REPORT

Return to:
TOM ARNISON
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53168

843-3491
262

PADDOCK LAKE INVESTIGATIONS AND MANAGEMENT PLAN

Prepared for
Village of Paddock Lake and
Paddock Lake Protection and
Rehabilitation District

February 1994

Woodward-Clyde

Woodward-Clyde Consultants
8383 Greenway Boulevard
Middleton, Wisconsin 53562

Project Number 93C7028

Woodward-Clyde Consultants

Engineering & sciences applied to the earth & its environment

February 18, 1994

Mr. Thomas M. Arnison
Paddock Lake Protection & Rehabilitation District
6418 238th Ave.
Paddock Lake, Wisconsin 53168

Ms. Marlene Goodson; President
Village of Paddock Lake
6969 236th Ave.
Paddock Lake, Wisconsin 53168

Re: Final Report of Paddock Lake Investigations and Management Plan
Project No. 93C7028

Dear Mr. Arnison and Ms. Goodson:

Enclosed are seventeen (17) copies of the final report for the above referenced project. This report is the final deliverable for this project.

We wish to thank both of you for your input and assistance throughout the project. Because of the local involvement, we believe this report will more fully meet the management needs and provide a sound basis for taking actions regarding the protection and improvement of Paddock Lake.

As discussed previously, we are available for a follow up meeting with you and the Wisconsin Department of Natural Resources to discuss the next steps in the implementation process.

If you have any questions on this report please do not hesitate to call us. We appreciate working with you on this challenging project and hope to work with you again in the future.

Sincerely,

WOODWARD-CLYDE CONSULTANTS

James A. Bachhuber

James A. Bachhuber
Senior Project Scientist

JAB/kjs

Enclosures

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1.0 INTRODUCTION

The citizens of Paddock Lake have an extended and active history in the protection of the lake. For many years, they have supported and funded projects to study and improve the quality of Paddock Lake. In July of 1992, the Paddock Lake Rehabilitation and Protection District (PLRPD) selected a lake study proposal prepared by Woodward-Clyde Consultants (WCC) to submit for funding through Wisconsin's Lake Planning Grant Program. The program is administered by the Wisconsin Department of Natural Resources (DNR) and in September of 1992, the PLRPD was awarded a state grant for 75% of the cost of the study. The remainder of the study is funded by local sources.

The study, as described in the proposal, set out the following objectives:

1. Water Quality Monitoring/Trends in Lake Trophic Status

   Paddock Lake has been monitored in 1951, 1970, 1973, 1974, and 1975. The water quality monitoring conducted in 1993 will help to document any trends since 1975, and provide information to help establish the current and predict the future trophic status of the lake.

2. Develop the Lake's Nutrient (phosphorus) Budget and Identification of Pollutant Sources

   The nutrient budget will help determine remediation measures and the potential water quality goals for the lake.

   The purpose of this task is to identify the drainage areas, and land uses that are most significant from a pollutant loading standpoint to the lake. This task will help focus where future pollutant control measures will have the most impact.

   To develop the nutrient budget, a watershed evaluation to determine the quantity and quality of runoff to the lake was conducted. The nonpoint source pollution was quantified by land use type within the watershed.

3. Development of the Lake's Water Budget

A major concern of the local citizen's has been the fluctuation in water levels of the lake, and especially, the low water levels which often occur in the late summer months. A water budget will help to define the lake's sources and volumes of inflow and outflow.

4. Develop a Lake/Watershed Management Plan

The results of Tasks 1-3 will supply the necessary information to develop a lake management plan which will guide the Village in future lake protection activities. This plan will allow the Village to make informed decisions on where best to put their resources and efforts to have the most significant benefits to the lake.

The topics to be included in the plan include:

- Types of management measures to best control the pollution sources.
- Estimated costs of the various management measures.
- A description of potential funding sources to implement the recommendations.
- The use of a lake trophic status model to predict changes in the lake's quality as a result of the recommended nonpoint source control measures.
- Recommendations on methods to maintain water levels during the summer months.

The study is documented within this report.

2.0 BACKGROUND AND SETTING OF PADDOCK LAKE

2.1 General Information

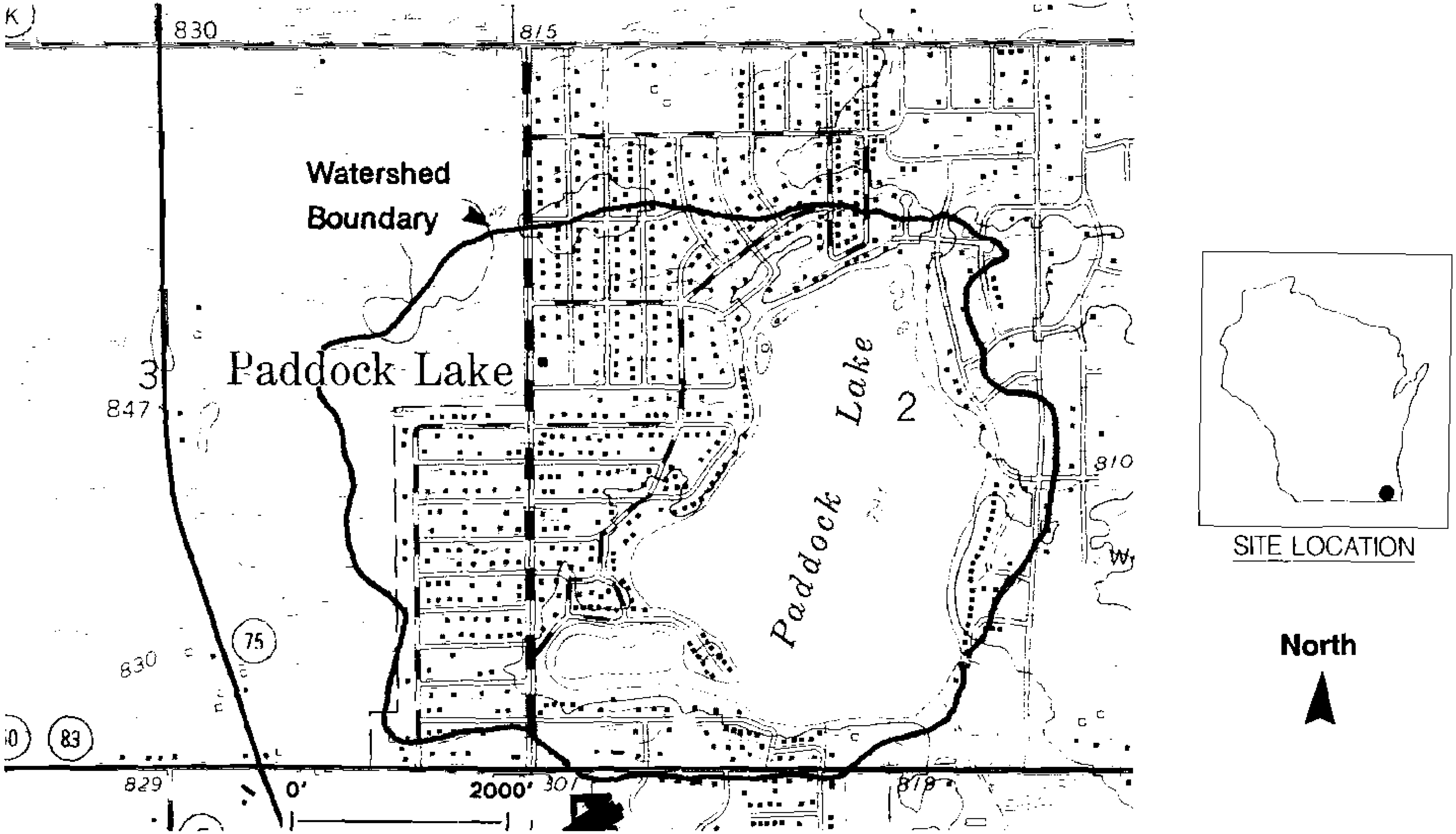
Paddock Lake is likely a "kettle" lake formed during the last glaciation period from a block of ice trapped in the glacial tills as the glaciers receded. The lake is about 132 acres in size. (see Figure 2-1). The maximum depth is about 32 feet and the lake's watershed is about 265 acres in size.

The lake itself is entirely surrounded by the Village of Paddock Lake. The lake is located in central Kenosha County in the southeast corner of Wisconsin. Paddock Lake experiences heavy recreational use, especially on weekends in the summer months. A county park on the south shore provides public swimming and picnicking. During a recent July 4th weekend it was estimated by local residents that the county park received about 3,900 visitors over the three day weekend. There are two other village parks and two property owner association parks on the lake. There is a single village boat launch and two property owner association boat launches also on the lake.

The lake has been classified as "mesotrophic" (DNR, 1979). This means that the lake is tending to the condition where the nutrient levels in the water may produce nuisance levels of algae and macrophyte (aquatic weed) growth during the summer. Occasional algae blooms have been noted by local residents. The lake also experiences nuisance levels of macrophyte growth, and the PLRPD operates an aquatic weed harvester to control this situation. The District has been awarded a grant from the State of Wisconsin to assist in the funding of a new weed harvester. The PLRPD is in the process of this purchase.

2.2 The Watershed Land Use and Soils

The Paddock Lake watershed encompasses approximately 265 acres. However, about 27 acres are internally drained and do not contribute surface runoff to the lake. The watershed is mostly within the Village corporate boundaries (see Figure 2-1). About 45 acres (17%) along the watershed's western boundary is outside of the Village corporate limits. Table 2-1 below summarizes the land use of the watershed.



Source: 1976 U.S.G.S. Paddock Lake Quadrandle Map

Woodward-Clyde Consultants

PADDOCK LAKE PROJECT AREA

KENOSHA, WISCONSIN

DRAWN BY: JAB	CHECKED BY: JAB	PROJECT NUMBER: 92C7028	DATE: 2-9-94	FIGURE NO: 2-1

Table 2-1
Land Use of Paddock Lake Watershed

Land Use	Acres	%
Residential	202.66	76%
Condominium	3.05	1%
Park	7.58	3%
Commercial	7.88	3%
Undeveloped (Agricultural)	44.63	17%
Total	265.80	100%

Source: WCC Paddock Lake Management Study, 1993

The soils of the watershed are dominated by the Morley soil series. This soil is generally of a silt loam texture in the top layer with a silty-clay texture below this level. Runoff from this type of soil can be moderate to very rapid on steeper slopes (USDA, 1970). According to the well logs of sites within the watershed, the clay soils are found to depths of 100 feet. Deeper wells report hitting sand or gravel layers between 100 and 150 feet or more. Bedrock was not encountered at these depths. The type of soil found in the watershed tends to inhibit rain infiltration and enhances the amount of runoff from a storm event. Also the deep clay layers generally reduces the velocity of groundwater movement.

