the development and calculation of the nutrient and sediment budgets. In the case of Onota Lake, there are no point sources of pollutants. The major vectors of nutrients and sediments are tributaries and runoff (non-point sources), septic systems, atmospheric contributions and internal sources. The relative contribution of these sources are discussed below.

10.2 CALCULATION OF THE NON-POINT SOURCE LOADS

Unit areal loading (U.A.L.) methodology was utilized to calculate annual non-point source phosphorus, nitrogen and sediment loads. An approach similar to that in the Clean Lakes Program Guidance Manual (EPA, 1980) was utilized. The EPA provides a range of non-point source loading coefficients for various land uses and development scenarios. Based on site-specific conditions for the Onota Lake watershed (slope, cover, soils, residential density, etc.) coefficients were selected from the EPA values (Table 10.1). Once the coefficients were established, the watershed was delineated into sub-watershed basins, and the area of each watershed sub-basin calculated. U.S.G.S. 7.5 minute topographic contour maps, tax maps, zoning maps and available data (BCRPC, 1978) were reviewed to establish land use activity within each watershed sub-basin. A ground truthing reconnaisance was then conducted to confirm and refine land use patterns. Land use patterns were defined as follows:

- High Density Residential - one or more housing units/acre or 2.5 or more units/hectare;
- Low Density Residential - less than one housing unit/acre or less than 2.5 units/hectare;
- Commercial - business, industry, airports, and parking lots; land use in which the majority of the area is impervious;
- Disturbed - Open - landfills and construction sites, areas of barren, undeveloped land use characterized by exposed soils, lacking substantial vegetative cover;
- Covered - Open - vacant lots, parks, large lawn areas; land use which has no appreciable canopy and sparse to dense vegetative cover;
- Agriculture - active productive farmland;
- Forested - areas covered by tree canopy.

For each land use category, an annual load was generated by multiplying the appropriate loading coefficient, specific for each land use, by the area of that land use type occurring in each of the watershed sub-basins. This non-point source load accounts for loads originating from each land use and conveyed to the lake as a result of storm runoff. Land use within each sub-basin was detailed in Section 4.0.

Review of the unit areal, non-point source loading data show that the lake's major nutrient and sediment loads originate from watershed sub-basin's VI, VII and VIII, the lake's three largest sub-watersheds (Table 10.2). However, on a per unit area basis, the greatest loads are from sub-watershed I. Land use in this sub-watershed is a combination of open-covered and high density residential land use types.

10.3 CALCULATION OF THE SEPTIC LOAD

Nutrient contributions resulting from septic sources were also accounted for in the development of the nutrient budget. The only major residential area within Onota Lake's watershed still not sewered is located along Blythewood Drive, sub-watershed II. Phosphorus originating from septic systems can be a significant component of a lake's nutrient budget and greatly affect in-lake productivity (PAS, 1984). In addition, excessive nitrate contributions can pose a health hazard if potable water sources become contaminated by improperly treated septic effluent. Ligman, et al (1974) reports the phosphorus load of domestic wastewater may be as great as 1.5 kg/capita/yr. Under proper operating conditions, septic systems effectively treat wastewater and minimize nutrient, as well as bacteriological, contamination of ground water or surfacewater. In a lake front setting, however, conditions such as high ground water table, sub-optimal soils and high density development; challenge the effectiveness of septic treatment. Unfortunately, many lake community residences originated as seasonal homes with wastewater disposal systems totally incapable of meeting the needs of year-round, full time residency. Often, as the summer homes become converted to year-round dwellings, there is no upgrading of the system.

The septic snooper survey indicated that the Blythewood Drive area may be contributing nutrients originating from improperly functioning systems.

There are approximately 50 dwellings on Blythewood Drive. Assuming year-round residency, and a per capita density per house of 3.5, yields 175 residents. This is possibly a conservative, over-estimate, of the actual Blythewood Drive population, but a reasonable estimate of the potential user population of this area. Using the National Eutrophication Survey (NES, 1975) loading coefficients for marginally operating septic systems located within 100 meters of a lake shoreline (TN = 4.39 kg/c/yr, TP = 1.07 kg/c/yr), the estimate of the annual TN and TP septic loads are 768.3 kg/yr and 188.2 kg/yr respectively.

Based on these data the septic load presently contributed to the lake is low. The phosphorus load is equivalent to that entering via precipitation and the nitrogen component is equivalent to the dryfall contribution. However, this does not suggest that this nutrient source should be ignored. These sources, both the Pecks Road sewer line leak and the Blythewood Drive septic systems, require immediate attention. These are much easier nutrient sources to control than the non-point storm runoff and soil erosion sources. In addition, these sources represent a vector by which bacteria and possibly pathogens enter the lake.

10.4 INTERNAL REGENERATION OF PHOSPHORUS

An often overlooked component of a lake's nutrient budget is the phosphorus load which is regenerated internally. Sedimentation processes result in particulate phosphorus being deposited in the bottom of the lake. This phosphorus is typically in a form not directly bio-available to phytoplankton or benthic algae. However, under anoxic conditions, the ferric-phosphate complexes are chemically altered and phosphorus undergoes desorption (Freedman and Canale, 1977). This can result in a phosphorus load significant enough to stimulate algal bloom even after a significant reduction in the external load (Welch and Rock, 1980). Most often the liberated phosphorus, due to stratification, is concentrated in the hypolimnion well below the euphotic boundary. Occasional mixing effects may erode the metalimnetic/hypolimnetic layer and distribute small concentrated pulses into the euphotic zone (Kortmann, et al., 1982). However, it is usually not until the fall turnover that the hypolimnetic phosphorus stores are transported in mass into the euphotic layer. This mixing process and resulting phosphorus load may trigger an autumnal algae bloom. This appears to be occurring in Onota Lake.

Sedimentary phosphorus regeneration has been studied extensively under laboratory and field conditions. The EPA (1980) provides a wide range of phosphorus loading coefficients for anaerobic sediments. Nurnburg (1984) devloped a series of internal loading coefficients based on a large sample of North American lakes reviewed in the literature. Based on Onota Lake's geographical and limnological characteristics an anoxic sediment TP loading rate of 6 $mg/m^2/day$ was selected. Souza and Koppen (1984) used a similiar coefficient in estimating internal loading in two large New Jersey lakes, Lake Hotatcong and Greenwood Lake.

Although the lake stratifies, the duration of stratification is much different for the two basins (Section 5). The dissolved oxygen profile data indicate that anoxic conditions exist in the south basin's hypolimnion ($\geq$ 10m) for 99 days. The north basin's bottom water ($\geq$ 6m) experiences anoxic conditions for only 29 days. The total area of north basin sediments exposed to anoxic conditions during summer stratification was calculated to be 58.1 ha or $5.8 \times 10^5 M^2$. The anoxic bottom waters of the south basin ($\geq$ 6m) over lay a total area of 16.1 ha or $1.6 \times 10^5 M^2$. Applying the 6 $mg/m^2/day$ loading coefficient, the estimated loads resulting from internal regeneration would be:

North Basin

$$(6.0\ mg/m^2/day)\ (5.8 \times 10^5 m^2)(99\ days)$$

$$= 3.45 \times 10^8\ mg \text{ or } 345\ kg\ TP$$

South Basin

$$(6.0\ mg/m^2/day)\ (1.6 \times 10^5 m^2)(29\ days)$$

$$= 2.8 \times 10^7\ mg \text{ or } 28\ kg\ TP$$

The estimated loads resulting from internal regeneration are 345 kg and 28 kg for the south and north basins respectively.

It should be noted that these estimates are conservative, as some regeneration, albeit much less, can be expected from aerobic, littoral sediments as a result of prop wash, boating activities, and macrophytes.

10.5 ATMOSPHERIC CONTRIBUTIONS

Nutrients, as well as pollutants such as heavy metals, may enter a lake from the atmosphere in a dissolved or particulate state. The loading coefficients for dryfall and precipitation related nutrients inputs are typically low (Table 10.1), except for TN, which has a precipitation loading coefficient equivalent to that of agricultural land use. The relative precipitation/dry fall nutrient load tends to be low unless the ratio of watershed to lake surface area is extremely large (USEPA, 1980). However, it has been calculated that the phosphorus and nitrogen component of the nutrient budget derived from atmospheric contributions can be as much as 25% and 10% respectively (Kortmann, 1980).

For Onota Lake, the potential does exist for precipitation/dryfall contributions to be sizable as the watershed-to-lake area ratio is approximately 10:1 (Cooke et al. 1980). Using the USEPA loading coefficients, the predicted precipitation and dryfall loads are respectively 62.5 kg/yr and 5.14 kg/yr for TP, and 2500 kg/yr and 1028 kg/yr for TN (Table 10.3). This amounts to atmospheric contribution which totals 5.4% of the annual TP budget and 30.5% of the annual TN budget (Table 10.4).

10.6 CALCULATION OF THE ANNUAL NUTRIENT AND SEDIMENT BUDGETS

The annual nitrogen, phosphorus and sediment loads were computed by summing the above predicted nutrient and sediment loads. The TP load is sizable (1261.7 kg/yr), with the majority (50.2%) originating from non-point sources (Table 10.4). The internally regenerated TP load accounts for approximately 29.6% of the annual total. In regard to TN, 62.9% of the 11,593.3 kg annual load originates from non-point sources. A substantial portion (30.5%) of the TN load, however, is from atmospheric sources (Table 10.4). No estimate was developed for internally regenerated TN. Kortmann (1980) demonstrated that for dissolved forms of nitrogen, a lake functions as a nitrogen sink.

The septic related phosphorus load is 14.9% of the total annual load. This is a significant component of Onota Lake's nutrient budget. These data indicate that although only a few dwellings still use septic systems for on-site wastewater treatment and disposal, their TP load is probably of great enough magnitude to influence lake productivity.

10.7 LIMITING NUTRIENT

Primary production is affected by the amount of available light, nutrients and micro nutrients. The amount of primary production supported by a lake ecosystem will be limited by that essential parameter of least availability. In the euphotic zone, there is ample light energy to fuel photosynthesis and it is typically a nutrient or micronutrient which is the limiting factor. In most cases, phosphorus is the limiting nutrient, particularly with respect to north temperate water bodies. However, nitrogen availability has also been found to be of critical importance, particularly with respect to southeastern lakes. As such, lake managers often determine the nitrogen:phosphorus ratio to establish which of these two essential nutrients is the limiting factor for a particular lake or pond. Studies have shown that when the N:P ratio is >12, phosphorus is limiting. Ratios <12 usually indicate nitrogen limitation (USEPA, 1980). However, the 12:1 criteria was originally developed from algal bioassays (Fogg, 1965) designed to examine the response of algal cultures to the addition of dissolved nitrogen and phosphorus compounds. Under in-situ conditions, the significance of such ratios may be minimal and even misleading, particularly when based on TN and TP data. Although of some utility, it is probably more informative and meaningful to examine the chemical nature of the nutrients (dissolved vs particulate), bioavailability, and any temporal pattern of nutrient loading rather than the TN:TP ratios alone. For instance, much of the nitrogen and phosphorus load may be particulate rather than dissolved. In addition, the introduction of nutrients from various sources is variable over time, thus ratios developed from the total annual loads may not accurately reflect nutrient ratios at discrete periods over the growing season.

The TN:TP ratio, derived from the annual nutrient budget, is 8.4:1 (Table

10.4), indicative of a nitrogen limited waterbody. This result is similar to data developed by BCRPB (1978) which were used in that study to formulate the conclusion that Onota Lake is nitrogen limited. However, although the TN:TP ratio data suggests Onota Lake to be nitrogen limited, it is unsupported by data developed in this study such as the seasonality of nutrient loading, the consistently low PO_4 concentrations, and the temporal variations in the in-lake concentrations of TP and TN. As such, it was determined by IT, following review of all available data, that either TP or TN could be limiting in Onota Lake. Lake trophic state was therefore examined using models developed for both nitrogen and phosphorus limited waterbodies.

10.8 TROPHIC STATE ANALYSIS

The data presented in Sections 10.1 through 10.7 are integrated in this section and utilized to calculate the lake's trophic state. The trophic state of the lake is a quantification of relative potential productivity derived from a regression analysis of nutrient, hydrologic and morphometric data. The trophic state models provide a means by which the impact of nutrient loading to the lake can be assessed. In essence, the utility of the various trophic state analysis models is in the interpretation of hydrologic and nutrient data in a manner which reflects the lake's ecological "health". With only a few key pieces of data it is possible to determine the existing trophic status of a water body with a reasonable degree of accuracy (Dillon, 1974; Reckhow, 1979; USEPA, 1980). In addition, these models can be used to predict the future degradation or improvement of a lake as a result of changes in nutrient loading or implementation of various management practices.

To test the phosphorus limited scenario, the empirical models of Ostrofsky (1978) and Dillon (1974) were utilized to predict TP retention and trophic state, respectively. More sophisticated models exist such as detailed in Reckhow (1979) and Walker (1977). But these models are very dissimilar from the available TN models. As such, it was determined that the Dillon model would best facilitate comparison of the TN and TP model results. The key input parameters were annual TP load, lake surface area, hydrologic retention time, and mean depth.

The nitrogen limited scenario was evaluated using a model developed by Baker, et al (1985). Although developed for Florida lakes, the model was utilized for Onota Lake, largely due to the fact that few nitrogen loading criteria models are available. This model is based on the same concept as the Dillon TP Model. It was anticipated that comparison of predicted lake trophic state under the TP and TN limited scenarios would be possible if a similar modeling approach was used for both conditions.

10.8.1 Phosphorus Retention/Critical Loading

The TP load to the lake is calculated to be 1261.7 kg/yr (Table 10.4). Using this annual load, in conjunction with the trophic state model of Dillon (Table 10.6), a spring TP concentration of 0.022 g/m^3 is predicted. The predicted spring TP concentration is an indication of lake trophic state and is used to predict summer in-lake productivity. The observed mean concentration of TP measured in the lake's surficial waters was 0.011 mg/l (whole lake) during spring turnover of 1986. These data compare fairly well with the predicted spring concentration. However, the Dillon model also predicts the lake's trophic state to be eutrophic and that the existing TP load exceeds the minimum eutrophic load (Figure 10.1). This prediction does not agree with observed conditions or monitored in-lake conditions. The observed mean spring TP concentration characterizes Onota Lake as mesotrophic (Figure 10.1). Also, Secchi disc transparency and in-lake productivity, as expressed in terms of chlorophyll concentrations, do not reflect conditions representative of a eutrophic water body (Section 5). Thus, although the Dillon model accurately predicts the spring TP concentration, it incorrectly characterizes the lake as eutrophic (Figure 10-1).