2.3 Water Resources of the Watershed

Besides Paddock Lake, there are no other named water bodies within the watershed. The lake supports a warm water fishery including northern pike, large mouth bass, and panfish (DNR 1991). The lake has a no wake restrictions on motor boats for designated times and days of the week.

There are no perennial inlet streams to Paddock Lake. The outlet of Paddock Lake is intermittent and often ceases to flow in the late summer months. The outlet flows south to Salem Branch (which is the outlet of Hooker Lake). The stream system is within the Des Plaines River drainage basin which flows south into Illinois.

3.0
WATER QUALITY MONITORING/LAKE TROPHIC STATUS

3.1 Methods

3.1.1 Existing Water Quality Data Sources

File data from the Wisconsin Department of Natural Resources were reviewed to determine water quality data that had been collected on Paddock Lake in the past. A 1979 report from the DNR's Office of Inland Lake Renewal cites a dissolved oxygen, temperature, and Secchi disc survey conducted in August of 1951 by the Wisconsin Conservation Department. A similar survey on Paddock Lake is also cited in this same report conducted by the DNR in July of 1970. The DNR's Bureau of Research also sampled Paddock Lake on a seasonal basis (four times a year) for two years beginning in September of 1973 and ending in April of 1975. The DNR used these data sources to develop "Feasibility Study Results: Management Alternatives" for Paddock Lake in 1979. This document also used water quality data collected by a private consultant in 1977. The raw data from these sources are in Appendix A.

3.1.2 1993 Water Quality Sampling Methods

Water Quality sampling of Paddock Lake, was conducted five times in 1993 by Woodward-Clyde Consultants. All lake sampling was conducted in the deepest part of the lake which is in the south central portion of the lake. Table 3-1 shows the dates of sampling and the parameters sampled. All nutrient and chlorophyll-*a* samples were immediately placed on ice. The nutrient samples were preserved with sulfuric acid provided by the Wisconsin State Laboratory of Hygiene (SLOH) in Madison, Wisconsin. All samples were submitted to SLOH within 24 hours of sampling.

Lake measurements of dissolved oxygen and temperature were conducted with a Yellow Springs Instrument Company (YSI) Model 59 dissolved oxygen meter. The probe's membrane was changed, stabilized, and air calibrated before each sampling trip. The complete results of the 1993 water quality monitoring are shown in Appendix A. The lab reports and field notes are in Appendix B.

Table 3-1
1993 Paddock Lake Sampling Dates and Parameters *

Parameters	Dates/Lake Depths of Sampling				
	2/25	5/1	6/17	7/14	8/21
DO/Temp Profile	X	X	X	X	X
Chlorophyll *a*	X	X	X	X	X
Total Phosphorus	X	X	X	X	X

* Total Phosphorus sampled at surface, mid-depth, and bottom of lake; Chlorophyll a sampled at 0.5 meter depth.

3.1.3 Trophic Status Determination and Trends

The "trophic status" of a lake refers to the general nutrient content of the lake's water and the result of these nutrients on the lake's algae and macrophyte growth. One measure of a lake's water quality is by the classification of it's "trophic status". The terms eutrophic, mesotrophic, and oligotrophic are used to describe a lake's trophic status from nutrient rich (eutrophic) to nutrient poor (oligotrophic). Although these terms tend to put lakes into three categories, there is actually a continuum of trophic conditions from very oligotrophic (clear, low nutrient waters with few macrophytes) to hyper-eutrophic (high nutrient waters, poor water clarity, and frequent algae blooms). Thus, a numeric scale is often used to describe a lake's trophic condition. Table 3-2 shows where Paddock Lake's water quality measurements rate on a scale developed by Carlson (1977) for midwest lakes.

Paddock Lake is considered on the border between mesotrophic and eutrophic based upon past monitoring results and the monitoring of 1993. This condition is generally characterized by occasional blooms of algae and dense growths of macrophytes (lake weeds). Paddock Lake has not had reported frequent dense blue-green algae blooms, although there are nuisance levels of macrophytes present in the summer.

Three measurements of a lake's trophic status are water clarity, (measured with a Secchi disk), Chlorophyll-*a* concentrations, and total phosphorus concentrations.

<u>Water Clarity</u> Measuring water clarity with a Secchi disk is an easily understood indication

of how clear a lake is perceived to be. Classification of clarity depths is shown on Table 3-2.

Chlorophyll-*a* Chlorophyll-*a* is a photosynthetic pigment found in algae. This parameter is a direct measure of the algal biomass. This measurement varies widely throughout the summer depending on the algal bloom cycle. Table 3-2 shows the classification of Chlorophyll-*a* concentrations relative to perceived water quality.

Phosphorus Concentrations Phosphorus is generally the nutrient most responsible for supporting the excessive algae and/or macrophyte growths. When a lake's surface layer of water is high in phosphorus, high algae production can be expected. Classification of total phosphorus concentrations are shown in Table 3-2.

3.2 Water Quality Data and Trophic Status Results and Discussion

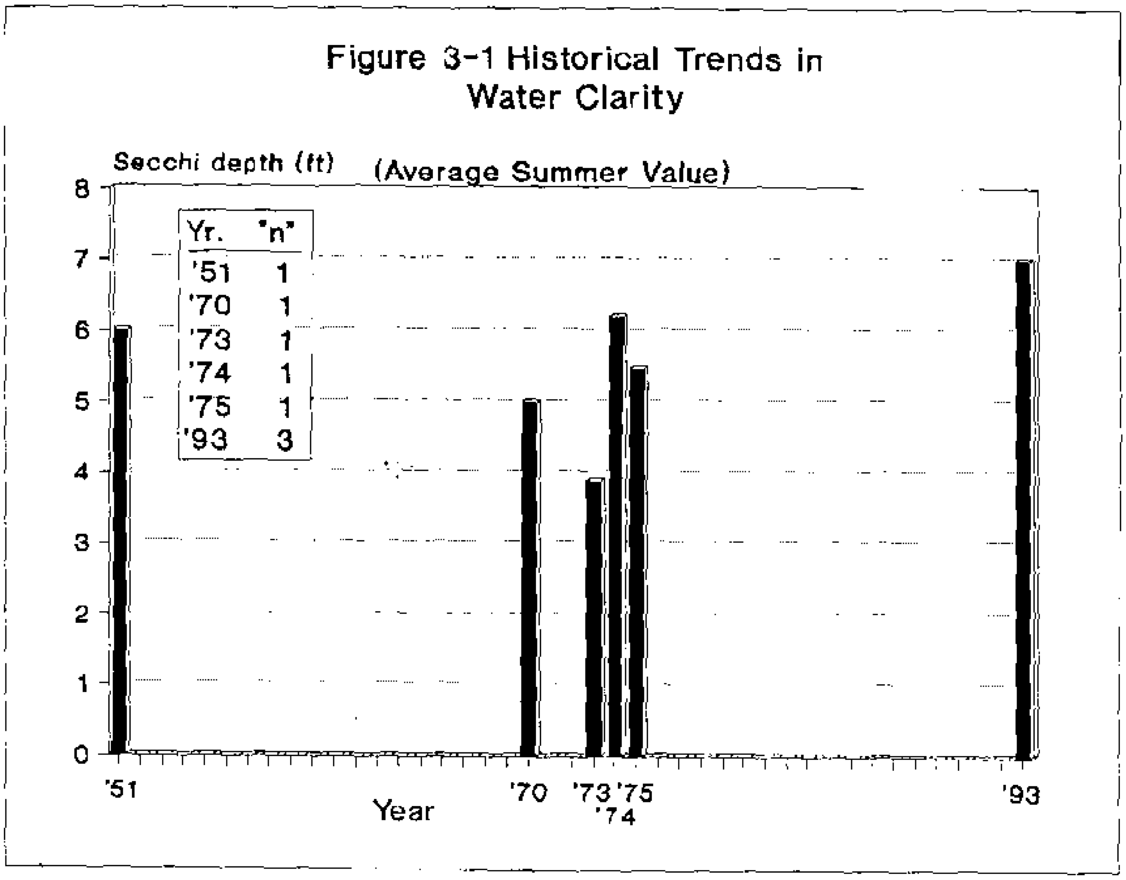
Selected parameters are discussed in this section relative to trends that have occurred in Paddock Lake, and by comparing Paddock Lake's water quality to other regional lakes.