10.8.2 Nitrogen Retention/Critical Loading

An approach similar to that used for TP was used with the TN loading data to predict lake trophic state. The annual TN load is calculated to be 11,593.3 kg (Table 10.4) and nitrogen retention is predicted to be 59.6%. Using these data in conjunction with the Baker, et al. (1980) model, the trophic state analysis predicts the lake to be oligotrophic. The existing annual TN load is slightly below the minimum mesotrophic load (Figure 10.2). The predicted

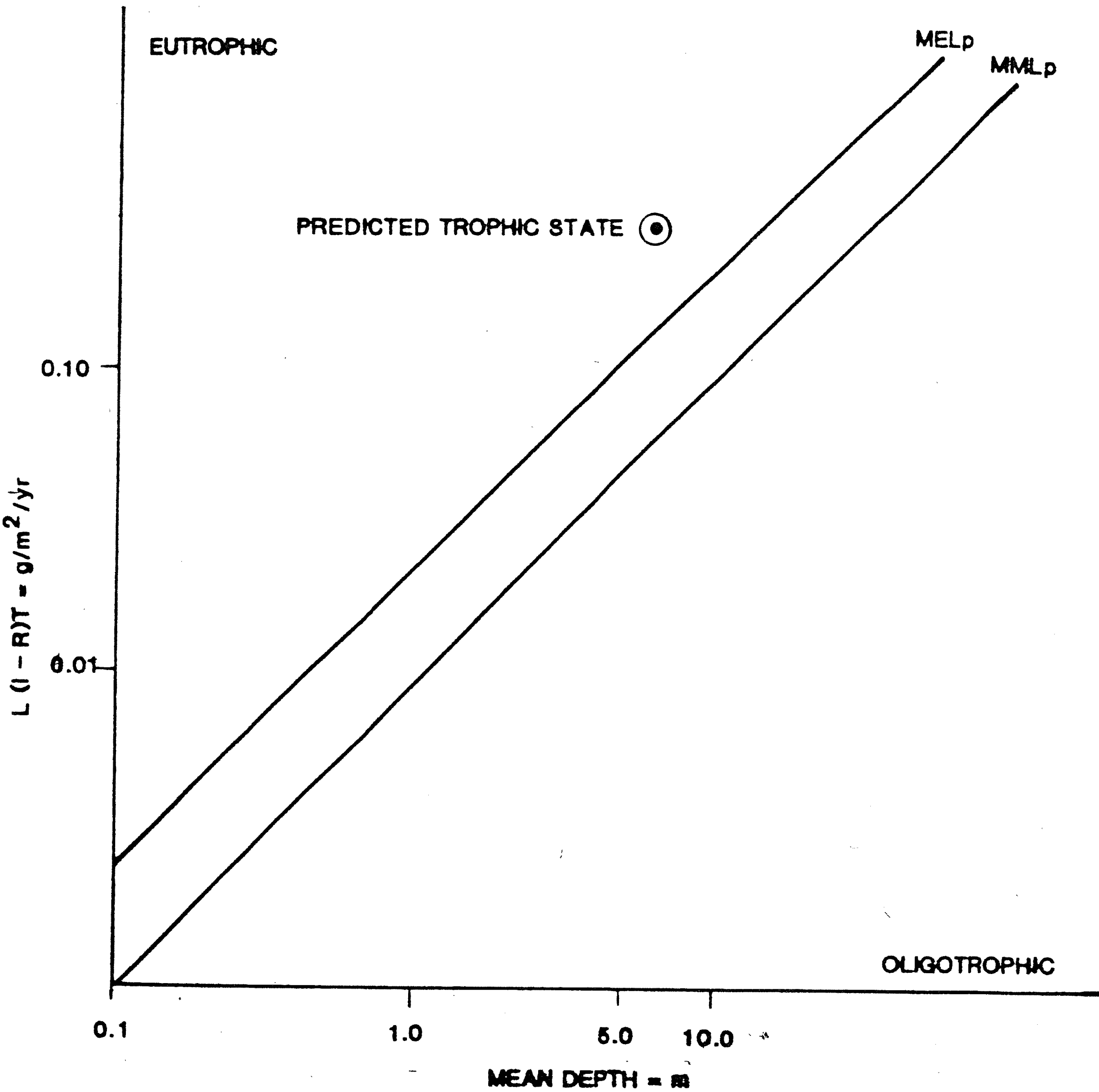

FIGURE 10-1

PREDICTED TROPHIC STATE OF ONOTA LAKE USING DILLON (1974) CRITERIA AND BASED ON TP LOADING

PROJECT NO. 541648

OCTOBER 1987

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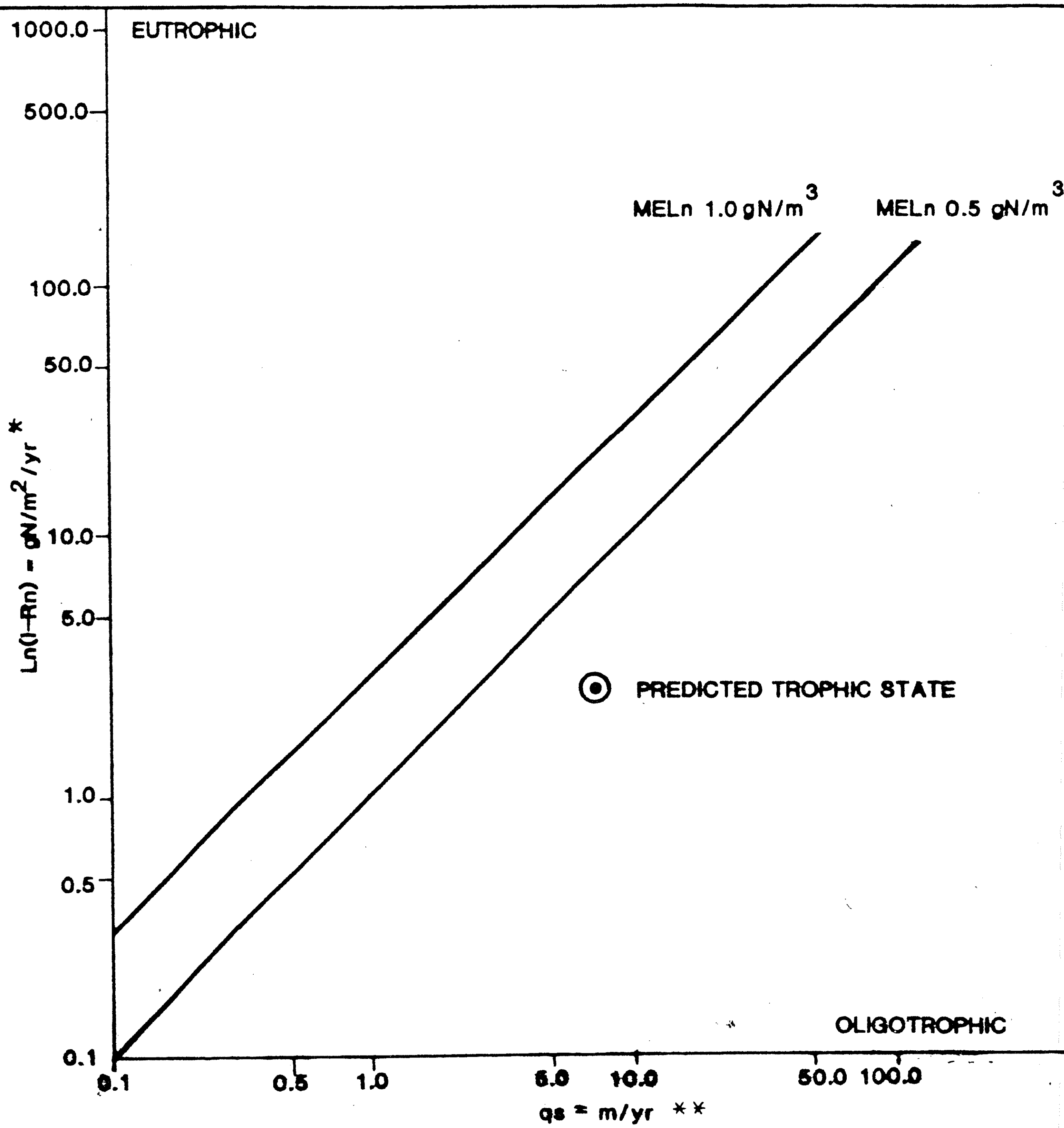

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* SEE TABLE 10.4 FOR DETAILS

** SEE TABLE 10.3 FOR DETAILS

FIGURE 10-2

PREDICTED TROPHIC STATE OF ONOTA LAKE USING THE CRITERIA OF BAKER, et al. (1985) AND BASED ON TN LOADING

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132298

"Do Not Scale This Drawing"

trophic state is not representative of conditions observed in the lake relative to chlorophyll and transparency data. In addition, in the north basin, macrophyte densities, sediment accumulation and winter dissolved oxygen concentrations reflect conditions associated with a non-oligotrophic waterbody.

Thus, the TP (Dillon) model data indicates the lake to be more eutrophic than measured lake parameters suggest and in contrast, the TN model data appears to underestimate lake productivity, particularly in respect to conditions observed in the North Basin. As such, neither model satisfactorily predicts lake trophic state.

10.9 ONOTA LAKE, TWO LAKES IN ONE

The widely differing results of the two models leaves some question of their utility for Onota Lake. Classifying the lake as eutrophic, as per the TP model, is inaccurate. Chlorophyll a concentrations, lake transparency and other biological indicators such as fish and benthos, for Onota Lake are characteristically meso to oligotrophic in nature, particularly in the south basin. Likewise, classifying the lake as oligotrophic, as based on the TN model, is also inaccurate. The density of weeds, as well as the magnitude of accumulated silt and the precariously low winter dissolved oxygen levels in the north basin are more characteristic of an eutrophic waterbody than an oligotrophic lake. As such, the lake is paradoxical. The south basin is mesotrophic in nature whereas the north basin is eutrophic.

It appears that the lake's trophic state may not be properly addressed by dealing with the lake as a whole. The presence of the sand bar which separates the north and south basins may be acting as a deterent to total lake mixing. Thus, the sand bar in effect may isolate the bottom waters from being mixed during turnover. This may cause the two basins to function more as independent ecosystems than as one lake. Intuitively, this approach has merit. First, the sand bar is a prominent physical feature. It clearly separates the two basins, and if not for the boat access channel would probably greatly impede hydrologic exchange. Although no measurements were made of inter-basin water exchange, net flow must be from south to north as elaborated upon further in Section 11.0.

The dual ecosystem approach to calculating predicted trophic state yielded improvement over the total lake approach (Table 10.12). As opposed to the data generated by the Dillon TP model, when the lake was treated as a whole, the basin specific data do not indicate the lake to be exceedingly eutrophic. Specifically, the south basin is predicted to be slightly eutrophic while the north basin is predicted to be on the mesoeutrophic border (Figure 11.5).

These data are still not totally in keeping with perceived condition of the lake, as based on field observations. However, they appear to be more accurate predictions of trophic state than that estimated under either the total lake TP or TN limited scenarios (Figures 10.1 and 10.2). Calculation of the south basin's trophic state based only on the external load would no doubt lead to a predicted trophic state in the oligo-mesotrophic range. However, the internal load must be included as part of the total load. This component of the annual load can significantly affect trophic state (Welsh and Rock, 1980).

Based on the outcome of this iteration, treating the lake as two lakes rather than one appears correct and justifiable. From a lake managers viewpoint, it does reveal some interesting aspects of Onota Lake. Specifically, septic management, non-point source control and internal load reduction strategies used in the restoration of Onota Lake will differ markedly between the two basins. These data will be used in determining the feasibility and priority of various in lake and watershed restoration/management techniques.

Further refinement of the predicted trophic state is possible if either the Reckhow (1979) anoxic lake model or the Walker (1977) model are used. However, use of either of these models will make it difficult to compare trophic state under TP versus TN limited conditions. Use of the Dillon model seems warranted given the uncertainty of whether Onota Lake is TP or TN limited.

the lake's spillway and discharge is in the North basin. Second, throughout the monitoring program it was observed that in general, water quality, sediments, macrophyte densities, and fish community data were different in the two basins. It is true that the origin and bathymetry of the two basins are dissimilar and these factors in themselves may be causing the observed physicochemical and biological differences. However, the north basin proportionally receives a greater percentage of the total nutrient, sediment and hydrologic loads (Tables 9.2 and 10.2). Its shoreline is also more densely populated and there are a greater number of discrete stormwater discharges than occur in the south basin. The sandbar may also limit flushing and dilution of nutrient inputs through partial isolation of the north basin from the south basin.

In an attempt to better characterize the lake's trophic state, a dual ecosystem approach was adopted. Lake trophic state was re-calculated using the Dillon (1974) TP model, but the north and south basins were modeled separately. The sandbar was designated as a physical boundary separating the two basins. Hydrologic exchange between the two basins was assumed, for this exercise, to be minimal. Using the data developed in Sections 9 and 10.1 - 10.6, hydrologic and nutrient budgets were calculated separately for each basin (Table 10.9 and 10.10). Although the north basin is physically smaller than the south basin, it is fed by 88% of the lake's total watershed by area. The non-point source TP load is approximately 3.5 times greater to the north basin than to the south basin. However, the overall TP load to the south basin is greater (Table 10.10) due largely to internal regeneration processes.

Entering the basin specific data into the phosphorus retention model yielded predicted TP retention coefficients of 0.593 and 0.734 for the north and south basins respectively (Table 10.11). Due to the south basin's larger volume and lower flushing rate, conditions favor the settling and retention of particulate phosphorus. In the north basin, the flushing rate is quicker, owing to the large hydrologic load and relatively small volume of the basin, leading to less settling and retention of particulate TP than occurs in the south basin. Aside from trophic state predictions, these data can be particularly useful in selecting lake management techniques. This will be

TABLE 10.1

LOADING COEFFICIENTS FOR VARIOUS LAND USE ACTIVITIES IN THE ONOTA LAKE WATERSHED

Land Use Category	ANNUAL LOAD kg/ha/yr TN	TP	TSS
Forest	2.5	0.2	250
Agriculture	10.0	0.6	1,600
High Density Res[1]	5.0	0.8	2,000
Low Density Res	2.0	0.25	200
Open-covered	5.0	0.30	400
Open-Disturbed	10.0	0.6	1,600
Precipitation[2]	10.0	0.25	-
Dryfall[3]	0.4	0.002	-

1 - includes commercial properties
2 - applied only to lake surface
3 - applied to entire watershed

Source: USEPA Clean Lake Program Guidance Manual

10.10 TROPHIC STATE CRITICAL LOADING BOUNDARIES

As a final check on the validity of the total phosphorus loading calculations, the critical loading boundaries between oligo-mesotrophic and meso-eutrophic conditions were calculated using the method of Vollenweider (1976). These calculations (Table 10.13) indicate that the critical load for the oligo-mestotrophic transition is 404.8 kg TP/yr (whole lake). The meso-eutrophic transition critical load was calculated to be 811.0 kg TP/yr. These TP load boundaries indicate that the TP budget for the lake (Table 10.4) should result in a eutrophic conditon, which, as previously stated, was not demonstrated by the data collected during this study.

TABLE 10.3

RELATIVE ATMOSPHERIC CONTRIBUTIONS OF NITROGEN AND PHOSPHORUS TO ONOTA LAKE

Parameter	Phosphorus Coefficient kg/ha/yr	Phosphorus Load kg/yr	Nitrogen Coefficient kg/ha/yr	Nitrogen Load kg/yr
Dryfall	0.002	5.14	0.4	1,028
Precipitation**	0.25	62.5	10.0	2,500
Total atmospheric Load		67.64		3,528

* Applied to area of lake
** Applied to area of watershed

TABLE 10.2

SUMMARY OF NON-POINT SOURCE
NUTRIENT AND SEDIMENT LOADING
TO ONOTA LAKE
ANNUAL LOAD PER SUB-BASIN

Sub* Basin	Area Ha	ANNUAL LOAD kg/yr TN	TP	TSS
I.	156	780.0	85.8	187,200
II.	87	352.4	46.1	103,095
III.	27	78.3	7.8	13,824
IV.	25	56.3	5.6	5,625
V.	77	192.5	15.4	19,019
VI.	865	2,508.5	190.3	275,935
VII.	310	1023.0	74.4	121,830
VIII.	635	1914.0	151.6	255,270
IX.	60	192.0	28.2	55,200
X.	77	200.2	27.7	43,120
Total	2,319	7297.0	632.9	1,080,118

* Refer to Figure 4.1 for sub-basin location.