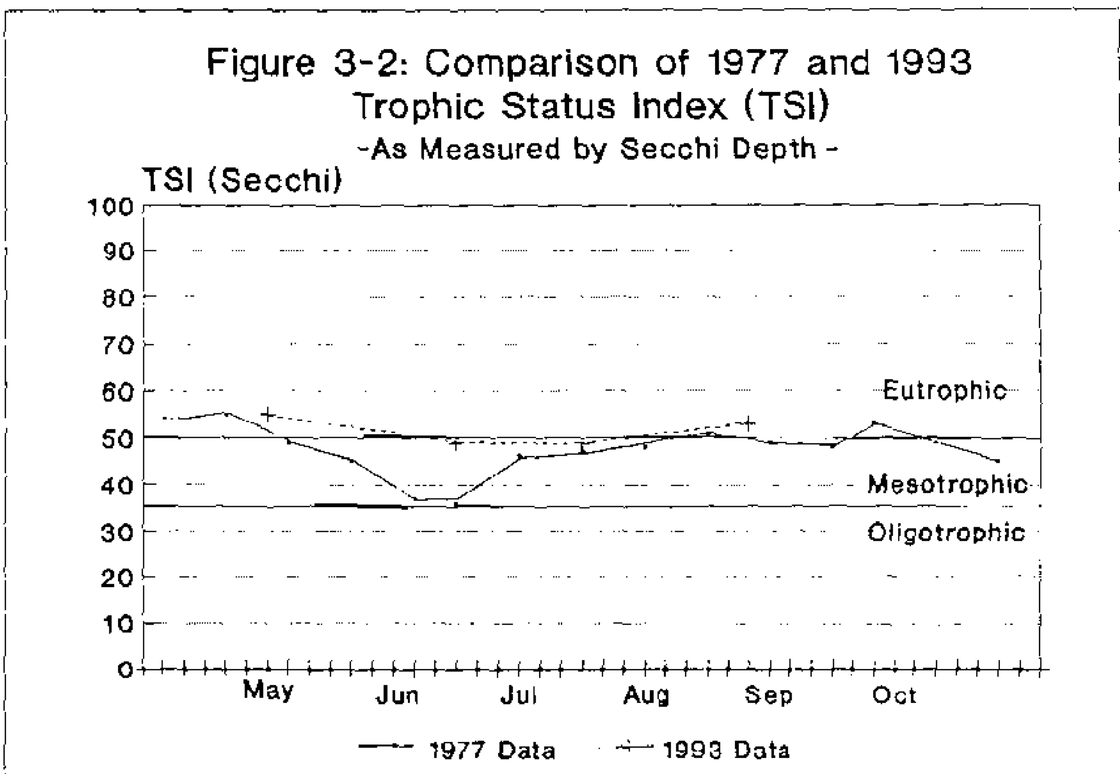
3.2.1 Trends in Paddock Lake Water Quality

Secchi Disk Measurements

Figure 3-1 below shows the Secchi disc measurements conducted on the lake since 1951. The values are average summer measurements (June, July, and August). The number of measurements obtained in any one summer is indicated on the chart with "n=?". The limited number of measurements and years of sampling does not show a trend in the lake's water clarity over the past forty years.

Figure 3-2 compares the Sechi disc measurements of the summers of 1977 and 1993. The data shows a slight decline in water clarity in 1993. This may be due to a difference in the climatic conditions during these two periods, and not indicate an actual trend in the lake's water quality. The comparison to the trophic status scale confirms Paddock Lake's mesotrophic classification.





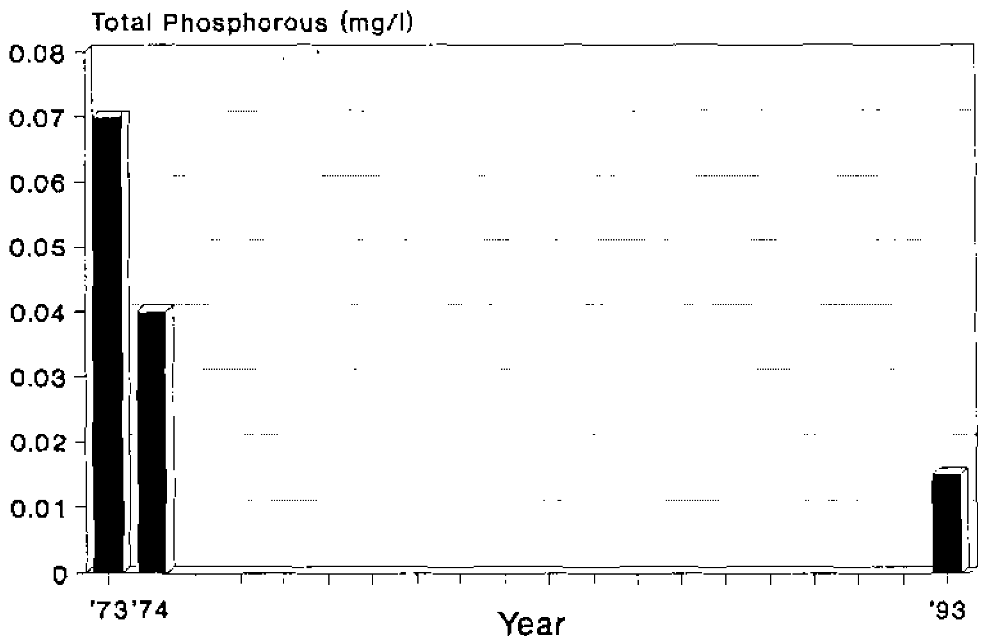
Source: WDNR 1979; and WCC 1993

Total Phosphorus Concentrations

Total phosphorus concentrations are available on Paddock Lake for the spring of 1974, 1975, and 1993. Spring concentrations are useful because this shows the amount of nutrients available for aquatic plant growth early in the season. Also, the Spring phosphorus concentrations reflect a lake's total nutrient level when the water from top to bottom of the lake has mixed after the ice has thawed and lake is not thermally stratified. Figure 3-3 below shows the phosphorus concentrations from the available data.

With only three spring values available, no trends or analysis can be made on the data.

Figure 3-3: Historical Trends in Total Phosphorous Concentration*

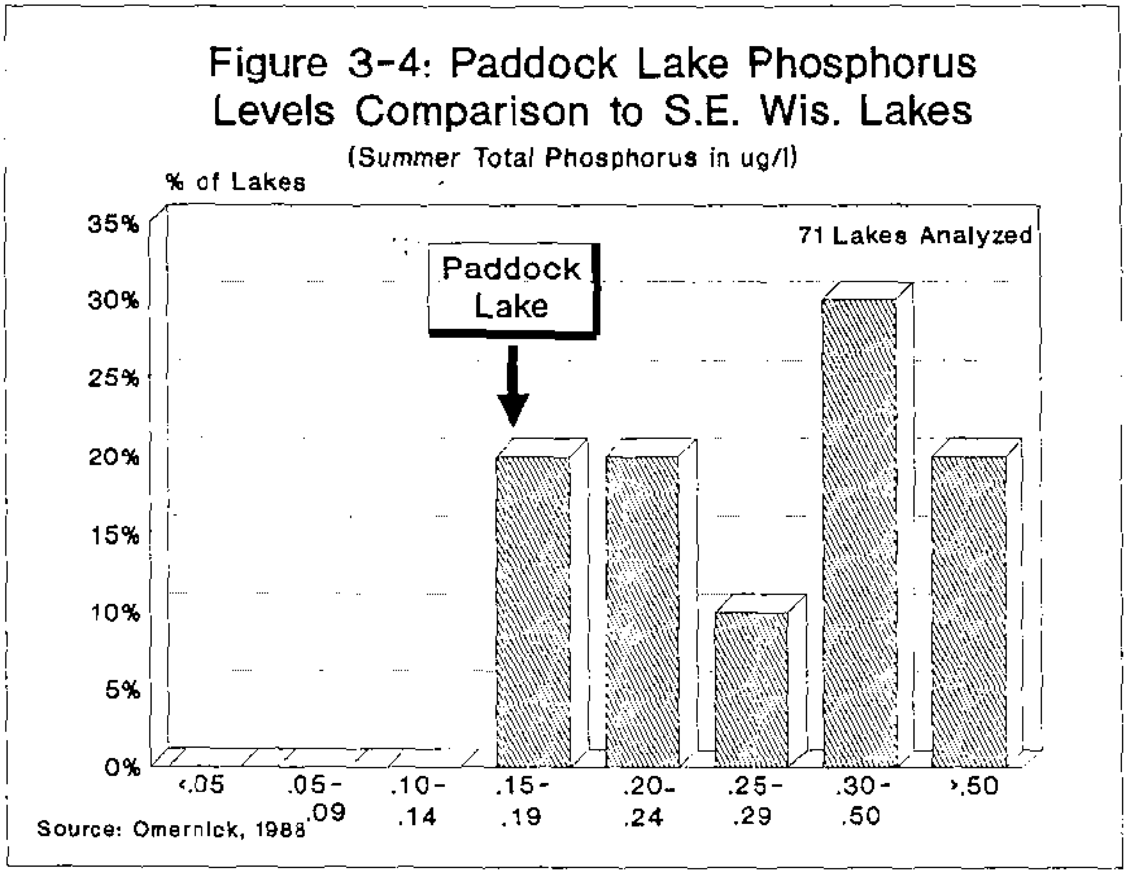


*(Spring, Surface Value)

Source: DNR, '73, '74; WCC, '93

Omernick et al (1988) analyzed summer phosphorus water concentration data from approximately 1,000 lakes in Michigan, Wisconsin, and Minnesota. The lakes were grouped into "eco-regions". These are areas of similar soils, vegetation, and other factors which affect a lake's water chemistry. Figure 3-5 shows Paddock Lake's phosphorus relative to other lakes within the same eco-region of southeastern Wisconsin.

The figure indicates that Paddock Lake is in better condition than most other lakes in the area. In fact, Paddock Lake's summer phosphorus concentrations were less than 80 per cent of the lakes in the eco-region.



Dissolved Oxygen

The dissolved oxygen concentration in a lake is critical to support sport fish. The amount of dissolved oxygen in a lake is dependent on the rate of biological decay in the lake bottom, and the amount of aquatic plant respiration occurring within the lake. These factors, in turn, are dependent on a number of environmental conditions including water temperature, and sunlight.

Dissolved oxygen is typically measured in the deepest part of a lake at various levels from surface to lake bottom. Along with dissolved oxygen, the water temperature is also measured at the various depths. This information provides what is called a "dissolved oxygen - temperature profile". Profiles of Paddock Lake from 1951, 1971, 1974, and 1993 are shown in Figures 3-5 through 3-8. Each graph shows a mid-summer profile. During the summer, the colder, denser, water remains on the bottom of the lake, and the warmer, less dense water remains in the lake's upper layer. This "stratification" of the lake is usually maintained throughout the summer. The layers of water do not mix until the surface layer cools down in the fall and reaches the same temperature as the lower layer. During the summer, aquatic plant photosynthesis and aeration from the surface of the lake keep the upper layer of water oxygenated. In the lower layer of the lake biological and chemical decomposition often depletes the oxygen in the water. The greater the amount of organic material (dead plants, leaves, etc) in the lake's bottom, the lower the dissolved oxygen level will be. This depletion of the dissolved oxygen can make this layer of the lake unsuitable for supporting fish.

This depleted oxygen condition in the lake's lower layer is found in Paddock Lake. The dissolved oxygen-temperature profile measured in August of 1951 is nearly identical to the profile measured in July of 1993. In both cases the lake's dissolved oxygen dropped to zero (became "anoxic") below about 20 feet of depth. These conditions are not unusual for a lake such as Paddock Lake. If the anoxic layer of the lake had increased between 1951 and 1993, this would indicate a degradation of the lake's water quality and an increase in organic material in the water. The limited dissolved oxygen data does not allow for a definitive conclusion on the lake's oxygen levels. However, there is no evidence in this data of a decline in the dissolved oxygen levels in Paddock Lake since 1951.