TABLE 10.5

PHOSPHORUS RETENTION
ONOTA LAKE

$$Rp = 0.201e^{(-0.0425\ qs)} + 0.5743e^{(-0.00949\ qs)}$$

where:

Rp = Phosphorus Retention

$$qs = \text{Areal water load} = \frac{\text{annual inflow } (m^3/yr)}{\text{surface area of lake } (m^2)}$$

Annual inflow 18.0 X $10^6 m^3/yr$

Surface area 2.497 X $10^6 m^2$

$$qs = \frac{18.0 \times 10^6\ m^3/yr}{2.49 \times 10^6 m^2} = 7.2\ m/yr$$

$$Rp = 0.201e^{(-0.0425)(7.2)} + 0.5743e^{(-0.00949)(7.2)}$$

Rp = 0.148 + 0.536

Rp = 0.684

% TP Retention = 68.4%

TABLE 10.4
NUTRIENT/SEDIMENT BUDGET OF ONOTA LAKE

SOURCE	TP kg	TP %	TN kg	TN %	TSS kg	TSS %
Direct Runoff and Tributary Loading	632.9	50.2	7297	62.9	1.08×10^6	100
Direct Precipitation	62.5	5.0	2500	21.6	---	---
Dryfall	5.14	0.4	1028	8.9	---	---
Internal Regeneration	373.0	29.6	---	---	---	---
Septic Loading	188.2	14.9	768.3	6.6	---	---
TOTAL	1261.7		11593.3		1.08×10^6	

TABLE 10.7

NITROGEN RETENTION
ONOTA LAKE

$$R_N = 0.426e^{(-0.271qs)} + 0.574e^{(-0.00949\ qs)}$$

where
R_N = Nitrogen Retention
qs = Areal water load = $\frac{\text{annual inflow } (m^3/yr)}{\text{lake surface area } (m^2)}$

Annual discharge $18.0 \times 10^6 m^3/yr$

Surface Area $2.497 \times 10^6 m^2$

$$qs = \frac{18.0 \times 10^6 m^3/yr}{2.49 \times 10^6 m^2} = 7.2\ m/yr$$

$$R_N = 0.426e^{(-0.271)(7.2)} + 0.574e^{(-0.00949)(7.2)}$$

$$R_N = 0.06 + 0.536$$

$$R_N = 0.596$$

% TN retention = 59.6%

TABLE 10.6

TROPHIC STATE ANALYSIS OF ONOTA LAKE

USING THE CRITERIA OF DILLON (1974)

Parameter	Value
Annual Load	1261.7 kg/yr
Areal Load (L)	0.505 $g/m^2/yr$
Phosphorus Retention (R)	0.684
Hydraulic Retention Time (T)	0.88 yr
Mean Depth (Z)	6.4 m

Predicted spring TP concentration (g/m^3) = $[P_s] = \frac{L(1-R)T}{Z}$

$$[P_s] = \frac{0.505\ g/m^2/yr\ (0.316)(0.888\ yr)}{6.4\ m}$$

$$[P_s] = \frac{0.142\ g/m^2}{6.4\ m}$$

$$[P_s] = 0.022\ g/m^3$$

TABLE 10.9

PERTINENT HYDROLOGIC AND MORPHOMETRIC CHARACTERISTICS OF ONOTA LAKE'S NORTH AND SOUTH BASINS

Parameter	Value	North Basin	South Basin
Basin surface area	$10^6 m^2$	0.794	1.7
Basin volume	$10^6 m^3$	1.5	14.5
Hydrologic load	$10^6 m^3/yr$	12.85	5.15
Flushing rate	times/yr	8.6	0.36
Residence time	yr	.116	2.82
qs	m/yr	16.2	3.02
Mean depth	m	1.8	8.5

TABLE 10.8
TROPHIC STATE ANALYSIS OF ONOTA LAKE
USING THE TN CRITERIA OF BAKER, ET AL. (1985)

Parameter	Value
Annual load	11593.3 kg/yr
Areal load	4.65 $g/m^2/yr$
Nitrogen Retention (R)	0.596
Hydraulic Retention (T)	0.88 yr
Mean Depth (z)	6.4 m

$$[TN] = \frac{L\ (1-R)T}{z}$$

$$[TN] = \frac{4.65\ g/m^2/yr\ (1-0.596)(0.88\ yr)}{6.4\ m}$$

$$[TN] = \frac{1.65\ g/m^2}{6.4m}$$

$$[TN] = 0.26\ g/m^3\ TN$$

TABLE 10.11
PHOSPHORUS RETENTION*
AS CALCULATED INDEPENDENTLY
FOR ONOTA LAKE'S NORTH
AND SOUTH BASINS

SOUTH BASIN

$$Rp = 0.201e^{(-0.0425)(3.02)} + 0.5743e^{(-0.00949)(3.02)}$$

$$Rp = 1.76 + 0.558$$

$$Rp = 0.734$$

P retention = 73.4%

NORTH BASIN

$$Rp = 0.201e^{(-0.0425)(16.2)} + 0.5743e^{(-0.00949)(16.2)}$$

$$Rp = 0.10 + 0.492$$

$$Rp = 0.593$$

P retention = 59.3%

* Calculated as per Ostrofsky (1978)

TABLE 10.10

ANNUAL TOTAL PHOSPHORUS LOADING (KG/YR) TO THE NORTH AND SOUTH BASINS OF ONOTA LAKE

Source	North Basin	South Basin
Tributary and direct runoff	493.2	139.7
Direct precipitation on lake surface	19.8	42.6
Dry fall	4.6	0.5
Internal regeneration	28.0	345.0
Septic systems	-	188.2
Total	545.7	716.0

TABLE 10.13
CALCULATION OF CRITICAL LOADING BOUNDARIES BETWEEN OLDIO-EUTROPHIC CONDITIONS BASED ON VOLLENWEIDER (1976)

$$L_c\ (mg/m^2/yr) = \overline{[P_c]}_{sp} \cdot \bar{Z}\ \left(\frac{1 + tw}{TW}\right)$$ Vollenweider (1976)

From Vollenweider (1976)
Transitional Boundaries Between Olgiotrophy --> Eutrophy (L_c)
10 mg/m^3 -- 20 mg/m^3

APPLICATION TO ONOTA LAKE

1. Olglio-Mesotrophic Transition (10 mg/m^3) Boundary

$Tw = 0.73$ yrs.
$\bar{Z} = 6.4$ m

$$L_c = 10.0\ mg/m^3 \cdot (6.4m)\ \left(\frac{1 + 5.75\ yr}{0.73\ yr}\right)$$

$$= 10.0\ mg/m^3 \cdot (6.4m)\ \left(\frac{1.85}{0.73\ yr}\right)$$

$$= (10\ mg/m^3) \cdot (6.4\ m)\ (2.53)$$

$$L_c = 161.9\ mg/m^2/yr$$
or 404.8 KgTP/yr

2. Meso-Eutrophic Transition (20 mg/m^3) boundary

$$L_c = 20.0\ mg/m^3 \cdot (6.4m)\ \left(\frac{1 + .73\ yr}{.73\ yr}\right)$$

$$= 20.0\ mg/m^3 \cdot (6.4m)\ (2.53\ yr)$$

$$L_c = 324.4\ mg/m^2/yr$$
or 811.0 KgTP/yr

TABLE 10.12

LAKE TROPHIC STATE AS PER DILLON (1974) CRITERIA CALCULATED INDEPENDENTLY FOR ONOTA LAKE'S NORTH AND SOUTH BASINS

SOUTH BASIN

$$[P_s] = \frac{0.42\ g/m^2/yr\ (1-.734)(2.82\ yr)}{8.5m}$$

$$[P_s] = \frac{0.315\ g/m^2}{8.5m}$$

$$[P_s] = 0.037\ g/m^3$$

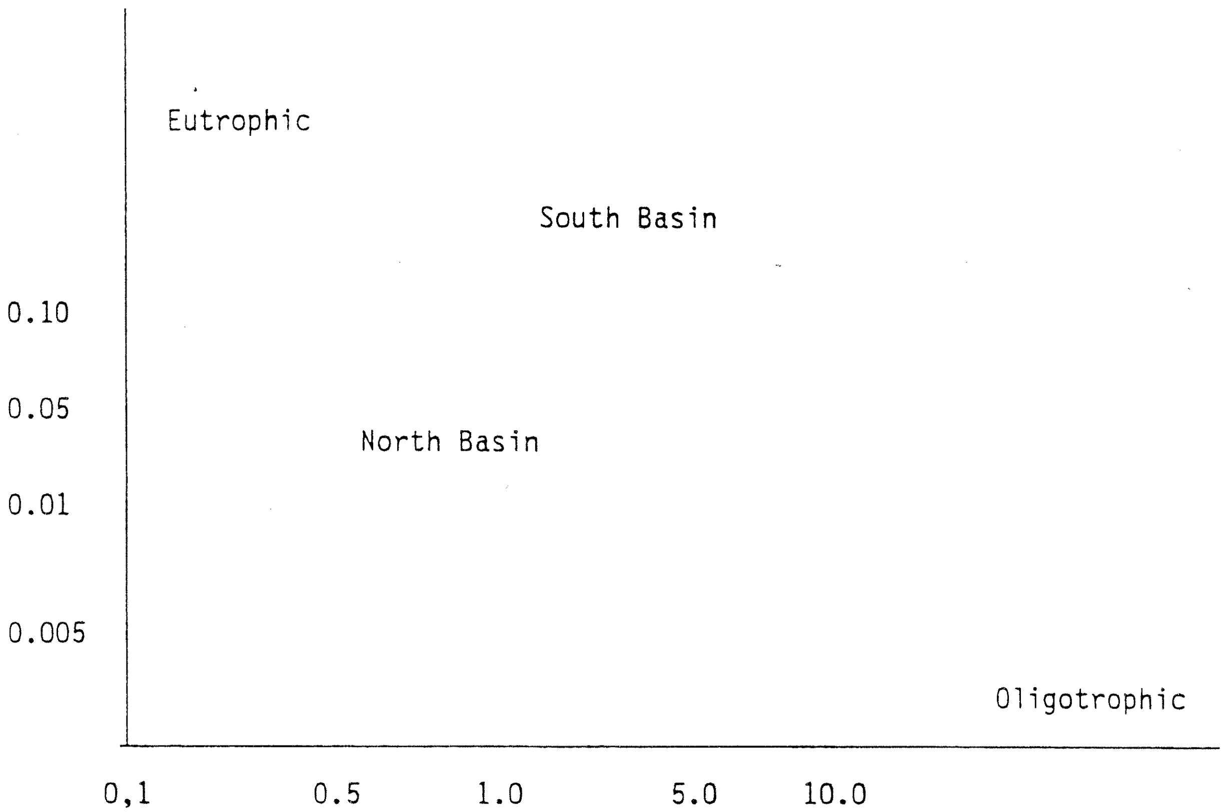
NORTH BASIN

$$[P_s] = \frac{0.687\ g/m^2/yr\ (1-.593)(.116\ yr)}{1.8m}$$

$$[P_s] = \frac{0.032\ g/m^2}{1.8m}$$

$$[P_s] = 0.018\ g/m^3$$

FIGURE 10.3
TROPHIC STATE AS PREDICTED
INDEPENDENTLY FOR ONOTA LAKE'S
NORTH AND SOUTH BASINS



11.0 RESTORATION/MANAGEMENT PLAN

11.1 INTRODUCTION

The data base developed in the diagnostic portion of this study identified the problems which affect Onota Lake. Nutrient and sediment loading were quantified and utilized to establish the lake's trophic state. Water quality data were reviewed and the lake's general environmental condition determined. As well as documenting the current status of the lake, these data provided the means by which the factors responsible for the lake's degredation could be identified and prioritized. With this information, a management plan could be developed in a manner insuring that the proper amount of effort and money was allocated to each factor impacting the lake.

11.2 DEVELOPMENT OF THE FEASIBILITY ANALYSIS

In this section, detail is provided concerning the formalization of the management plan. Once the lake's problems were identified and prioritized, a feasibility analysis was conducted to determine which restoration/management techniques are most applicable for the problems of Onota Lake.

In general, the lake's eutrophication can be attributed to watershed urbanization and subsequent increase in sediment and nutrient loading. The lake's morphometry exacerbates the effects of increased sediment and nutrient loading. The north basin's shallow depth is favorable to the growth of macrophytes and the south basin's large anoxic hypolimnion favors the internal regeneration of phosphorus. From the results of the diagnostic evaluation, it appears that the restoration/management plan should address the following:

1. Excessive aquatic macrophyte growth.
2. Accumulation of organic sediment and silting in of shallow embayments, and
3. Reduction in dissolved oxygen concentrations.

Doing so, will require that the following nutrient and/or sediment sources be controlled, corrected or abated:

1. Septic inputs
2. Non-point source loading of sediments and nutrients caused by watershed urbanization, and
3. Internal regeneration of nutrients.

11.3 MANAGEMENT PLAN

The most pervasive cause of the lake's problems stem from excessive sediment and nutrient loading. Based on data compiled in the diagnostic sections, it is evident that erosional, non-point, and septic sources need to be controlled. It appears that this is best achieved through stormwater and soil erosion management, land-use management practices, and sewering. In addition, certain in-lake techniques appear to be needed to aid in the restoration of the lake specifically to improve water quality and aesthetics. Most of the in-lake measures should not be viewed as means of controlling the causes of eutrophication but as means of reducing the impacts of eutrophication. The combination of in-lake and watershed management measures will allow for the maintenance of the lake as a viable recreational water body while providing for its long-term management.

The recommendations presented in the management plan will require the integration of many water resource programs, government agencies and funding sources. The full implementation of the plan will require a number of years to complete. To achieve the goal of restoring and managing the lake, activities will have to be well coordinated. A lead agency, such as the Lake Onota Preservation Association (LOPA), will be required to interface with the various government, funding and planning groups. LOPA will also be needed to ensure that the level of effort and the direction of that effort does not falter.

The following sections provide a detailed evaluation of the general components which were presented above. Specifically, this includes a feasibility analysis for in-lake and watershed management measures, public education program, and institutional arrangements.

11.3.1 WATERSHED MANAGEMENT

The objective of the watershed management plan is to reduce external nutrient and sediment loading. If done properly, this will effectively slow the rate of the lake's eutrophication. Nutrient and sediment control can be achieved through a variety of methods, so it is important to thoroughly evaluate the merits, applicability and cost of various options. The following should be considered as part of this evaluation:

- Practicality of non-point source control,
- Cause-effect relationship between existing load, lake response, and load reduction following management/control,
- Performance characteristics and cost,
- Required maintenance, and
- Ease of implementation.

Both structural and non-structural methods are available. Structural methods rely on the construction of catch basins, silt traps or other engineered devices to intercept, divert, or control nutrient/sediment inputs. Non-structural methods are conservation techniques, product modification, and ordinances which reduce loading and regulate activities responsible for nutrient/sediment influx.

In order to objectively evaluate the applicability of various watershed management methods, a feasibility matrix was developed (Table 11.1). An ordinal ranking, based on a score of 1 to 5, was obtained for each alternative. Those alternatives scoring the highest were given priority consideration. The feasibility of each option was judged on the basis of:

- Cause-effect - how effective would this method be in immediately contributing to a noticeable improvement in lake conditions.

- Degree of load reduction - once implemented how substantial a decrease in nutrient and/or sediment loading could be expected.

- Practicality - can the method be practically implemented.

- Performance characteristics - based on the scientific literature, how effective is this measure in abating nutrient/sediment loading.

- Cost - is the cost of the method, its implementation, or its maintenance prohibitive relative to the expected returns.

Although each was given equal weight relative to scoring, attention was focused on the scores associated with load reduction, practicality and cost. The higher the score for each of these three matrix components, the more favorable the management option.

Review of the matrix scores indicate that the top five watershed management options are:

- Stormwater retention/detention,
- Erosion control,
- Land use ordinances,
- Stormwater management, and
- Product modification.