3.2.2 Paddock Lake's Current Trophic Status

Table 3-2 below compares the 1993 water quality data with an index developed by Carlson (1977) for midwest lakes. The shaded values show where Paddock Lake's water quality fits in this index using summer phosphorus concentrations, summer chlorophyll *a* concentrations, and summer Secchi disk measurements.

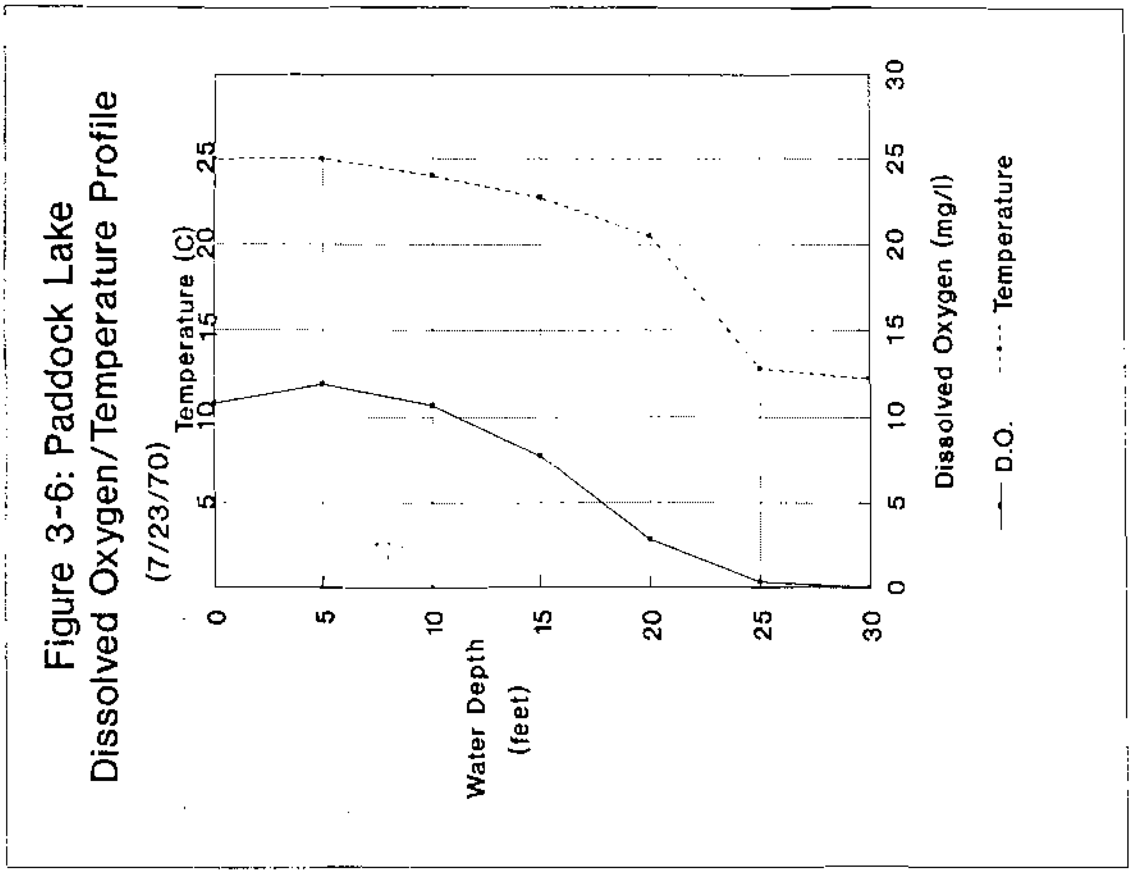


Figure 3-6: Paddock Lake Dissolved Oxygen/Temperature Profile (7/23/70)

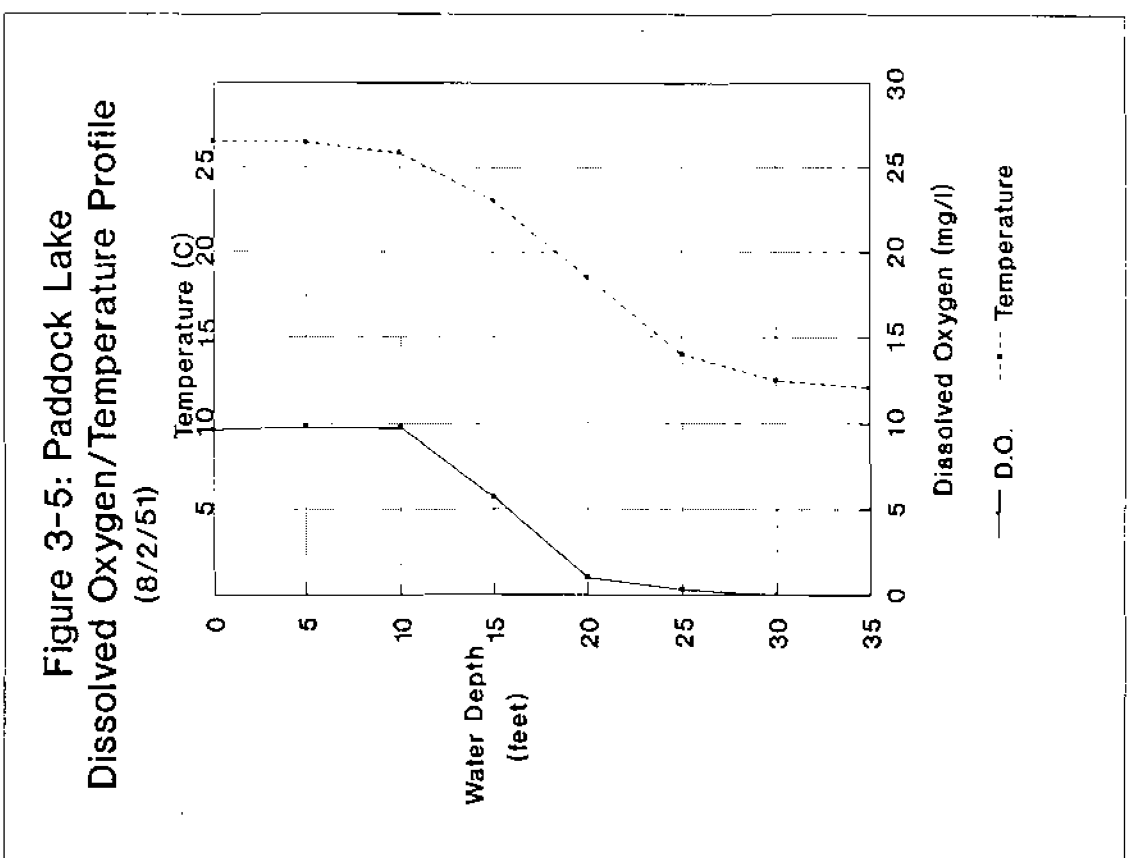
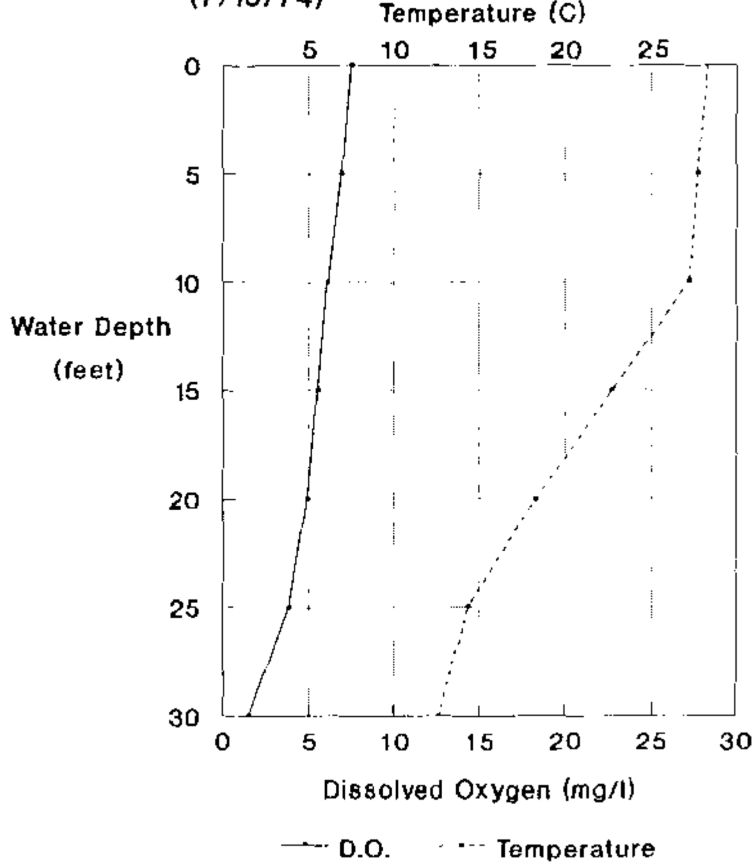


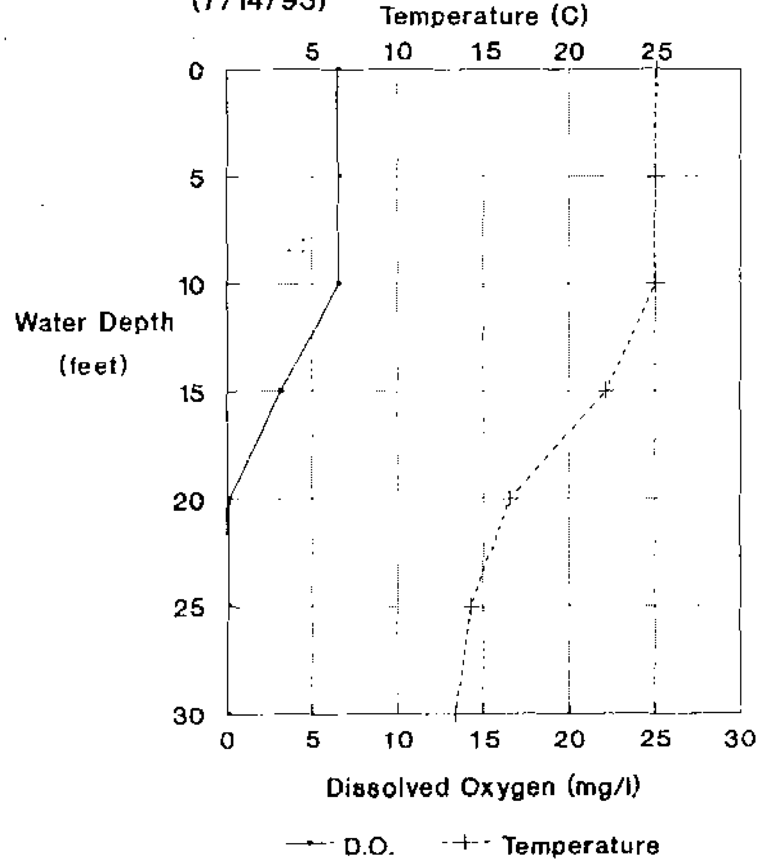
Figure 3-5: Paddock Lake Dissolved Oxygen/Temperature Profile (8/2/51)