TABLE 11.1

WATERSHED MANAGEMENT FEASIBILITY MATRIX

METHOD	CAUSE-EFFECT	DEGREE OF LOAD REDUCTION	PRACTICALITY	PERFORMANCE CHARACTERISTICS	COST	TOTAL
Diversion of inflow	5	4	1	1	1	12
Treatment of inflow	5	2	1	1	1	10
Stormwater Detention - Retention	5	4	4	4	2	19
Erosion Control	4	4	5	4	3	20
Sewering	3	2	4	5	1	15
Up-Grade of Existing Point Sources	2	2	5	5	1	15
Land Use Ordinances	4	4	5	3	5	21
Stormwater Management	5	4	4	4	2	19
Product Modification	3	3	5	4	5	20
Public Education	2	2	5	4	5	18

Each of these management options are feasible, cost-effective means by which loading can be reduced and the lake's water quality improved. Implementation recommendations for the above options are as follows.

11.3.1.1 Stormwater Retention/Detention

As with most established lake communities, Onota Lake is faced with a limited amount of available land for the construction of offstream detention basins. Of the three main tributaries (Parker, Churchill and Daniels Brooks), the construction of an off-stream basin appears most feasible for Parker Brook at a site located at the base of Cascade Street on property owned by Camp Winadu. The proposed basin should be a dry, grassed basin which evacuates 90% of its volume in 18 hours. The outlet structure should be either a stand pipe device or a dual orifice head wall. If a dual orifice headwall is used, the small outlet orifice should not exceed 4 inches and should be protected by a trash rack. Sizing of the detention basin should be such that it detains a total volume equivalent to 10% of the 1 year storm volume. It is recommended that HECII modelling be conducted as part of the design analysis to ensure that offsite flooding will not occur.

For Churchill and Daniels Brooks a different approach is recommended. Full advantage should be taken of the backwater located north of the causeway. This area is colonized by wetland plants and macrophytes. It serves, in its present state, as a biofilter and retention basin. Storm flow from both brooks empties into this area. Its quiescent nature coupled with the existence of vegetation promotes settling of particulates and associated decrease in nutrient loading. Additional settling could be promoted by erecting a gabion wall at the mouth of tributaries. This type of wall, constructed of concrete cylinders or similar material, will aid in dissipating the energy of storm surges and facilitate settling.

At the mouth of each stream, downstream of the gabions, a variety of sedges, rushes and bullrushes, should be planted. These vegetation types can withstand a variety of hydrologic conditions and provide an excellent means of trapping sediment and uptaking nutrients. If protected from storm surges and scouring by the gabion energy dissipator, the introduced vegetation should greatly assist in decreasing the Churchill and Daniels Brook pollutant loads.

This "natural" basin should be augmented by the creation of a small sump on the south side of the causeway. It is recommended that a depression approximately four feet deep and 100 x 100 be excavated. A shallow (3 foot) gabion wall should be erected along the perimeter of the depression. The objective of the sump would be to promote the settling of particulates and sediments. The gabion lip would aid in dissipating flows and facilitate settling of material in the basin. Rather than have sediments accumulate and form a delta, the creation of the sump would promote the settling of materials in an area easily accessible for future maintenance. It would decrease loading to the lake, aid in decreasing the rate of silting in of the north basin, and could even create a new fishery habitat.

A similar approach is recommended for Blythewood Drive. The small tributary which flows off Blythewood into the lake can be addressed in two ways. A small sump, similar to that described for Churchill and Daniels could be excavated at the mouth of the brook. The sump would act to promote settling and trap sediments.

An alternative and more desirable approach would be the creation of a small, confined wetland at the mouth of the brook. This would be accomplished by first erecting a gabion wall and placing a set amount of fill within its confines. Wetland species, such as Typha, would be planted within the confined area. This wetland would serve as a biofilter. Sediment settling would be achieved as well as attenuation of nutrients. Precise bathymetric measurements in the vicinity of the mouth would be necessary to establish the feasible extent of such an area.

11.3.1.2 Erosion Control

Several sites throughout the watershed were observed to be in need of erosion control. Most of these sites are located along the southwest side of the lake. Gully erosion along road beds, building lot excavation and agricultural activities were some of the specific causes of the problems. Three approaches, each of which can be easily implemented, are recommended to correct erosion.

First, stricter enforcement of the City of Pittsfield's soil erosion control ordinance is required. The existing ordinance is well structured and will protect the lake and its tributaries from excessive sedimentation. This represents the most effective means of alleviating future soil erosion perturbations. Therefore, it must be stressed that development in the watershed, whether it be of one or multiple parcels, adhere to existing soil erosion control guidelines.

Secondly, there is a need to maintain a buffer of at least 50 feet between cultivated land and the stream banks. These buffers should be bermed and vegetated. Course vegetation will filter soils eroded from croplands during storm events prior to their transport to the lake's tributaries. Conservation tillage practices as specified by the Soil Conservation Service should be implemented. If possible, there should be a minimum amount of time when land lies fallow. Planting of clover or alfalfa is recommended for areas which are being rotated and will not be cultivated over the course of a year.

Improved agricultural practices can greatly decrease sediment, nutrient, and pesticide losses to a lake (U.S. EPA, 1980). Among the various alternatives, the following Best Management Practices (BMP's) should be Onota Lake:

(1) Conservation tillage, including no-plow methods,
(2) Winter cover crops,
(3) Timing of field operations to avoid long fallow periods,
(4) Contouring, graded rows and terracing,
(5) Grassed or vegetated buffer zones along the perimeter of cropland particularly where they abut roads or streams,
(6) Avoid winter spreading of manure,
(7) Proper storage of animal wastes,
(8) Containment and passive treatment of runoff from feed lots,
(9) Proper calculation, application, and timing of fertilizer usage,
(10) Optimization of pesticide formulation, the timing of placement, and the method of application to insure

effectiveness while minimizing loss.

Finally, individual existing sites of erosion must be comprehensively catalogued and the specific corrective actions needed to remediate the sites, developed. In many situations, such as roadway washout and unstable stream banks, non-structural corrective actions will be effective. This would consist essentially of regrading, planting and possible stormwater diversion. In other cases, structural measures such as retainer walls, will be needed.

To accomplish this cataloging, a detailed reconnaissance of the area, concentrating on the general sections of the lake identified above must be conducted. Due to seasonal nature (road wash out) and unpredictability (new development) of some of these problems, it is necessary that the reconnaissance immediately precede the development of specific restoration and erosion control measures. It is highly likely that many of the problem areas observed during the 1986 survey have been corrected as part of the Burbank Park upgrade and/or comments directed by IT to LOPA or city officials.

11.3.1.3 Land Use Ordinances

In order to protect the lake from future nutrient, erosion, and pollutant loading, sensitive environment land use ordinances are required. This relates specifically to slopes in excess of 20%, soils of limited stability and septic suitability, and wetlands. These areas are sensitive and must be protected by limiting development. In order to achieve this, development restrictions must be enacted. This appears most needed in the section of the watershed along Blythewood Drive. This area presently utilizes septic systems. It is recommended that to decrease future septic related inputs the area be re-zoned to R-43, 1 acre minimum. Even if this area is sewered in the future, the R-43 zoning classification should be implemented. The proximity of this area to the lake, the presence of small intermittent streams which channel runoff, and steep to moderate slope, all contribute to making this an environmentally sensitive area. By designating this area as environmentally sensitive, a legal basis will exist by which future development can be restricted.

11.3.1.4 Stormwater Management Ordinances

Measures must be imposed to control stormwater runoff from new development to the lake. In essence, this requires the creation of stormwater management ordinances. . Such ordinances require that stormwater management provisions be incorporated into sub-division, roadway construction, and commercial property. These provisions are different from flood control in that they are designed to improve stormwater quality and reduce sediment/nutrient loading. Attention is focused on small storms and the first flush of major storms. Detention basins, retention basins, catch basins and grassed swales are commonly employed techniques. When the situation allows, dry wells, roof top detention, pervious soils and created wetlands are other viable stormwater management techniques. A sample model ordinance prepared by IT Corporation is included in Appendix B. This can serve as the basis for the development of a basin-wide stormwater management ordinance for Onota Lake.

11.3.1.5 Product Modification

At the grass roots level, there are measures which can be implemented which have been proven effective in decreasing nutrient loading. These include the use of non-phosphorus detergents and non-phosphorus fertilizers. This also encompasses public education in septic system maintenance and low flow water devices. It is strongly recommended that non-phosphorus fertilizers be used. A time release nitrogen, non-phosphorus fertilizer is manufactured specifically for lake front communities. This material can be made available through the Onota Lake Preservation Association or local hardware/garden supply stores. The use of such fertilizers will be part of the Phase II public education program.

11.3.1.6 Sewering and Infrastructure Improvements

The matrix scores for sewering and upgrade of existing infrastructure were lower than for many other management options. This stems primarily from the high cost of such sewering and the limited achievable reduction in loading. However, both are highly recommended due to acute factors currently affecting the lake and recorded improvements in lake quality following sewage diversion

(Welch and Rock, 1980). Although, septic loading accounts for only 14.9% of the total annual TP load, results of the "septic snooper" study reveal major acute septic problems in Thomas Island Cove and problems along the Blythewood Drive shoreline. The Thomas Island problems stem from a break in the Peck's Road sewer line. Faulty septic systems, resulting from soils of marginal treatment ability, are responsible for the problems along Blythewood Drive. Although only a 15% reduction in TP loading will be gained by sewering this area, the health risk problems posed by faulty septics will be corrected. In addition, if this area is further developed, the septic related TP loading could greatly increase depending on final densities and proximity of new dwellings to the lake.

A bond has recently been approved by the City of Pittsfield which will make available funds to locate and repair the Peck's Road break. Once this is corrected, sewage infiltration into the storm sewer will be alleviated. The contamination problem currently affecting Thomas Island Cove will then be abated.

Sewering of the homes along Blythewood Drive is highly recommended. Although this will conceivably be costly, such action is required. Review of existing data, including preliminary engineering specifications, suggest that the best approach to sewering the area would be to install a line along the lake's shore line. A pump station would be used to pump the sewage upgrade to a trunk line which runs along West Street.

Although this is a sound approach other alternatives should be reviewed. A possible option would be to retain the existing septic tanks for those homes located on the east side of Blythewood Drive. The tanks would be used to accumulate solids and sludge. Liquid wastes would be piped to a small diameter line located along the lake's shore. Servicing of future development along the west side of the road would be accomplished through the use of standard lines. There would be two distinct advantages to such an approach. First, it would be less costly. At present the majority of the development is on the east side of the road along the lake's shoreline. Future development will occur primarily along the western side of the road. Rather than incur costs for a single large system designed to service both existing and future densities, it would be possible to correct the existing septic problems at a much lower cost to the individual home owner. New development will inevitably require the up-grade of Blythewood Drive in order to better meet the transportation and servicing needs of this area. Sewering of new development could be timed to coincide with this. Also, the smaller diameter mains would require a smaller pump station. This would translate to a savings once again in cost and also in operations and maintenance.

Second, the installation of a small diameter pipe would require less excavation. This would reduce potential impacts to the lake resulting from construction activity.

In order to protect that section of the lake from excessive nutrient and sediment loading resulting from future development, re-zoning of this area is warranted. Due to the environmentally sensitive nature of this area, re-zoning to R-43 is highly recommended. Limits should also be placed on the use of this area for cluster development. In this way, sewering of the area will not lead to environmental repercussions resulting from increased nutrient and sediment loading.

11.3.1.7 Diversion and Pretreatment

Neither diversion of inflow or the chemical treatment of stormwater is recommended. It is felt that both would be very impractical and too costly. Diversion would also disrupt the lake's hydrologic budget. Pretreatment would have a high O&M cost associated with it. For these reasons, neither of these watershed management options are recommended.

11.3.2 In lake Restoration Measures

Given Onota Lake's recreational and aesthetic attributes, the development of an in-lake restoration program is necessary. In-lake programs offer, in some cases, an immediate improvement in lake quality. Unlike watershed management techniques, in-lake measures are usually easier to implement, somewhat less expensive, and provide much quicker improvements in lake quality and utilization. Although some in-lake management measures are primarily cosmetic, they can lead to substantial reductions in nutrient loading as well as to an improvement in the appearance and recreational opportunities of the lake.

As was performed with the watershed management measures, a feasibility matrix of the various in-lake options was conducted. Matrix components and scoring were similar to that utilized for watershed management. The results of the analysis are presented in Table 11.2. Of the numerous techniques assessed, the following proved to have the highest scores.

- Short circuiting of inflow
- Aquatic macrophyte harvesting
- Aeration
- Use of macrophyte barriers
- Spot dredging

Each of these promises to yield the greatest benefits to the lake. Interestingly, lake conditions are somewhat dissimilar between the two basins. As such, different in-lake management options are prescribed for each basin. In the south basin, summer aeration and limited macrophyte harvesting are needed. In the north basin extensive harvesting, flow short-circuiting, spot dredging, weed barriers and winter aeration are recommended. The utility of each in-lake technique is detailed in the following sections.

11.3.2.1 Short Circuiting of Flow

The presence of the sand bar effectively isolates the north and south basins. Although water exchange occurs between the two, the sand bar physically impedes mixing. This has been documented in Section 10 and is supported by the observed conditions and problems of the two basins. The majority of tributary inflow is to the north basin. Thus, the majority of tributary related influxes of nutrients and sediments is to the north basin (refer to Table 10.10).

Review of the lake's morphometry and the location of the tributaries suggest that it would be possible to increase flushing and short circuit flow by construction of a culvert under Thomas Island Road. Presently, there exists a narrow causeway (-50 feet wide). Two box culverts, each 4-8 feet wide, could be placed under the roadway. Opening of this area, coupled with dredging, could promote flushing of Thomas Island Cove and the small cove northwest of the island. In addition, inflow from Daniels and Churchill Brooks would be partly diverted as a result of the construction, and induced to flow through the culverts as opposed to around the island. As the outlet of the lake is located in Thomas Island Cove, this would, in effect, short-circuit nutrient rich water out of the lake and the altered circulation pattern would promote better flushing of the North Basin (Figure 11.1).

There are a number of ways to engineer this project. The first would be to hydraulically dredge the sediments on either side of the causeway, possibly disposing of the spoils in the abandoned quarry pits in the Daniels Brook watershed (Figure 11.2) Once dredging had been completed the lake could be lowered and the box culverts installed. The optimum level of the culverts would be determined during the engineering survey, but would be such that flow would not be interrupted by normal low lake levels.

An alternate approach would be to lower the lake. Once the sediments had been allowed to dewater, conventional equipment would be used to remove accumulated sediment. This would probably include the use of muddozers, a pond excavator such as the Smalley Excavator, and a dragline. Spoils would have to be trucked off site. Once again, the quarry pits could be used for spoil disposal. Other approaches including the use of coffer dams, and a combination of dry and hydraulic dredging could be pursued.