Figure 3-7: Paddock Lake
Dissolved Oxygen/Temperature Profile
(7/15/74)



Source: DNR

Figure 3-8: Paddock Lake
Dissolved Oxygen/Temperature Profile
(7/14/93)



Source: WCC, 1993

Table 3-2
Water Quality Index for Wisconsin Lakes Based on Total Phosphorus, Chlorophyll *a* Concentrations, and Water Clarity

Water Quality	Approximate Total Phosphorus (mg/L)	Secchi disk Depth (ft)	Approximate Chlorophyll a (μg/L)	Approximate Trophic Status Index*
Excellent	<.001	>20	<1	<34
Very Good	.001-.01	10-20	1-5	34-44
Good	**.01-.03**	**6-10**	**5-10**	44-50
Fair	.03-.05	5-6	10-15	50-54
Poor	.05-.15	3-5	15-30	54-60
Very Poor	>.15	<3	>30	>60
*After Carlson (1977)			"<" means "less than"	
Source: DNR Technical Bulletin 138 (1983)			">"means "greater than"	

3.2.3 Trophic Status Trends

Future trophic status model can predict the lake's future water quality in terms of the three basic parameters (Secchi disk clarity, total phosphorus concentration, and chlorophyll *a* concentration) based on projected reductions in nutrient (phosphorus) pollution from the watershed. For example: "The average summer Secchi disk is currently 'X' feet. With a reduction of phosphorus pollution of 'Y %' (through nonpoint source control practices), the summer Secchi disk measurements can be expected to be 'Z' feet."

The trophic status modeling was conducted using software available from the DNR for common lake situations in Wisconsin. There are several models to chose from to compare to the actual monitored conditions within Paddock Lake. Table 3-3 below, shows the input data used to run the trophic status models.

Table 3-4 compares the trophic models' results with the monitored conditions. All of the models tested produced reasonable predicted results using the input data shown on Table 3-3. It appears that the Vollenweider, 1975 model best predicts the water quality conditions of Paddock Lake. This model was selected for use in predicting future changes in the lake's trophic condition with phosphorus control measures. These predicted changes are shown on Table 3-4 for various phosphorus reduction levels.

Table 3-3
Parameters Used for Input to the Paddock Lake Trophic Status Modeling

Parameter	Value
Water Surface Area (acres)	132
Maximum Depth (feet)	32
Mean Depth (feet)	9.9
Lake Volume (acre feet)	1,281
Average Annual Out Flow Volume (cfs)	0.33
Phosphorus Retention Coefficient	0.938
Average Annual Phosphorus Load (lbs/yr.)	281

Source: DNR, 1979 for lake area, maximum depth, mean depth, and lake volume. WCC 1993 investigations for average annual outflow, and average annual phosphorus load from surface runoff, atmospheric, and lake bed sediments (see section 4.0 of this report for calculated phosphorus loads). Model calculation used for phosphorus retention coefficient.

Table 3-4
Comparison of Lake Trophic Model With Monitored Conditions

Model	Tot. P (mg/l)	Secchi (feet)	Chlor a (ug/l)
Monitored [1]	0.015	6.5	6.4
Dillon Rigler 1974B	0.026	6.2	8.5
Vollenweider, 1975 [2]	**0.023**	**6.9**	**6.7**
Vollenweider, 1976	0.134	2.1	84.6
Bachman & Canfield, 1979 (natural lakes)	0.058	4.6	25.9
Bachman & Canfield, 1979 (artificial lakes)	0.036	4.2	19.5
Reckhow, et.al., 1980	0.019	7.7	5.4

[1] Spring total P 5/1/93 (WCC). Secchi Disk and Chlorophyll a average from 6/17, 7/14, & 8/21/93 data (WCC)
[2] Model selected for predictive use.

Table 3-5
Predicted Changes in Trophic Status Indicators
With Various Levels of Phosphorous Reduction

% Phosphorus Load Reduction	Predicted Lake Changes [1]					
	Total Phosphorous[2]		Secchi Disk		Chlorophyll *a*	
	(mg/l)	(% change)	(ft)	(% change)	(mg/l)	(% change)
0%	0.023	0%	6.9	0%	6.7	0%
10%	0.020	-15%	7.4	+7%	5.7	-15%
20%	0.018	-22%	8.1	+17%	4.8	-28%
30%	0.016	-30%	8.8	+28%	4.0	-40%
40%	0.014	-39%	10.3	+49%	3.2	-52%
50%	0.011	-52%	11.2	+62%	2.4	-64%

[1] Using Vollenweider, 1975

[2] % change compared to current condition (0% phosphorous load reduction)

Table 3-5 shows a fairly linear relationship between the reduction phosphorus load to the lake and the predicted improvements in the three trophic status parameters. Although the Vollenweider, 1975 model did not exactly match the monitored values found in Paddock Lake, the relative per cent change for each parameter may be used as an estimate of change in the lake under potential future phosphorus loads. The sources and potential for controlling future phosphorus loads are discussed in Section 4.0 below.

4.0 LAKE NUTRIENT BUDGET & POLLUTANT SOURCE IDENTIFICATION

4.1 NONPOINT SOURCE POLLUTION INVENTORY METHODS

4.1.1 General Background

Nonpoint source pollution is the pollution that enters Paddock Lake from rain fall runoff, or snow melt runoff. As water from rain or snow melt flows over the land, it picks up whatever substances that may be on the surface. These substances include: sediment, nutrients (from fertilizer, and vegetative material), pesticides, road salt, oil, grease, heavy metals, and bacteria. These pollutants are delivered to the lake at different times of the year and can result in turbid water, algae blooms, macrophyte growths, fish kills, and unsafe swimming conditions.

The inventories conducted as a part of this study were done for several reasons including:

- to quantify the amount of various pollutants entering Paddock Lake every year;
- to identify the cultural activities that contribute the most significant amounts of pollutants to Paddock Lake; and
- to determine how much reduction of pollutants could be achieved through various management approaches.

The inventories concentrated on three pollutants: sediment, phosphorus, and heavy metals (lead). Sediment is a concern from a water quality perspective because suspended sediment can cause turbid waters, impede boat navigation (where sediment is deposited), and destroy fish spawning habitat. Also, sediment will often carry with it several other pollutants that are "attached" to the sediment particles such as metals and nutrients.

Phosphorus is a concern because it is the major source of nutrients for supporting algae and some macrophytes (aquatic weeds). When these aquatic plants die they fall to the lake bottom, and their decomposition can cause low dissolved oxygen conditions in the lake.

Heavy metals are a major pollutant found in runoff from commercial and heavy traffic areas. Some heavy metals can enter the food chain and impair fish survival, or cause some fish to become unsafe for human consumption.

If control can be achieved on these pollutants (sediment, phosphorus, and lead), then many other pollutants of concern will also be controlled.

To calculate nonpoint source pollution loads, the Paddock Lake watershed was subdivided into several smaller, sub-watershed areas. These areas are shown on Figure 4-1. By subdividing the Paddock Lake watershed into smaller areas, the sources of pollutants can be identified by their location, as well as by land use or cultural activity.

4.1.2 Estimating Urban Nonpoint Source Pollution

Nonpoint Pollution loadings from the urban areas of the watershed were determined using a model called "Source Load and Management Model" (SLAMM). This model is used by the DNR in it's Nonpoint Source Pollution Abatement Program. The model calculates, on an average annual basis, the amount of sediment, phosphorus, and heavy metals, expected in the runoff waters from an urban area. SLAMM calculates these pollutant loadings based on several factors including:

- Land use
- Street conditions
- Drainage system characteristics
- Existing drainage control practices
- Existing street sweeping program
- Climatic conditions

Procedure for Using SLAMM

The steps taken in this study to calculate the urban nonpoint source pollution loads with SLAMM are listed below.

1. Determine Paddock Lake drainage areas

   Using the 1" = 200' topographic map (from Kenosha County Planning Department), Paddock Lake watershed was subdivided into ten drainage areas. These areas are listed on Table 4-1 and shown on Figure 4-1.

2. Determine types and extent of existing land uses

   WCC met with Village of Paddock Lake representatives to obtain information on the current land use. This data was supplemented with air photos of the Village and field verification. The areas of each land use type (as listed on Table 4-1) were digitized from the 1"=200' topographic map.