Based on our review of the site and discussions with LOPA and Pittsfield officials, it appears the most feasible approach would be dry excavation. First, dry excavation will minimize the spoil handling/disposal problems. Hydraulic dredging will require pumping of the slurry. Due to the distance and topography of the potential disposal site, it will be necessary to traverse one of two roads and pump the material upgrade (approximate 30' change in elevation). Sophisticated sediment containment/dewatering basins will need to be constructed to accept the slurry, all of which increases the cost of the project. Dry excavation will alleviate much of these problems and additional costs. By allowing the sediments to dewater in place, for 1-2 months, before excavation, an appreciable amount of water will drain from the

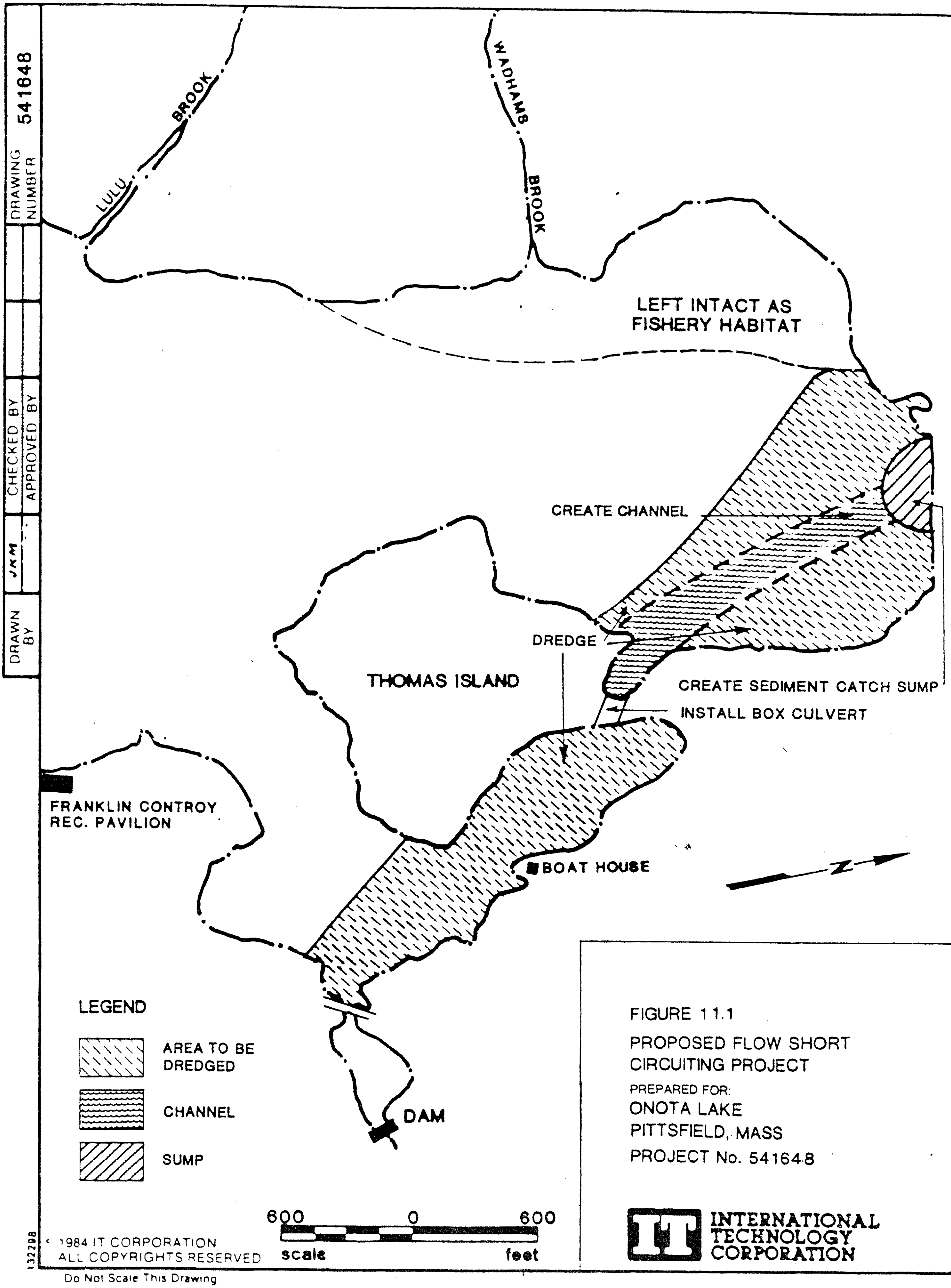


FIGURE 11.1

PROPOSED FLOW SHORT CIRCUITING PROJECT

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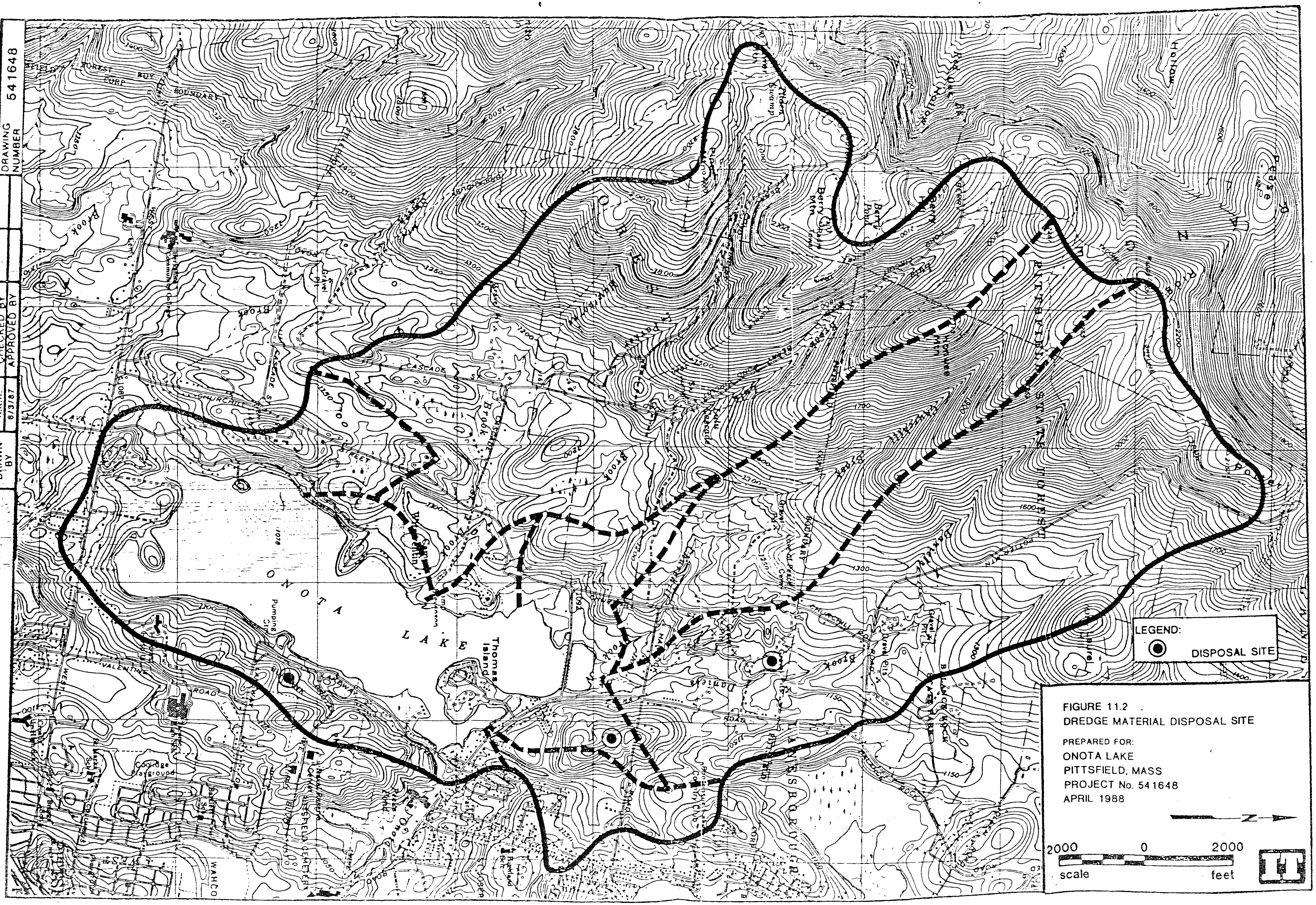

FIGURE 11.2
DREDGE MATERIAL DISPOSAL SITE

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spoils. (Dewatering characteristics would be determined from core samples taken prior to the project.) If needed, as the spoils are being excavated, localized containment/dewatering areas or spoil stockpiling areas could be created within the boundaries of the excavation area to allow for final dewatering.

Second, during the lowering the lake additional restoration activities could be conducted. This could include a general cleanup of refuse and debris, placement of benthic barriers, and excavation activities associated with in-lake sumps or biofilter (created wetlands).

Third, the total operation could be completed much quicker using dry excavation techniques.

The short circuiting project should coincide with the repair of the dam. It will be necessary to lower the lake to accomplish both projects. As such, it would be prudent to schedule both projects to occur simultaneously.

The nutrient budget data indicate that approximately 58.3% (517.7 Kg/yr) of the total annual external TP load enters to the north basin (Table 10.10). Approximately 71.4% of the lake's annual hydrologic load discharges into the north basin. In addition, the TP load generated by the Churchill Brook and Daniels Brook watersheds amounts to 226 kg (35.7%) of the total annual load. As such, the north basin, although only 10% the volume of the south basin, receives a significant proportion of the annual pollutant load. In addition, this basin, particularly in the vicinity of Thomas Island, is characterized by deep, organic sediments (Section 7.0), low dissolved oxygen (Section 5.0), and a substantial weed problem (Section 5.0). Implementation of the proposed project would improve conditions of the north basin and entire lake as follows:

1. Remove a significant (2-4 x $10^5 yd^3$) amount of accumulated organic sediment.

2. Decrease the density of weed growth in approximately 25 to 40 ha of lake surface.

3. Help alleviate the water D.O. problem by removing the organic silt and macrophyte layer.

4. Improve flushing of the two backwater coves which lie on either side of the Thomas Island Road causeway.

5. Decrease the hydraulic residence time in the north basin thereby decreasing the retention of sediment and associated particulate forms of nutrients.

11.3.2.2 Aquatic Macrophyte Harvesting

Dense beds of *Elodea* and mixed beds of *Myriophyllum*, *Vallisneria* and *Elodea* occur throughout the north basin. These plants impede recreational use of the area, primarily in relation to boating and fishing. The seasonal dieback of the weeds also contributes to the lake's nutrient load. The bacterial decomposition of the dead macrophytes during the winter appears to be causing a severe reduction in dissolved oxygen (D.O.). This depletion in D.O. is substantial enough to potentially cause winter fish kill in the north basin.

TABLE 11.2

IN-LAKE MANAGEMENT FEASIBILITY MATRIX

METHOD	CAUSE/ EFFECT	DEGREE OF LOAD REDUCTION	PRACTICALITY	PERFORMANCE CHARACTERISTICS	COST	TOTAL
Macrophyte harvesting	3	3	5	5	3	19
Short Circuit in-flow	5	5	5	5	3	23
Spot Dredging	3	3	3	4	1	14
Aeration	5	5	3	4	2	19
Use of Macrophyte Barriers	1	1	4	4	5	15
Algaecide/ Herbicide	1	1	1	1	4	8
Lake Lowering	1	1	4	2	5	13

Potamogeton is the primary species of concern in the south basin, although *Myriophyllum* and *Elodea* have been observed. Densities reach nuisance proportions primarily in the shallow littoral areas along the lake's south shore.

The implementation of an intensive weed harvesting program would greatly aid in the control of macrophyte densities (Nichols, 1974). In addition to increasing the total weed free surface area of the lake, harvesting could greatly influence the internal regeneration of nutrients in the north basin (Souza, et al 1987, Carignan, 1985). The objective of the harvesting operation should be management of macrophytes to acceptable levels and not their elimination. For this reason, even in the north basin, areas of appreciable standing crop of macrophytes should be allowed.

Specifically, intensive harvesting (two cuts per summer) is required in the following locations:

- Thomas Island Cove (between Lakeway Drive and Thomas Island Road),
- Majority of the North Basin from Dan Casey Memorial Drive,
- Along the west shore in the vicinity of Camp Winadu, and
- To a lesser extent in the vicinity of Apple Tree Point in the Main Basin.

The majority of the macrophyte harvesting will occur in the north basin. Harvesting could be effectively accomplished using a mid-size Harvester such as the UMI HP7-400 or a full size unit such as the UMI HP8-700. Although appreciable densities of macrophytes exist in the main basin, water depth and obstructions may inhibit harvesting. In addition, relative to cost/benefits, harvesting in the north basin will yield the greatest returns.

If harvesting is implemented independent of any of the other recommended in-lake restoration measures (particularly short circuiting of flow), it will be necessary to purchase equipment for Onota Lake. The proposed program will be effective only if done intensively. Based on existing weed growth patterns and given weed management objectives, it is estimated that 75 to 100 ha would require harvesting. Over 80% of the total area is in the north basin. The limited truck access to much of the north basin will influence harvesting efficiency. It is estimated based on review of design specifications of various harvesters, that it will take 30 to 40 working days, to conduct a single harvest of the lake. Since the objective is to remove as much biomass as possible, multiple harvests are recommended. A double harvesting of the lake, and possible triple harvest in particularly nuisance areas such as Thomas Island Cove, will require 60 to 80 working days to accomplish. As such it does not appear feasible to borrow equipment used at Lake Pontoosuc or Richmond Pond for use at Onota Lake. To accomplish the macrophyte management objectives, a single unit must be dedicated full time to operation at Onota lake.

However, if the short circuiting of flow project is implemented, a different weed control scenario will develop. The sediment excavation required as part of the short circuiting channel will eliminate most of the weeds in Thomas Island Cove and to the north of Thomas Island Drive. If this project is combined with the creation of a sump on the south side of the Dan Casey Causeway (11.3.1.1) and use of benthic barriers the total amount of harvestable lake surface will probably be reduced to approximately 25 ha. The purchase of machinery to harvest such a small amount of Lake surface is not justified. Given such a scenario, it would be more cost effective to rent equipment from Pontoosuc Lake or Richmond Pond. Based on a price of $150 to $200/acre (much less than commercial harvesting costs), Onota Lake could be maintained in a managed state for approximately $7500 to $20,000/season (depending on the number of harvests). Since the county owns the equipment, and harvesting could be done by Pittsfield DPW employees, it is highly likely that the harvesting costs could be less.

11.3.2.3 Spot Dredging

The sediment accumulation study (Section 7.0) indicates that the majority of accumulated sediment is in the north basin. Considerable quantities (4.29×10^5 yd^3) of organic sediments have been deposited in the Thomas Island Cove and at the base of Dan Casey Memorial Drive. If previous identified projects were implemented, such as the creation of sumps (11.3.1.1) and the short-circuiting of flow discussed above, the amount of ancillary dredging required in the lake would be minimal. If the short-circuiting recommendation is not implemented, however, dredging of the coves on either side of Thomas Island should still proceed. As much as 6 feet of silty, organic material was measured in these areas. Its removal would benefit the lake as follows:

- Decrease the sediment organic load, thereby decreasing oxygen depletion,
- Decrease the availability of in-lake pools of nitrogen and phosphorus,
- Decrease dense stands of nuisance macrophytes,
- Improve recreational utilization, and
- Improve aesthetic attributes.

Either dry or hydraulic dredging could be implemented. The use of diver operated suction dredge equipment is promising only if an adequate and ecologically sound means of handling the spoils and dredge slurry is developed. As discussed above, IT recommends that as much dredging as possible be done using dry excavation techniques.

As with any dredging operation, some negative impacts will result. These are namely destruction of the benthic community, temporary increase in turbidity (hydraulic), possible regeneration of nutrients, possible algal bloom resulting from removal of shading macrophytes and regeneration of nutrients. All of these problems are temporary and short-term (USACOE, 1977). The benefits and improvements to the lake definitely outweigh these negative impacts.

11.3.2.4 Aeration

A sizable percentage of the lake's total phosphorus load is generated from anoxic sediment. The internal load is 345 kg TP/yr from the main (deep) basin and 28 kg TP/yr from the shallow basin. The majority of sediment regeneration of phosphorus occurs in the main basin. Hypolimnetic aeration could effectively reduce the internal load by oxygenating the deep level of the lake. An additional benefit which will be accrued through aeration will be the addition of available trout habitat. Based on an anoxic volume of 5.85×10^6 m^3, one large or two small aerators would be required.

Installation of the units would require the fabrication of a pump house and O&M associated with the compressor system. It will be necessary to shut the system down in the winter, first because it is not needed and second to avoid interference with ice fishing.

Conversely, a smaller aeration unit is required for the north basin. Its purpose would not be associated with aerating the hypolimnion in the summer but in contravening winter oxygen depletion. The DO curves show a substantial decline in winter DO concentrations. February concentrations reach potential critical levels (Figure 5.16). The cause for this depletion is most likely bacterial decomposition of detrital plant material and subsequent respiratory oxygen demands. The aeration unit would disrupt ice fishing in a section of the north basin. However, it would prevent fish kills from occurring. In addition, it would most likely improve the lake's fishing as it would increase the volume of the north basin suitable for cold water game fish (DO > 7 mg/l).

An alternate approach to controlling the internal regeneration of phosphorus is through sediment inactivation. This typically involves the subsurface application of sodium aluminate or aluminum sulfate. The alum inactivates the phosphorus, significantly decreasing its availability to primary producers (Cooke and Kennedy, 1980).

Alum, in the form of aluminum sulfate, could be added to the hypolimnion using a submergible manifold. The correct concentration of alum would be determined on the basis of analyses conducted just prior to the application. The concentration of phosphorus, the pH, and the alkalinity of the hypolimnion will determine the dosage rate and concentration of the alum. Application should occur in mid-August after hypolimetic phosphorus release has commenced but before lake turnover. In this manner, adequate precautions could be taken to help insure that the sediment-liberated phosphorus is inactivated before it is circulated into the trophogenic zone. The specifics concerning cost and manpower allocation are yet to be fully developed. However, based on previous studies, the cost for an operation of this magnitude may exceed $25,000 in the cost of alum alone. Conversely, a single treatment could yield as much as 5 or 6 years of control of the internal phosphorus load (Cooke, et al., 1982).

However, the utility of alum inactivation is limited at Onota Lake. First, in lakes of low buffering capacity, problems arising from aluminum toxicity are possible. Trout are particularly sensitive to aluminum. Second, TP inactivation does nothing to improve hypolimnetic dissolved oxygen. As it is as equally desirable to increase available fish habitat as it is to decrease internal TP loading, aeration appears to be more feasible than nutrient inactivation.

11.3.2.5 Macrophyte Barriers

An extensive weed bed occurs along the northwest shore of the lake adjacent to a large wetland (Figure 11.3). A combination of emergent and submergent species dominate the area. Fishing access could be improved in this area through the development of "fishing lanes". These lanes can be created by using mechanical barriers which impede weed growth as opposed to harvesting. Material such as Texel or Dartec could be laid out. Lanes 50 - 75 feet long and approximately 12 feet wide would be created. This would also cause the creation of an edge ecotone which could also improve diversity and utilization of the area by large predator fish. The approach is relatively inexpensive.

11.3.2.6 Algacide/Herbicide Application

The present concentrations of algae do not require control via application of algacides. This will be better achieved through decreasing the nutrient load to the lake. Harvesting is greatly preferred in respect to herbicide application as the means of macrophyte control. For these reasons neither is recommended.

11.3.2.7 Lake Lowering

Manipulation of a lake's water level is used as a means of controlling macrophyte growth. The practice basically relies on the exposure of the lake bottom and the subsequent dessication or freezing of the weeds. When done properly, the roots and rhizomes of the plants, are adversely affected. In turn growth in the subsequent season is impeded. The literature shows this practice to be successful for only a few weed species. In some cases, weed growth may actually be promoted. Lake level manipulation has been used extensively at other lakes neighboring Onota. The results have been mixed. Although both Richmond Pond and Lake Pontosuc have been subjected to

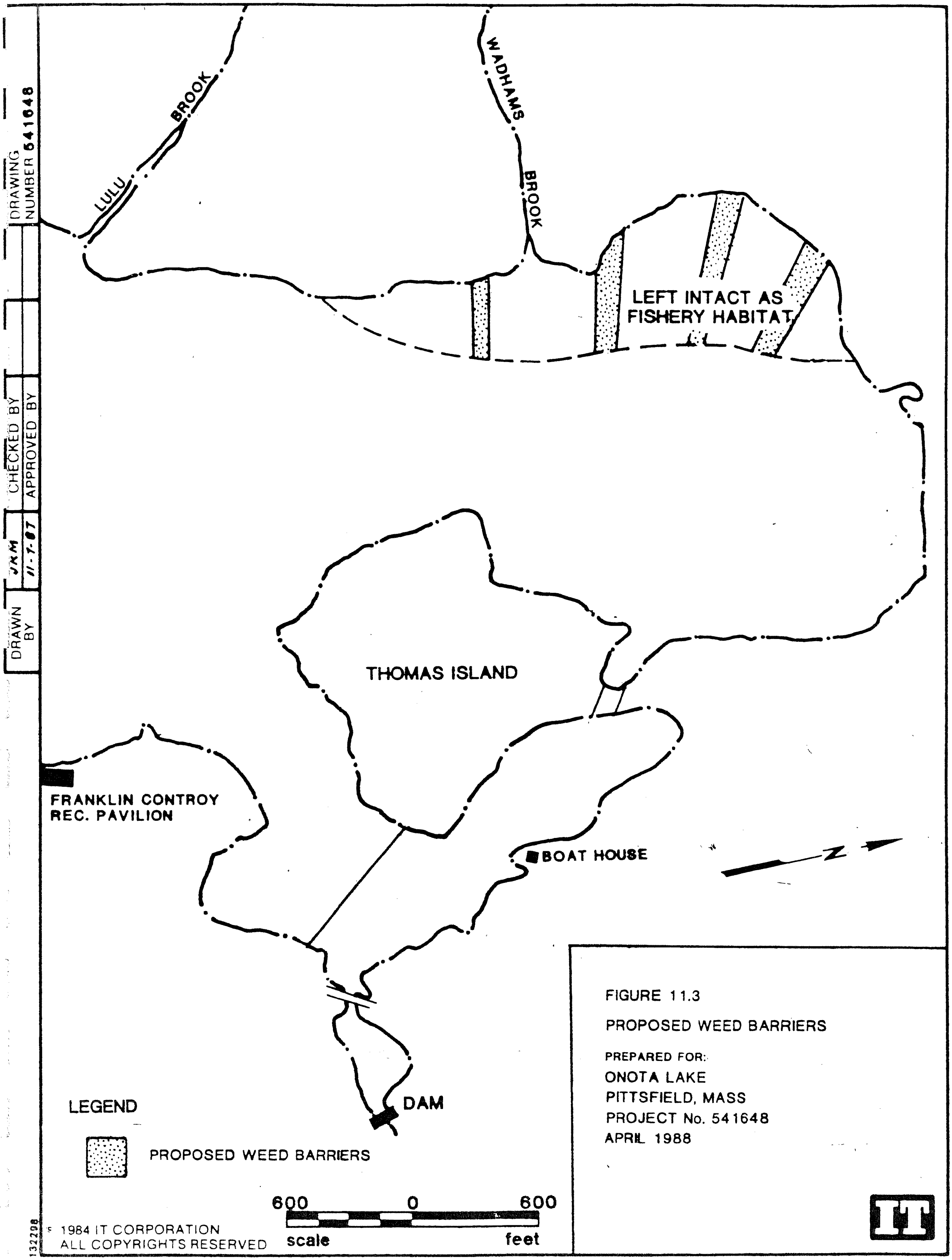

FIGURE 11.3

PROPOSED WEED BARRIERS

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drawdowns, both still support a proliferation of nuisance aquatic macrophytes. Mr. William Enser, however, reports (Person. Comm., 1987) that drawdown has had successful results in other Berkshire County Lakes.

In the past, the lake level manipulations practiced at Onota Lake have not been conducted in the most ecological manner. Communication with LOPA officials (LOPA, Pers. Comm. 1986) indicate that lake drawdown has been unstructured relative to duration or objectives. It has also been conducted too frequently (annually). Although drawdown has, reportedly, not caused excessive beach erosion, it is possible that drawdown has contributed to fishkills and low D.O.level in the North basin. The lake was not drawn down at any time during IT's study.

Given the occurrence of species whose growth may increase after exposure of short duration, it is best to ensure that the drawdown is of major proportions. It should coincide with that period of time when freezing or dessication will occur, and be done infrequently so that the plants do not adapt to exposure.

Due to the frequency of <u>Potomogeton</u> in Onota Lake it is recommended that drawdown be implemented only as part of some other restoration measures (dredging, short circuiting of flow, benthic barriers, creation of sump basins, etc.) In itself, it is doubtful that drawdown can improve the condition of the lake or reduce weed densities. As a measure used in conjunction with harvesting, it appears drawdown has promise. It is therefore recommended that lake lowering be limited to once every 3 or 5 years and as an augmentative measure to harvesting.

11.3.2.8. <u>Power Boat Limitations</u>

As indicated on Section 6.0 (Macrophyte Survey) there exists some evidence to support the contention that nuisance plant are being introduced to the south basin as a result of prop disturbance, fragmentation and boat-related distribution. In order to curtail the spread of weeds by boats a speed restriction (no wake, <5 mph) should be applied to the entire area northwest of Thomas Island. Although water skiing is popular in the north basin, most activity is confined to the south side of Thomas Island and the beach area adjacent to Camp Winadiu.

Low speeds in the northwest end, which is heavily weed choked, will decrease the fragmentation of Elodea and help reduce the boat related spread of nuisance weeds.

In addition, through a public education effort, boaters should be encouraged to clear their props when travelling from the north to south basin. The shallow water depths in the vicinity of the sand bar already require boats to slow down during passage to the south. Removal of weeds fouling props would take but a few additional minutes.

11.3.2.9 Low Priority Options

Other in-lake management options were reviewed including:

- Bottom sealing,
- Selective discharge,
- Dilution flushing,
- Biological controls,

None of these appear to be reasonably feasible management options. Bottom sealing and selective discharge are means of decreasing internal regeneration of nutrients. The use of the aeration system will accomplish the same, while increasing hypolimnetic DO, increasing cold water fish habitat and only slightly disrupting the thermocline.

As a large proportion of the lake's hydrologic budget is comprised of groundwater seepage, dilution/flushing will not provide a great benefit. In addition, a substantial quantity of ground water would be required to decrease the lake's flushing rate (more frequent flushing). As such, it is not recommended.

At present, biological controls have had only a limited success in lake management. Of the various techniques, management of macrophytes by herbivorous fish such as grass carp is the most promising. However, at this time, the Commonwealth of Massachusetts prohibits the introduction of grass carp. Until proper stocking ratios are better established, use of grass carp should not be pursued.

11.3.3 Recommended Plan

Following the review of the diagnostic data, the feasibility assessment and dialogue with LOPA and city officials, a Restoration Management Plan consisting of a combination of in-lake and watershed techniques was developed. In order to achieve improved water quality, recreational potential, and aesthetic attributes in a cost-effective manner, which is responsive to local needs, the schedule of implementation should be as follows:

1. Lower lake in fall, allow sediments to de-water in situ and conduct the necessary excavation and construction required to facilitate short circuiting of flow in the north basin.

2. While the lake is lowered, conduct any repairs needed to maintain the structural integrity of the lake's spillway.

3. Concurrent with the short circuiting project, create a sump at the south side of Dan Casey Causeway and supplement the wetland area north of the causeway with additional planting to further facilitate nutrient and sediment retention,

4. Install benthic barriers along the northwest shore of the north basin, placement of which being designed to improve fishing access, and enhance existing fish habitat by creating edge ecotone,

5. During the first spring/summer following these activities, observe weed growth and determine the necessity for harvesting. Given low remaining acreage of nuisance beds following implementation of Tasks 1, 3, and 4, contract with the county to share a harvester from either Pontoosuc Lake or Richmond Pond.

6. Conduct reconnaisance of immediate shoreline, identify areas of existing soil erosion and erosion prone areas. Develop the required approach to address each site and provide for future monitoring to identify new areas as they arise.

7. During spring, install hypolimnetic aeration unit(s) in south basin,

8. Initiate required bonding provisions for the sewering of Blythewood Drive,

9. Initiate public education program,

10. Develop final engineering drawings and bid specifications for the Parker Brook detention basin and the Blythewood Drive biofilter, once land availability and easement issues are rectified, and

11. During course of any restoration, implement a monitoring program, designed specifically to examine the objectives of each project. These project specific monitoring programs should be part of a continuing lake-wide monitoring program designed to examine the status of the lake.

11.3.4 <u>Public Education and Involvement Program</u>

An integral component of the Restoration/Management plan is Public Education. In order to maintain public interest and support, it is important that the public be kept informed of interim findings and proposed solutions. Equally important is the fact that they must know what is being done, why it is being done, and how they, the lake users, will benefit. In addition, they must become educated as to what they can do as individuals to improve the lake. This can all be accomplished through several avenues, including:

1. News releases to local newspapers,
2. Special quarterly public meetings or seminars to discuss the issues that affect the lake, progress being made, and proposed activities,
3. Monthly <u>public</u> meetings of LOPA,
4. Presentation of papers at conferences and Technology Transfer Seminars,

5. For all projects which may impact the lake or its tributaries, involvement of LOPA in the decision-making processes of local government, particularly the Environmental Commission, Board of Health and Planning Board,

6. Special presentations to the various officials and professionals of the communities in the watershed,

7. Active participation in the data-gathering activities of the study, and

8. Dissemination of information to watershed residents concerning Best Management Practices and grass roots activities which help reduce pollutant loading to the lake.

LOPA and the City of Pittsfield recognize that, as well as being informed, the public has to be involved. The residents of the watershed will be requested to support the plan. To date, volunteers have provided assistance in the monitoring of rain and staff gages and the collection of storm samples. Public involvement of this type identifies the community as being sincerely concerned and interested in the lake's restoration. It is important that the public considers the plan and the lake as their's and that they are obligated to implement it and provide for the lake's future management.

Local citizens can be especially helpful in contacting their elected representatives and gaining support for the project. The public, and public officials at all levels of government, must become more fully aware that Onota Lake is the city's most important natural resource. The economic welfare of the area also depends in part upon the quality of Onota Lake as a recreational resource. This effort has to be continued and intensified if the plan developed herein is to be successful.

In addition to the above, the following are specific recommendations which will aid in the acceptance and implementation of the lake restoration plan:

1. The City of Pittsfield should examine, strengthen, enforce, and/or adopt storm runoff control and erosion control ordinances and septic system ordinances.

2. The master planning process and zoning ordinances should channel development toward areas which will have no impact on lake water quality and away from environmentally sensitive areas such as Blythewood Drive.

3. Once new zoning and development ordinance are adopted, the communities should insist on rigid compliance with the plan. The temptation to zone by parcel through variances and zoning adjustments should be resisted. A

municipality can have an excellent master plan and ordinances, but, fail to achieve their goals because of lack of enforcement.