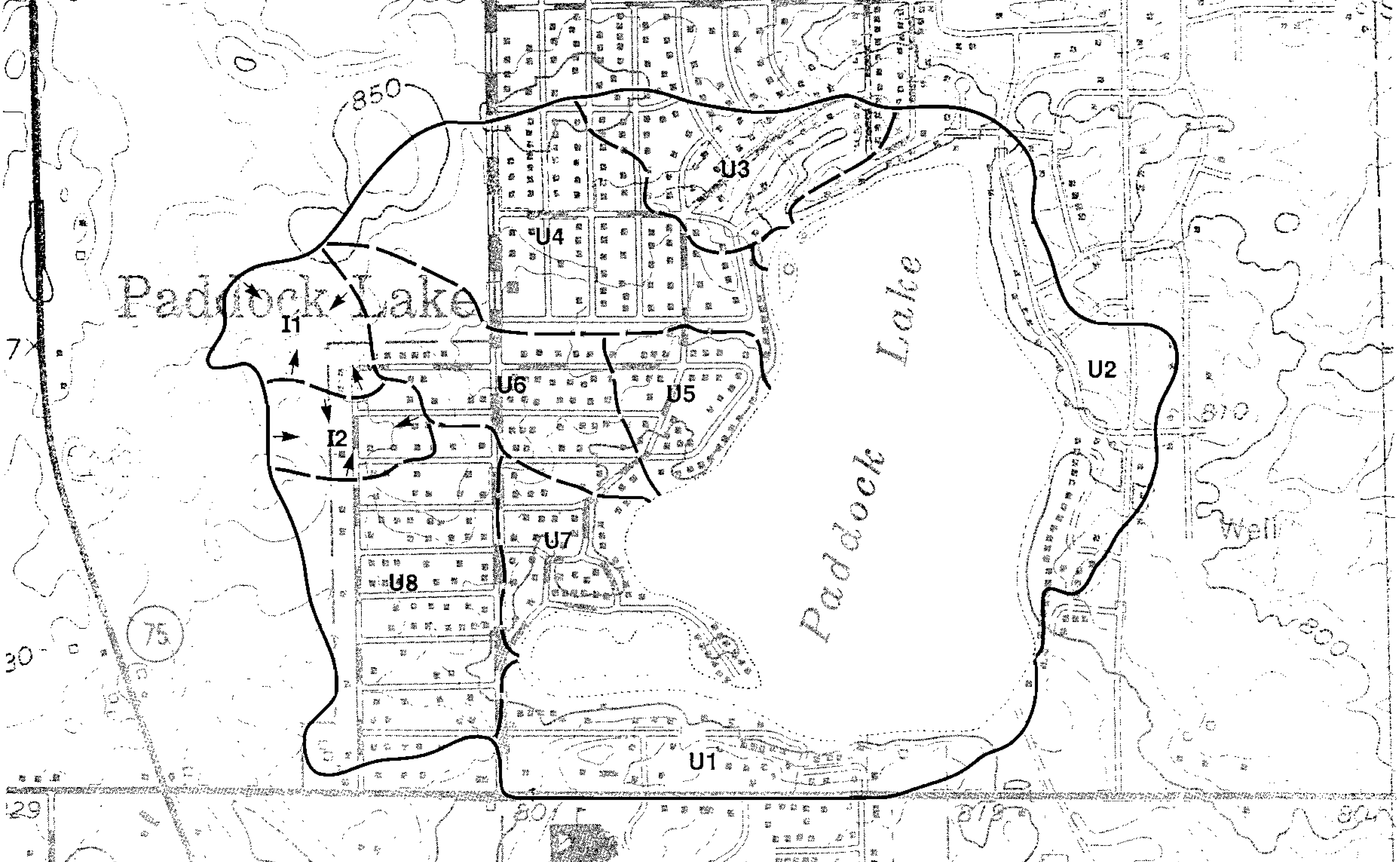
3. Set SLAMM conditions to Village characteristics

   For each land use type, SLAMM calculates the quantity of pollutants produced based upon several physical characteristics and management conditions. For each land use the following characteristics were set, based upon WCC discussions with the Village and field observations.

   - Road surface roughness
   - Road drainage type (ditch, curb and gutter, undeveloped)
   - Street sweeping schedule
   - Present storm water control measures (basins, ponds, etc)
   - Roof drainage type (direct connection to street or connection to grass areas)
   - SCS hydrologic soil type
   - Street parking density

4. Run SLAMM for pollutant loads

   The model was then run for each of the eight drainage areas that contributed runoff to the lake (two drainage areas are internally drained, and thus contribute no surface runoff to the lake). The pollutants selected for calculation were sediment, total phosphorus, and lead. The model



660'

SOURCE:
BASE MAP WAS
PADDOCK 7.5 M
MAP, DATED 19

Woodward-Clyde Consultants

Engineering & sciences applied to the earth & its environment

8383 Greenway Boulevard

WARNING

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IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS

DESIGNED	
DRAWN	MAS
CHECKED	JAB
PEER REVIEWED	
PROJECT MANAGER	

PADDOCK LAKE WATERSHED MAP

Subwatershed Divides for

reports a result for each pollutant in pounds (or tons) per year. This means that in an average year, the runoff waters from a land use, or a drainage area of interest, contains approximately, the calculated quantity of the selected pollutant. This quantity is delivered to Paddock Lake during periods of rainfall runoff or snowmelt. The results of this calculation are shown on Table 4-2.

Table 4-1
Drainage Basins and Land Uses Within the Paddock Lake Watershed

Sub-watershed ID#	Land Use											
	Residential		Condominium		Park		Commercial		Undeveloped		Total	
	(ac.)	(%)	(ac.)	(%)	(ac.)	(%)	(ac.)	(%)	(ac.)	(%)	(ac.)	(%)
U1	15	55%	0	0%	5	17%	8	28%	0	0%	28	10%
U2	29	88%	3	9%	1	2%	0	0%	0	0%	33	12%
U3	21	97%	0	0%	1	3%	0	0%	0	0%	22	8%
U4	33	71%	0	0%	0	0%	0	0%	14	29%	47	18%
U5	18	100%	0	0%	0	0%	0	0%	0	0%	18	7%
U6	25	76%	0	0%	0	0%	0	0%	8	24%	33	12%
U7	16	98%	0	0%	0	2%	0	0%	0	0%	17	6%
U8	37	87%	0	0%	1	3%	0	0%	5	11%	43	16%
I1	2	9%	0	0%	0	0%	0	0%	14	91%	16	6%
I2	7	62%	0	0%	0	0%	0	0%	4	38%	11	4%
Total	203	76%	3	1%	8	3%	8	3%	45	17%	266	100%

Source: WCC 1993 Lake Management Study

4.1.3 Estimating Atmospheric Sources of Phosphorus

Dust and precipitation falling through the atmosphere, carry with it phosphorus (along with other compounds). This atmospheric deposition from dust and/or precipitation falling directly on the lake's surface is another source of nutrients to the lake.

No direct measurements of this source were conducted as part of this study. Values from research efforts in similar conditions were used to estimate the significance of this source of phosphorus. The lake study conducted by DNR for Paddock Lake in 1979 used an atmospheric phosphorus loading value of 0.4 kilograms per hectare (0.36 pounds per acre) of lake surface per year. Since Paddock Lake is 132 acres in size, the estimated phosphorus loading to the lake from atmospheric deposition is 47 pounds/year. This is about 17 per cent of the annual phosphorus load to Paddock Lake. Although the figure represents a significant source of phosphorus to the lake there is very little potential for reducing this source.

4.1.4 Lake Bottom Sediment Phosphorus Source

The muck and sediment at the bottom of Paddock Lake is also a potential source of phosphorus to the water, and thus to the algae and aquatic weeds in the lake. Phosphorus that is contained in the sediment can become soluble and be released into the water under certain conditions.

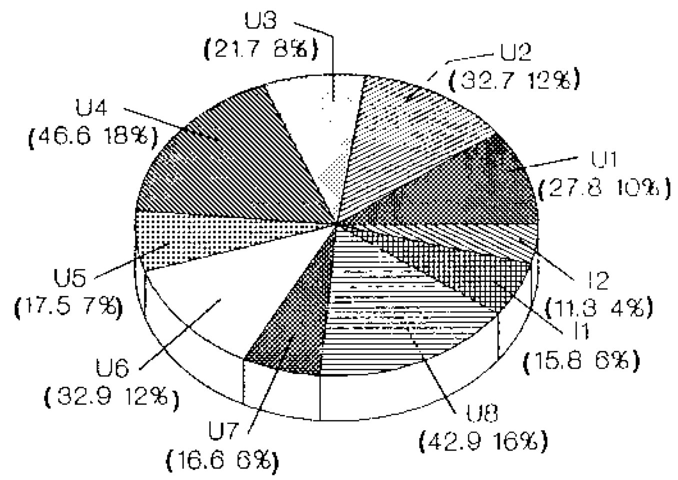
A very rough estimate of the significance of this source can be made by comparing the amount of phosphorus in the lake's lower layer of water in August (called the hypolimnion) to the amount of phosphorus in this layer of the lake during spring turnover. For a short period in the spring, the lake's water is the same temperature from top to bottom. This allows complete mixing of the lake's nutrients. As summer progresses, the top layer of the lake is warmed, and this warmer layer (called the epilimnion) is less dense then the colder, bottom layer. In Paddock Lake the boundary between these two layers was found to be about twenty feet below the lake's surface in August. These two layers of water generally do not mix. Thus, the nutrients (phosphorus) from surface water runoff and atmospheric deposition, generally stay in the upper layer of the lake. The only source of additional nutrients (phosphorus) to the lower layer of water is from sediment release, and groundwater inflow. It has already been determined that Paddock Lake receives little if any input from groundwater. That leaves the lake bottom sediments as the only potentially significant source of nutrients to Paddock Lake's lower layer of water in the summer.

In comparing the amount of phosphorus in lake's hypolimnion between spring and late summer, it was found that between 85 to 500 pounds of phosphorus were added to this water layer during that time period. These values mean that the lake may be receiving as much or more phosphorus from the lake's sediments as it receives from surface runoff during the year. The actual calculations for this estimate are contained in Appendix C.

It should be emphasized that this is only a very rough approximation of the significance of the lake bottom sediment as a source of phosphorus. However, this does indicate that the lake bed sediments should be further investigated to confirm it's significance as a nutrient source.