4. Tighten up ordinances to include Environmental Impact Statements for all major and minor subdivision projects.

11.3.5 Institutional Arrangements

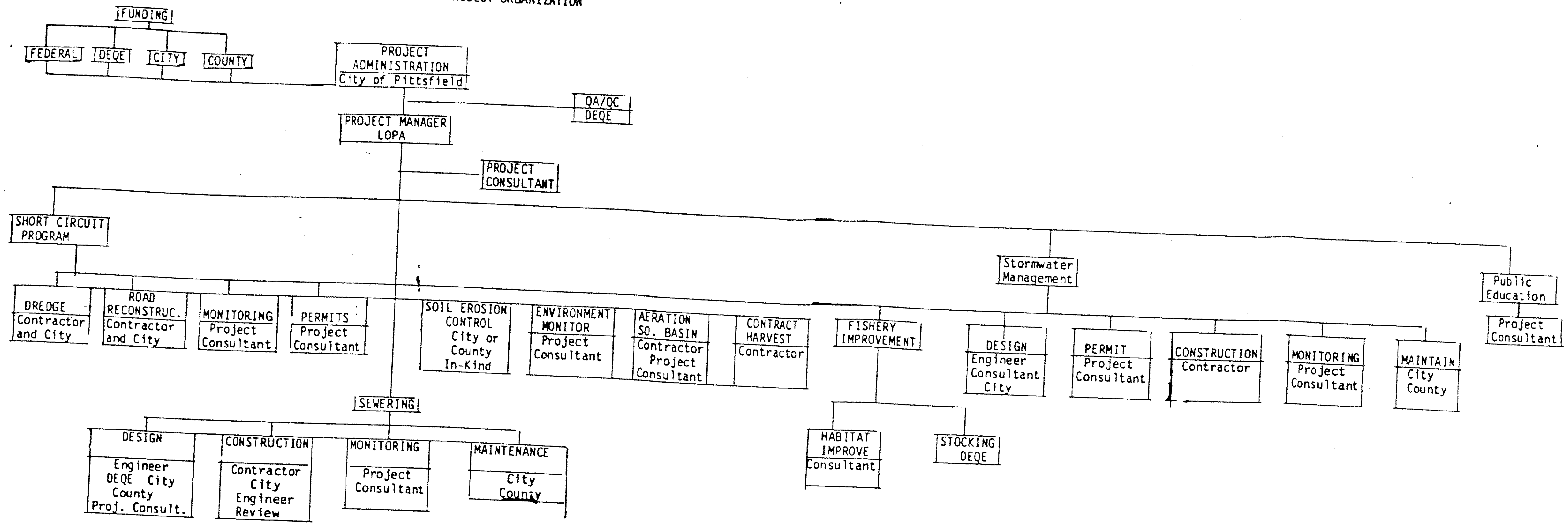
The proposed lake restoration and watershed management plan will be successful only if local, state and federal institutions see them through. The institutional arrangements for implementing the plan presented in this report will necessitate approval by the city, the county and the Commonwealth (Figure 11.4). The number of agencies, laws, regulations and levels of government that are involved with implementing the program could become complicated. For instance, construction of stormwater management basins (as proposed at the mouth of Parker Brook) could involve DEQE, COE, and County Environmental Commission approval.

Therefore, it is essential that one local organization be made responsible for coordinating and implementing the plan. The organization serving this coordinating function at this time is the Onota Lake Preservation Association. It is recommended that the DEQE and City of Pittsfield recognize the LOPA to implement and oversee the management/restoration plan. LOPA should act on behalf of the city in the management of Phase II activities.

To provide for the long-term management of Onota Lake, the Commonwealth of Massachusetts should examine the feasibility of creating an Onota Lake Management District. Among other powers, the district could assess taxes throughout the watershed, apply for, receive and administer grants, and assess user charges to develop and implement lake management and restoration and watershed management programs.

LOPA should continue coordinating with the various political entities to maintain and improve Onota Lake as a viable recreational resource. It should be LOPA's responsibility to implement the management and restoration plan in cooperation with the various governmental and private institutions. Also, as an independent organization concerned with the lake's improvement, they should review and comment on all zoning changes, master plans, development and

FIGURE 11.4
PROJECT ORGANIZATION



regulations that affect Onota Lake.

11.3.6 Permit Requirements

ermits must be secured from the required state, federal and local conservation agencies before implementation of the restoration measures can begin.

Activity	Permit Required	Permitting Agency
. Lake lowering	Notice of Intent	Pittsfield Conservation Commission
	(NOI) Ch. 91	DEP-Div. of Wetlands and Waterways
		Mass. Div. of Fisheries and Wildlife (MDFW)
	ENF	MEPA (if >5000 ft^2 of wetlands involved)
2. Dredging	Notice of Intent	Pittsfield Conservation Commission
	(NOI) Ch. 91	DEP-Div. of Wetlands and Waterways
	Sec. 404	Army Corps of Engineers (ACOE)
	Water Quality Cert.	DEP - Div. of Water Pollution Control
	ENF	MEPA
. Construction	N.O.I.	Conservation Commission
	Ch. 91	DEP
	Sec. 404	ACOE
	ENF	MEPA
	Water Quality Cert.	DEP-Div. of Water Pollution Control
4. Wetland	N.O.I.	Conservation Commission
	ENF	MEPA
	Sec. 404	ACOE

The Soil Conservation Service does not have a required permit. The Phase II consultant would file Section 404 and Chapter 91 permits. The city of Pittsfield would file Notice of Intent and the Environmental Notification Form (ENF). The city must write a letter to the Director of Massachusetts Divison of Fisheries and Wildlife ten days prior to lowering the lake specifying depth of drawdown, duration and expected refill date.

11.3.7 Monitoring Program

A two stage monitoring program should be developed as part of the Phase II Program. The first stage would be designed for the continued assessment of lake quality. This should involve quarterly monitoring at each of the in-lake and tributary stations monitored during the 1986 study. Monitored parameters should include:

- TP
- Soluble reactive phosphorus (SRP)
- NO_3
- NH_3
- TKN
- TSS
- Chlorophyll a,b,c phaeophytin
- Alkalinity
- Fecal coliforms
- Transparency
- D.O.*
- Temperature*
- Conductivity*
- pH*

Those parameters followed by an asterisk should be conducted in-situ throughout the entire water column at 1.0 m intervals.

Concurrent with this "background" monitoring program, individual programs need to be developed as part of each restoration task. These project-specific programs should be designed to assess environmental impact during program implementation and assess the effectiveness of the program.

Lake lowering and projects which include construction (in-lake sumps, biofilters, short circuiting of flow, dredging) should have a monitoring program which requires weekly sampling during drawdown or construction. During drawdown an in-situ station in each basin should be monitored for D.O., NH_3, NO_3, TP, and SRP. Samples should be collected 1/2 meter below the surface and 1/2 meter above the bottom. D.O. should be monitored in-situ throughout the water column at 1 meter intervals.

For any construction related projects, sampling should occur up-stream, within, and downstream of the project boundaries. If the lake is lowered to facilitate operations, a station should be located within 50' of the project boundary or where water depths are at least one meter. A second station should be located approximately 50' downstream of the first. Regardless of the scenario, the following parameters should be monitored:

D.O.	NH_3
pH	NO_3
TP	TKN
SRP	TSS
Transparency	

Following the completion of each stormwater management project, sampling emphasis should be placed on quantification of storm load reduction. This requires wet weather sampling. At a minimum, samples should be collected during three storms, every year for a total of 3 years.

Stations should be established above, within and below the stormwater management structure. Storm sampling should be consistent with DEQE Phase II requirements and include analysis for:

TP	TSS
SRP	As, Cd, Cr, Pb, Hg, Fe, Al, Ni, Zn, Cu
NO_3	Oil and Grease (Petroleum Hydrocarbons)
NH_3	Chlorides
TKN	Fecal coliform
TDS	

The monitoring program associated with macrophyte control should utilize the in-lake "background" water quality data. This will reduce sampling redundancy. The water quality should be augmented by plant surveys done in June, August and September. A ten x ten meter test plot (harvested quadrats) and control plot (non-harvested quadrats) located in each basin should be monitored on each date for:

density

species composition
percent coverage
total biomass

Seine or electrochocking techniques should be used to assess the fish community associated with each plot. These data could be used to assess the success of the harvesting program relative to changes in macrophyte species composition, re-growth time, biomass harvested, and affects on fish utilization.

11.4 ANTICIPATED IMPROVEMENTS

Implementation of the recommended restoration projects are anticipated to improve the water quality, recreational use and aesthetic attributes of the lake. Improvements in water quality are based on literature cited performance capabilities of the proposed stormwater management measures and the loading data developed in Chapter 10. The load reduction and improvements in lake use assume the following restoration plan will be implemented:

South Basin

1. Sewer Blythewood Drive

2. Aerate hypolimnion during summer.

North Basin

1. Repair Peck Road sewer break,

2. Implement short circuiting project:

   a. lower lake, expose north basin sediments,
   b. allow sediments to dewater,
   c. install box culvert under Thomas Island Road,
   d. excavate accumulated sediment,
   e. create sump at the base of Dan Casey Causeway

f. Refill Lake

3. Conduct selective weed harvesting.

4. Improve fishery habitat.

Watershed Management

1. Implement stormwater management measures.

2. Conduct public education programs.

3. Correct soil erosion problems.

It is anticipated that the South Basin projects should reduce the total phosphorus load associated with septic sources by 188.2 kg and from internal sources by 173 kg, assuming a 50% improvement due to aeration. The total south basin TP reduction would, therefore, be 361.2 kg (based on Table 10.10 values). The North Basin project will result in an estimated reduction in loading of 197.3 kg. This is a conservative estimate and assumes that the combination of short circuiting, the Dan Casey sump, and the biofilters at the mouth of Churchill and Daniel Brooks will provide only a 40% reduction in TP loading. The excavation associated with the short circuiting program should substantially reduce the north basin's volume of organic sediments. This should effectively eliminate the TP regeneration associated with the anoxic hypolimnion, resulting in the elimination of 28.0 kg/yr of total phosphorus.

The sum of the load reductions associated with the various restoration measures totals 361.2 kg for the South Basin and 225.3 kg for the North Basin. This amounts to a 50% and 41% TP load reduction for the south and north basins respectively, and results in a total TP load of 354.8 kg for the south basin and 320.4 in the north basin. The trophic state for each basin will improve given these reductions (Table 11.3, Figure 11.5).

As equally important, the implementation of the proposed Restoration/ Management Plan will increase the recreational potential of the lake. This

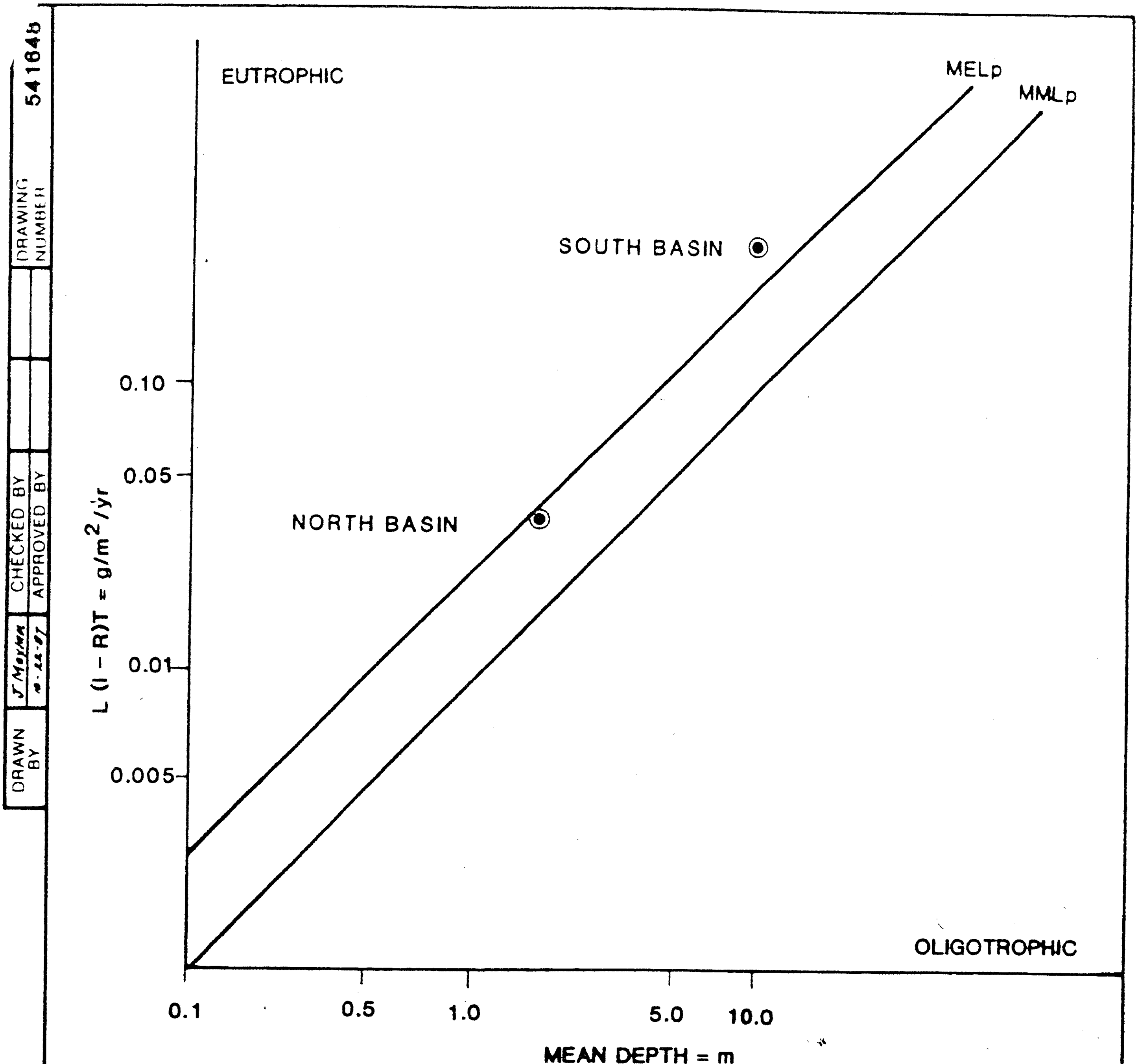


FIGURE 11.5

TROPHIC STATE AS PREDICTED INDEPENDENTLY FOR ONOTA LAKE'S NORTH AND SOUTH BASINS

PREPARED FOR:

ONOTA LAKE
PITTSFIELD, MASS

PROJECT No. 541648

NOVEMBER 1987

INTERNATIONAL TECHNOLOGY CORPORATION

will be achieved through macrophyte control, deepening of shallow areas, improvements in fishing access, and improvement in cold water fish habitat. These improvements in the lake will greatly benefit lake users. In addition, the public education program will help users become attuned to the overall scope of the Restoration Management Plan. Through seminars and other planned activities, individuals can also become more aware of how they can help improve or maintain the quality of the lake at the grass roots level.

11.5 SCHEDULE OF ACTIVITIES

The proposed plan will take at least five years to implement. A projected time line has been prepared (Figure 11.6). The time line shows the preferred scheduling of activities. If this schedule is followed, the restoration of Onota Lake should proceed in a manner consistent with the prioritization analysis conducted in previous sections of this report. This will help insure cost effectiveness.