Figure 4-2: Subwatershed Areas Paddock Lake Watershed

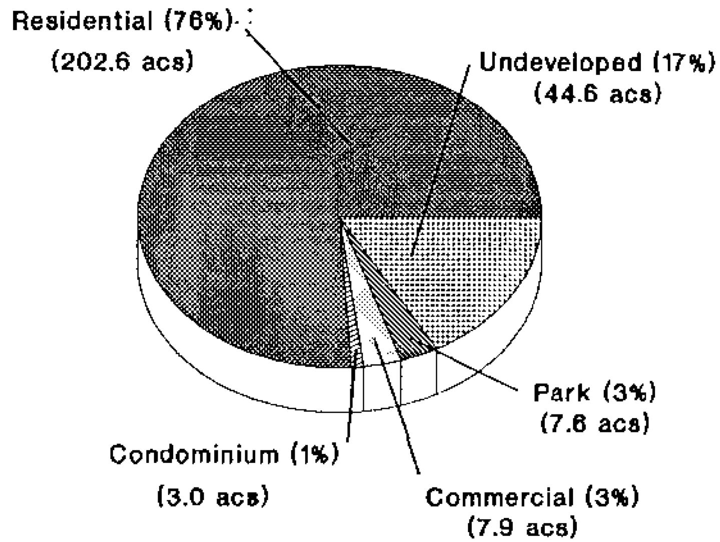
(Acres & % for Each Subwatershed)



source: WCC 1993

Figure 4-3: Land Use in Paddock Lake Watershed

(Acres & % for Each Land Use)



Source: WCC 1993

4.2 RESULTS AND DISCUSSIONS FROM NONPOINT SOURCE CALCULATIONS

Table 4-2
Calculated Annual Nonpoint Source Sediment Load to Paddock Lake
(tons per year)

Sub-watershed	Residential		Condominium		Park		Commercial		Undeveloped*		Total	
I.D. #	(t/yr)	(%)	(t/yr)	(%)	(t/yr)	(%)	(t/yr)	(%)	(t/yr)	(%)	(t/yr)	(%)
U1	1.14	11%	0.00	0%	0.36	4%	8.76	85%	0.00	0%	10.26	37%
U2	2.17	81%	0.45	17%	0.06	2%	0.00	0%	0.00	0%	2.68	10%
U3	1.57	96%	0.00	0%	0.06	4%	0.00	0%	0.00	0%	1.63	6%
U4	2.48	60%	0.00	0%	0.00	0%	0.00	0%	1.63	40%	4.11	15%
U5	1.32	100%	0.00	0%	0.00	0%	0.00	0%	0.00	0%	1.32	5%
U6	1.88	67%	0.00	0%	0.00	0%	0.00	0%	0.95	33%	2.83	10%
U7	1.23	98%	0.00	0%	0.02	2%	0.00	0%	0.00	0%	1.25	5%
U8	2.80	81%	0.00	0%	0.08	2%	0.00	0%	0.55	16%	3.43	12%
I1*	0.00	0%	0.00	0%	0.00	0%	0.00	0%	0.00	0%	0.00	0%
I2*	0.00	0%	0.00	0%	0.00	0%	0.00	0%	0.00	0%	0.00	0%
Total	14.59	53%	0.45	2%	0.58	2%	8.76	32%	3.13	11%	27.51	100%

Table 4-3
Calculated Annual Nonpoint Source Phosphorus Load to Paddock Lake **
(pounds/year)

Sub-watershed	Residential		Condominium		Park		Commercial		Undeveloped *		Total	
I.D.#	(#/yr)	(%)	(#/yr)	(%)	(#/yr)	(%)	(#/yr)	(%)	(#/yr)	(%)	(#/yr)	(%)
U1	5.52	15%	0.00	0%	1.74	5%	30.01	81%	0.00	0%	37.28	32%
U2	10.51	79%	2.55	19%	0.28	2%	0.00	0%	0.00	0%	13.33	11%
U3	7.62	96%	0.00	0%	0.28	4%	0.00	0%	0.00	0%	7.89	7%
U4	12.00	69%	0.00	0%	0.00	0%	0.00	0%	5.33	31%	17.33	15%
U5	6.36	100%	0.00	0%	0.00	0%	0.00	0%	0.00	0%	6.36	5%
U6	9.10	75%	0.00	0%	0.00	0%	0.00	0%	3.09	25%	12.18	10%
U7	5.94	98%	0.00	0%	0.09	2%	0.00	0%	0.00	0%	6.04	5%
U8	13.52	86%	0.00	0%	0.41	3%	0.00	0%	1.80	11%	15.73	14%
I1 *	0.00	0%	0.00	0%	0.00	0%	0.00	0%	0.00	0%	0.00	0%
I2 *	0.00	0%	0.00	0%	0.00	0%	0.00	0%	0.00	0%	0.00	0%
Total	70.56	61%	2.55	2%	2.79	2%	30.01	26%	10.22	9%	116.14	100%

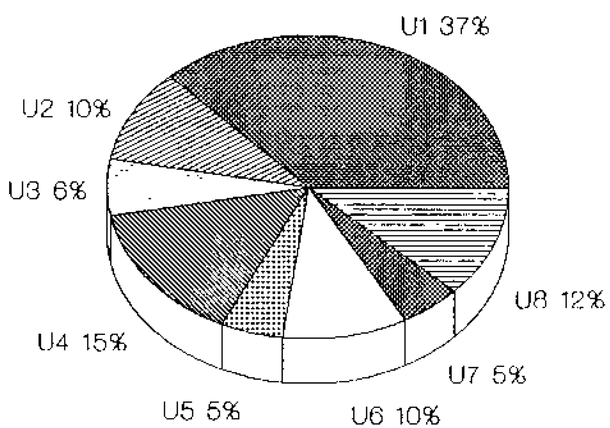
Table 4-4
Calculated Annual Nonpoint Source Lead Load to Paddock Lake
(pounds/year)

Sub-watershed	Residential		Condominium		Park		Commercial		Undeveloped *		Total	
I.D. #	(#/yr)	(%)	(#/yr)	(%)	(#/yr)	(%)	(#/yr)	(%)	(#/yr)	(%)	(#/yr)	(%)
U1	1.66	3%	0.00	0%	0.52	1%	58.40	96%	0.00	0%	60.58	75%
U2	3.16	80%	0.72	18%	0.08	2%	0.00	0%	0.00	0%	3.96	5%
U3	2.29	97%	0.00	0%	0.08	3%	0.00	0%	0.00	0%	2.37	3%
U4	3.61	100%	0.00	0%	0.00	0%	0.00	0%	0.00	0%	3.61	4%
U5	1.91	100%	0.00	0%	0.00	0%	0.00	0%	0.00	0%	1.91	2%
U6	2.73	100%	0.00	0%	0.00	0%	0.00	0%	0.00	0%	2.73	3%
U7	1.79	98%	0.00	0%	0.03	2%	0.00	0%	0.00	0%	1.81	2%
U8	4.06	97%	0.00	0%	0.12	3%	0.00	0%	0.00	0%	4.19	5%
I1 *	0.00	0%	0.00	0%	0.00	0%	0.00	0%	0.00	0%	0.00	0%
I2 *	0.00	0%	0.00	0%	0.00	0%	0.00	0%	0.00	0%	0.00	0%
Total	21.21	26%	0.72	1%	0.83	1%	58.40	72%	0.00	0%	81.17	100%

* Assumes internally drained areas do not contribute runoff to Paddock Lake
* Assumes no phosphorus loading from atmosphere or lake bed sediment.

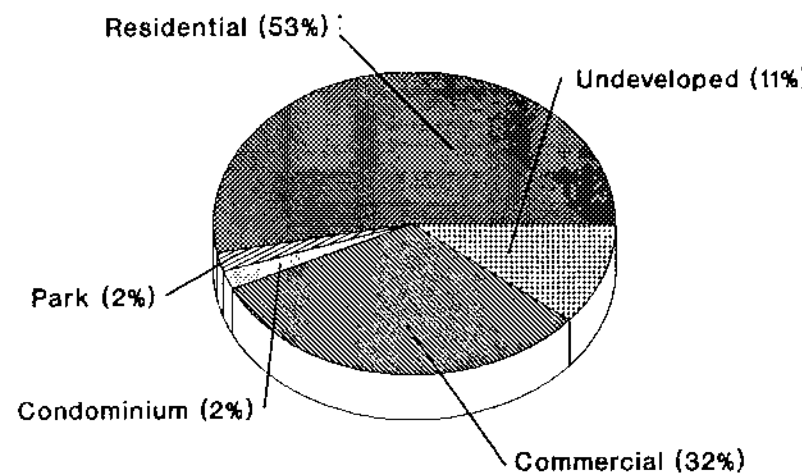
Figures 4-4 and 4-5 on the following page graphically show the sources of sediment in runoff to Paddock Lake. Figures 4-6 and 4-7 show the sources of phosphorus to Paddock Lake. The two subwatersheds with the largest contribution of sediment to the lake are U1 and U4. These two subwatersheds account for 52 per cent of the sediment load although they make up only 28 per cent of the lake's watershed area. Also, it should be noted that commercial land use makes up 3 per cent of the land use but accounts for 32 per cent of the sediment and 26 per cent of the phosphorus entering Paddock Lake from nonpoint source pollution. Because residential land use makes up such a large proportion of the area in the lake's watershed (76 per cent) it also accounts for a large portion of the sediment and phosphorus pollution loads to the lake (53 per cent and 61 per cent respectively).

Figure 4-4: Sediment Sources by Subwatershed; Paddock Lake Watershed



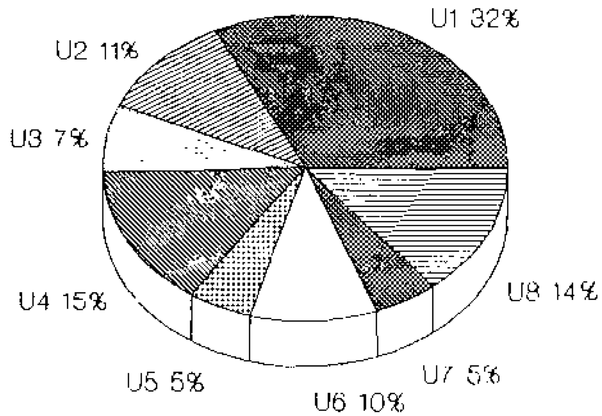
Source: WCC 1993

Figure 4-5: Sediment Sources by Land Use: Paddock Lake Watershed



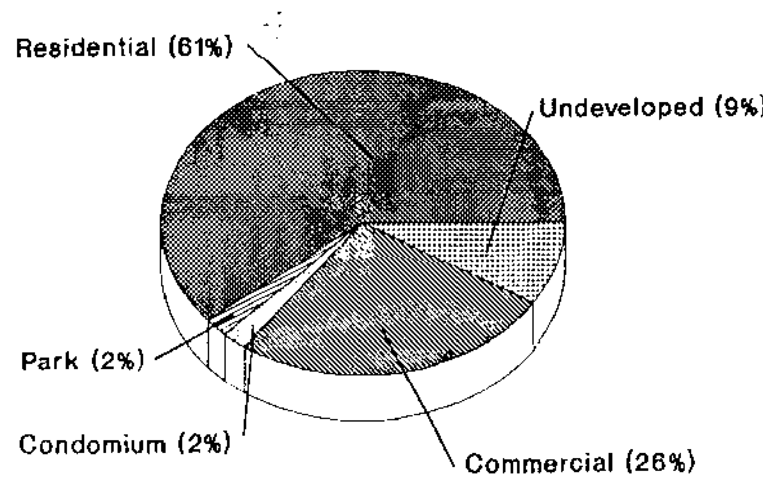
Source: WCC 1993

Figure 4-6: Phosphorus Sources by Subwatershed; Paddock Lake Watershed



Source: WCC 1993

Figure 4-7: Phosphorus Sources by Land Use; Paddock Lake Watershed



Source: WCC 1993

5.0
WATER BUDGET AND LAKE LEVEL

5.1 METHODS OF ANALYZING WATER BUDGET COMPONENTS

A water budget for a lake is determined by assessing the sources of water contributing to a lake and the various pathways for water to leave a lake. Sources of water to a lake are surface runoff, direct precipitation on the lake, groundwater, and point source discharges. Water can exit a lake through a surface outlet stream, evaporation, groundwater outflow, and point source withdrawals. Each of these routes were analyzed for Paddock to determine the potential for controlling the water level of the lake for improved recreational uses. There are no known point source discharges or withdrawals in the project area. Thus point sources were assumed to be minor and not included in this analysis.