11.6 BUDGET

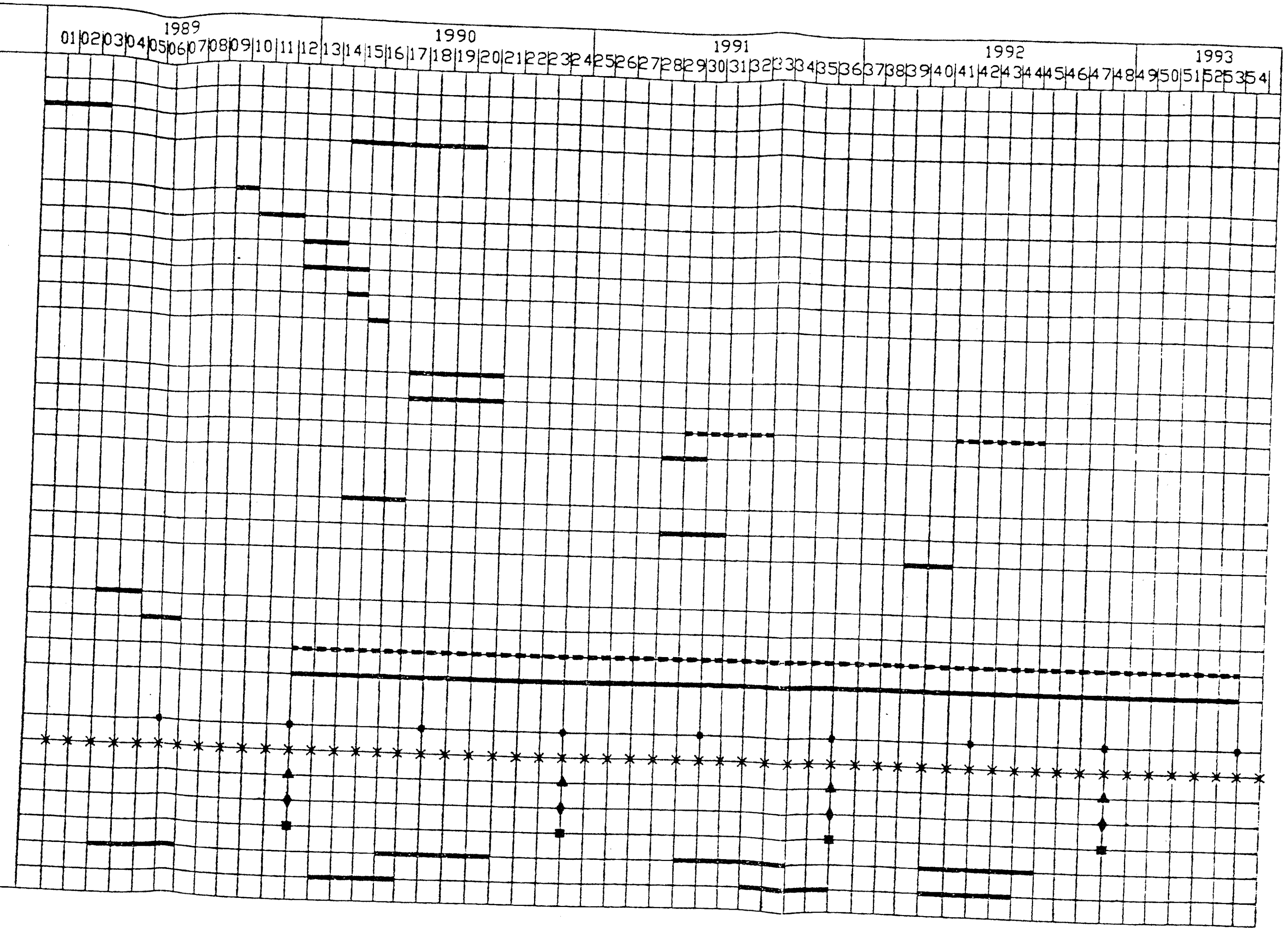
The budget has been prepared using engineering estimates (Means, 1985), review of literature, and communication with restoration contractors and/or suppliers. The budget has been prepared assuming the Thomas Island short circuiting project is implemented and the schedule of activities as presented in Figure 11.6.

The budget breakdown is presented in Table 11.4. It should be noted that an approximate 5 year completion period is projected for the proposed plan. The elements of the plan have been scheduled not only to meet restoration needs but to avoid an excessive monetary burden being placed on the city or Commonwealth.

The budget associated with the restoration and management of Onota Lake is difficult to actually project (Table 11.4). This is largely due to the costs associated with the sewering of Blythewood Drive. Basically, there were a few different engineering approaches to this project. These alternatives are presented previously. Depending on which is deemed most feasible, the cost

FIGURE 11.6
SCHEDULE OF ACTIVITIES AND MILESTONES
FOR THE RESTORATION OF
ONOTA LAKE

TASK	ACTIVITY
	SEWERING
01	REPAIR PECK ROAD BREAK
02	SEWER BLYTHEWOOD DRIVE
	SHORT CIRCUIT OF FLOW IN NORTH BASIN
03	LOWER LAKE
04	SEDIMENT DEWATER
05	BOX CULVERT INSTALLATION
06	EXCAVATION OF SEDIMENT TO CREATE CHANNEL
07	CREATE SUMP AT DAN CASEY CAUSEWAY
08	REFILL LAKE
	WEED HARVESTING
09	MONITOR NEED AFTER COMPLETION OF NORTH BASIN EXCAVATION
10	FISHERY IMPROVEMENTS
11	IF NEEDED, CONTRACT WEED HARVEST
12	INSTALL AERATION UNIT
	CONSTRUCTION OF STORM WATER MGMT. STRUCTURES
13	CHURCHHILL/DANIELS
14	PARKER BROOK
15	BLYTHEWOOD
	SOIL EROSION CONTROL
16	CONDUCT INTENSIVE SURVEY
17	PREPARE RESTORATION MEASURES
18	IMPLEMENT
19	CONTINUE SURVEILLANCE
	PUBLIC EDUCATION
20	SEMINARS
21	MONTHLY LUPA MEETINGS
22	SCIENTIFIC PRESENTATIONS
23	NEWS PAPER ARTICLES
24	INTERIM REPORTS
25	MONITORING IN-LAKE
26	STORM MANAGEMENT



could vary by as much as an order of magnitude.

Weed harvesting costs were estimated on a contract cost/unit area of $325/acre. If the total acreage in need of harvesting, following the Thomas Island short circuiting project, is 60 acres, the annual contract harvesting cost will be $19,500/yr. This is admittedly an over estimate. IT experience with other lake harvesting projects show that as much as 175 acres can be harvested for $20,000/yr, particularly if the county owned equipment and City DPW employees are used to do the harvesting. The contract cost should be anticipated to increase by 10% annually.

The estimated cost of aeration includes the cost of equipment, its deployment and set up and its annual cost of operation (Atlas COPCO, pers. comm., 1987). In terms of annual cost, aside from routine maintenance which require scuba divers, cost of operation is only $2,000-$4,000 according to the manufacturer, with most of that associated with the electricity needed to power the compressor.

Land use management and the reduction in nutrient/sediment loading to Onota Lake will require implementation of a number of small to medium independently executed projects. The specifics of these projects were presented previously in this section. The creation of wetlands and construction of in-lake sumps are best accomplished by first drawing down the lake and utilizing standard construction equipment. There is a substantial amount of design work associated with these programs and environmental monitoring is also required. In addition, permits will be needed. These costs are ancillary expenditures associated with the actual construction but need to be addressed. It is expected that the total cost of watershed management projects will be $1,500.000. This will cover the design and construction of the Blythewood Drive Biofilter ($75,000.00), the Daniels/Churchill wetland enhancement ($85,000.00), and the Parker Brook Detention Basin ($750,000.00). The remaining $59,000.00 would be used to correct existing soil erosion problems.

The Pecks Road sewer line break requires immediate attention. The City of Pittsfield has recognized the need to correct this problem rapidly and as such has authorized a $1.2 million construction bond. A city council resolution authorizing this expenditure was enacted in May of 1987.

A continuing public education program is strongly recommended. At present, the lake community is essentially represented by a few independent lake associations. To do so will require a moderate budget to prepare presentations, distribute information and conduct seminars on current lake issues. A consultant will most likely be required to provide technical guidance and support. An annual operating budget of $7,500 should cover such activities.

In addition, further lake monitoring is recommended. This will generate the data base required to quantify the success of restoration practices listed below and enabled identification of improvements observed in lake quality, aesthetics or use.

1. lower lake
2. excavate sediment
3. Re-build Thomas Island Road culvert.

A comprehensive monitoring program would cost in the vicinity of $30,000/year.

As with any dredging project, costs associated with lab analysis, permitting and monitoring must be accounted for. Mobilization and demobilization of major construction equipment and provisions for a temporary access road for Thomas Island residents are other factors which must be considered.

It is anticipated that a total of 4.5×10^5 yd^3 of sediment will be excavated as part of this project. This includes dredging to the north and south of Thomas Island Road, creation of a sump at the base of Dan Casey Memorial Causeway, and excavation of a "canal" from the sump toward the new culverts to promote short circuiting of flow. Preliminary cost estimates developed through means (1985) projections set the sediment excavation component of the project at $730,000.

Reconstruction of the road at current engineering rates will cost approximately $750,000. This includes the demolition of the old road, installation of box culverts and provisions made for temporary access and relocation of water, sewer and power lines.

Permit requirements, including analytical costs, monitoring and consulting could add as much as $75,000 to the project cost.

In total, the short circuiting project is anticipated to cost $1,555,000.

The cost associated with most of these projects could be decreased substantially if in-kind services were provided by the city or county. These services could be in the form of labor and equipment. This could include the preparation of design spec drawings and calculation of engineering estimates.

11.7 ADMINISTRATION OF FUNDING

The successful implementation of the proposed plan will require substantial cooperation and integration of effort at the local, county and state levels. The City of Pittsfield will officially be the recipient of restoration funds. However, LOPA should act as the City's grant administrator. LOPA should remain prominent in the restoration of the lake by assisting the city in the selection of contractors, overseeing project activities, etc.

The bulk of Phase II funds will be sought from DEQE. Matching funds will have to be obtained from local and county levels. It is recommended that in-kind services be provided to help defray the cash contribution needed for local match. Potential in-kind services include:

1. LOPA Project Administration
2. LOPA volunteer monitoring
3. City and county donated equipment and labor for use in weed disposal, sediment excavation, dredge spoil disposal, soil erosion control
4. Monies spent in sewering and/or the repair of the Pecks sewer line break
5. Improvements to Burbank Park related directly to increased public access or use of Onota Lake.

To properly implement the plan, allocate funds, and provide in-kind services, the project organization should be as identified in Figure 11.4.

11.8 ENVIRONMENTAL EVALUATION

1. Will the project displace people?

   No.

2. Will the project deface existing residences or residential areas?

   The construction of detention basins and the retrofitting of existing stormwater collection systems with sediment traps may temporarily disrupt residential areas during the construction phase. The installation and repair of sanitary sewers may have similar effects on residential areas. Residential land use will not be impaired and existing residences will not be defaced.

3. Will the project be likely to lead to changes in land use patterns or an increase in development pressure?

   There will be increased pressure to develop along Blythewood Drive once this area is sewered. Stricter zoning and identification of areas as environmentally sensitive will be required to protect this section of the lake from future impacts. Other sub-basins of the lake's watershed are either established residential areas or forests and parks protected from development. Implementation of sound watershed management should mitigate or greatly reduce the impacts of changes in land use or development induced by the improvement of the lake's trophic state.

4. Will the project adversely affect prime agricultural land or activities?

   No. Recommendations include the implementation of Best Management Practices to decrease nutrient and sediment loading from agricultural sources (Section 11.3.1.2). However, the BMPs do not adversely affect farming practices or prime agricultural land.

5. Will the project adversely affect parkland, public land or scenic land?

No. In fact, the project may actually lead to the preservation of additional open spaces through the implementation of environmentally sensitive zoning ordinances.

6. Will the project adversely affect lands or structures of historic, architectural, archaeological, or cultural value?

No.

7. Will the project lead to a significant long-range increase in energy demands?

The most significant energy demands will be associated with aquatic macrophyte harvesting and hypolimnetic aeration. As both are recommended annual restoration/management practices, there will be long term O&M costs. Part of this will be the energy demands required to operate both.

Previous analyses conducted by the manufacturer of both the harvesting equipment and the aerator indicate the energy demands to be minor. First, both will be in operation only 5 months per year (mid-May through mid-October). Based on fuel consumption guidelines provided by the manufacturers, the harvester should require only 900 gallons of diesel fuel/season. This is based on an average operating time of 200 hours/month and fuel usage of 0.90 gal/hour. The requirement for proper aeration of the hypolimnion will be 50 ft^3/minute. The compressor(s) will most likely be electrically powered. The draw will be comparable to the residential use of electricity for a one year period.

Dredging and the construction of sedimentation traps/detentions basins and the Thomas Island culvert will have associated energy demands.

8. Will the project adversely affect short-term or long-term ambient air

quality?

Due to construction of detention basins and repair and/installation of sanitary sewer lines, and the construction of the Thomas Island culvert, there may be a short-term decrease in air quality relative to the generation of dust from construction sites. Proper sediment erosion and dust control practices will minimize such impacts. Increased air emissions through activities such as dredging and weed harvesting, may result. However, as these equipment are fitted with emission control devices, their impact should be negligible.

9. Will the project adversely affect short-term or long-term noise levels?

Yes. A temporary increase in noise associated with construction or maintenance activity related with the restoration of the lake may result. All construction and maintenance vehicles will be equipped with the proper noise pollution control devices, thus an increase in noise related to the restoration of the lake should be minimal. There will be some increase in noise associated with weed harvesting.

10. If the project involves the use of in-lake chemical treatment, will it cause any short-term or long-term effects?

The use of chemicals to control weed growth are not advocated at this time in Onota Lake. Thus, the potential for toxicity problems associated with the use of herbicides will be avoided under this plan.

11. Will the project be located in a floodplain?

Yes, in part. All activities which occur along stream corridors or in the near shore, littoral areas of the lake will be considered in the floodplain.

12. Will structures be constructed in the floodplain?

It is conceivable that some of the passive stormwater treatment structures (i.e. detention basins, catch basins, sediment traps etc.) will be constructed in floodplains. However, the construction of such structures will be in compliance with existing laws and regulations of the Commonwealth of Massachusetts.

13. If the project involves physically modifying the lake shore, its bed, or its watershed, will the project cause any short or long-term adverse effects?

Dredging will be limited to only a few areas of the lake. Recolonization of these areas by benthic organisms should not be a problem due to the limited nature of the dredging operation. Destruction of aquatic macrophytes will occur; however, this is desirable and will enhance the quality of the lake. The dredging and macrophyte removal will actually improve fish habitat.

14. Will the project have a significant adverse impact on fish and wildlife, wetlands or other wildlife habitat?

Yes/No. Activities proposed in the plan will improve fish habitat and will actually benefit fish and waterfowl use. Specifically, this will be achieved in that the plan calls for reestablishing and protecting fishery habitat, reducing weed densities, minimizing siltation, influx of pollutants, and improving water quality. The full impact of lake level drawdown on adjacent wetlands must be further researched to fully determine potential impact upon wildlife, habitat and wetland resource via the E/R.

15. Have all feasible alternatives to the project been considered in terms of environmental impacts, resource commitment, public interest and cost?

Yes. All feasible alternatives have been thoroughly examined and analyzed. The proposed plan is the most cost effective restoration program for Onota Lake. It is also characterized by a minimal potential negative environmental impact. The efficiency of the proposed plan will be greatly diminished if only part of the plan is implemented. In order to preserve the integrated nature of this plan it is important that both the watershed and in-lake restoration measures be implemented in full.

16. Are there other measures not previously discussed which are necessary to mitigate adverse effects from the project?

Offsite disposal of the dredge spoils through the use of trucks will increase vehicular traffic and may cause some damage to roads. It will also be necessary to conduct comprehensive testing of the sediments to determine its suitability for upland disposal. The dewatering of the spoils, when done hydraulically, will create a supernatent. This water must be of a quality equal to that of the lake or receiving stream. These potential impacts associated with dredging can be mitigated using environmentally sound engineering practices and adhering to soil erosion and water quality regulations.

TABLE 11.3

PREDICTED POST-RESTORATION TROPHIC STATE
FOR THE NORTH AND SOUTH BASINS
OF ONOTA LAKE

SOUTH BASIN

$$[P_s] = \frac{0.212\ g/m^2/yr\ (1-0.734)(2.82\ yr)}{8.5\ m}$$

$$[P_s] = \frac{0.159\ g/m^2}{8.5m}$$

$$[P_s] = .019\ g/m^3$$

NORTH BASIN

$$[P_s] = \frac{0.403\ g/m^2/yr\ (1 - 0.593)\ (0.116\ yr)}{1.8\ m}$$

$$[P_s] = \frac{0.019\ g/m^2}{1.8\ m}$$

$$[P_s] = 0.011\ g/m^3$$

TABLE 11.4

ANTICIPATED COSTS OF

THE ONOTA LAKE RESTORATION PROGRAM

ACTIVITY	COST
• Weed harvesting (contract)	$19,500/yr x 4 yrs
• Aeration	
South Basin	150,000
• Watershed Management	1,500,000
• Pecks Road Sewerline	1,200,000
• Public Education	7,500/yr x 5 yrs
• Annual Monitoring	30,000/yr x 5 yrs
• Short Circuiting Project	
Dredging	730,000
Construction	750,000
Miscellaneous	75,000
PROJECTED TOTAL*	$4,670,500

* Excludes sewering of Blythewood Drive

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