At the end of this section, Figure 5-5 illustrates the lake's normal year water budget.

5.1.1 Surface Runoff to Paddock Lake

The surface runoff contribution of water to the lake was estimated by comparing Paddock Lake to a monitored watershed of similar land use. Underwood Creek in Milwaukee County drains a mostly residential area in the City of Wauwatosa. This creek has been monitored for stream flow since 1974. By dividing the average flow of this creek by the area of the watershed a "unit area" flow can be determined. This unit area flow can then be applied to other watersheds with similar land use (such as Paddock Lake) to estimate an average runoff volume.

For this study, 1981 was selected to represent an average year for precipitation and runoff. The 1981 rainfall conditions are also used in the SLAMM calculations to generate nonpoint pollution loads which represent an "average year." The estimated runoff values used for Paddock Lake are shown in Table 5-1.

5.1.2 Surface Water Outflow From Paddock Lake

Paddock Lake has an intermittent outlet stream at the southeast corner of the lake. Generally, the stream flows during the spring and early summer months, but usually ceases

Table 5-1
Calculated Annual Surface Runoff to Paddock Lake

Month	Underwood Cr. Discharge		Paddock Lake Watershed Runoff (cfs)
	(cfs)*	(cfs/sq.mi.)	
January	4.96	0.273	0.102
February	21.30	1.170	0.437
March	6.74	0.370	0.138
April	41.10	2.258	0.843
May	7.43	0.408	0.152
June	6.13	0.337	0.126
July	10.10	0.555	0.207
August	7.79	0.428	0.160
September	10.20	0.560	0.209
October	6.71	0.369	0.137
November	6.03	0.331	0.123
December	12.70	0.698	0.259
ANNUAL AVERAGE =			0.241

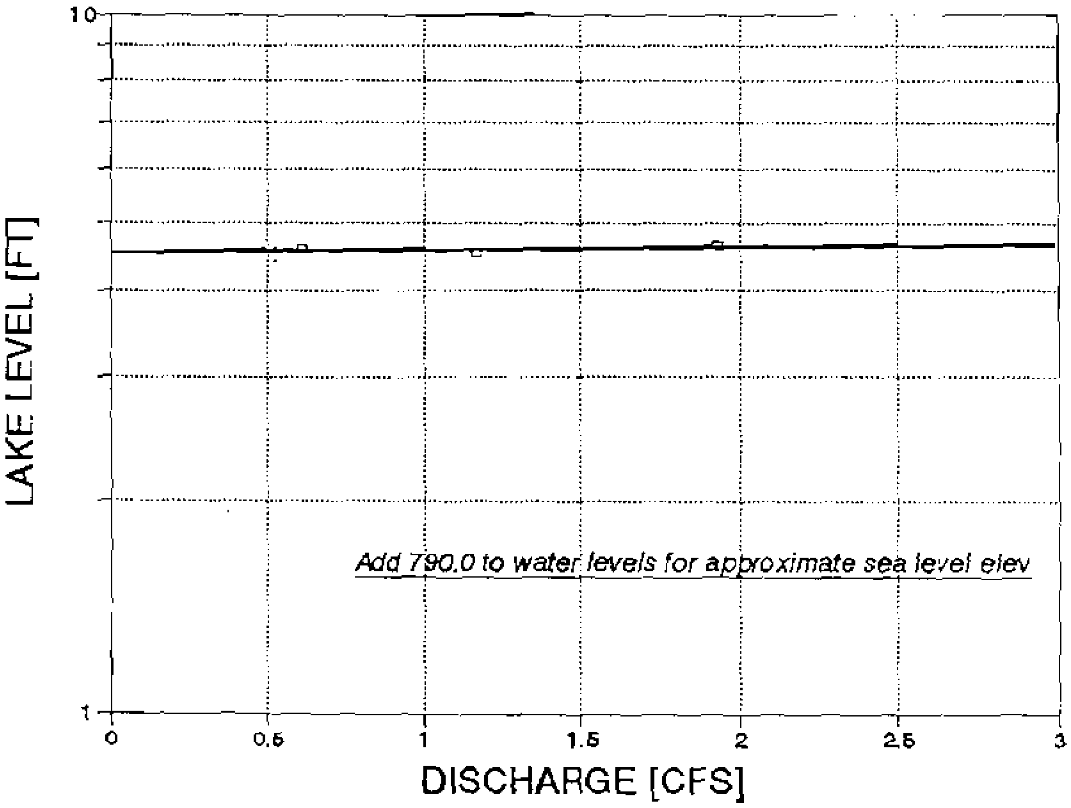
* cfs = cubic feet per second

to flow in July and August. To estimate the volume of water carried by this stream, the stream stage (the vertical elevation of the water) was measured by a local volunteer between April and August of 1993. Stream stage measurements were taken daily in April and about every other day between May and August. The lake stage was also measured by the local volunteer during the same period. The flow in the outlet stream was measured by a pygmy flow meter on May 1, June 17, and July 14 (there was no flow on August 21). With these flow measurements a relationship between the stream stage and the flow was developed. An approximate relationship between the lake stage and the stream flow was also developed (see Figure 5-1). This relationship is affected by accumulation and removal of debris at the outlet structure of the lake and, therefore, is not constant. However, the relationship was deemed adequate for making outflow estimates for the water budget.

To calculate an average annual outflow from the stream, a reservoir routing model was used. The modeled inflows included the normal year's watershed runoff and direct precipitation

FIGURE 5-1

EXISTING OUTLET RATING
PADDOCK LAKE

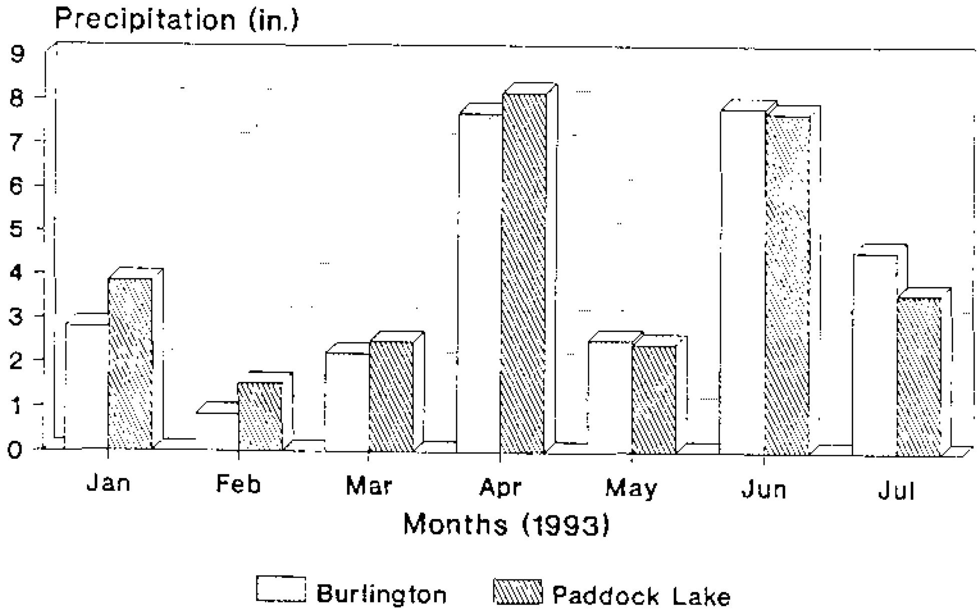


(see Sections 5.1.1 and 5.1.3). The direct precipitation portion of the inflow was modified to reflect the monthly normal evaporation rates (see Section 5.1.4). The resulting lake stage (elevation of the lake's surface) was compared to the outlet stream's elevation. The stage discharge rating curve (Figure 5-1) was used to estimate an annual outflow in cubic feet per second (cfs). The average annual outflow using this procedure was estimated to be 0.32 cfs.

5.1.3 Direct Precipitation to Paddock Lake

Daily precipitation records are kept at the Village of Paddock wastewater treatment facility, and at a National Weather Service station at Burlington (approximately twelve miles northwest of Paddock Lake). The Burlington station has precipitation records beginning in 1961. A comparison of records from these two sites for 1993 is shown on Figure 5-2 below. The figure shows that the measured rain amounts at both stations are similar enough to allow a long-term average at the Burlington Station to be used to calculate the average volume of water directly to Paddock Lake from precipitation. The Burlington station was used to produce a "normal" year's precipitation. The volume of water to the lake from this source was calculated directly given the annual precipitation and the area of the lake. These results are shown in Table 5-2.

Figure 5-2: Monthly Precipitation - 1993
Burlington Sta. & Paddock Lake*



* Nat. Weather Serv. & Paddock Lake WWTP

Table 5-2
Average Annual Volume of Direct Precipitation to Paddock Lake

Month	Burlington Station Monthly Avg. * (inches)	Paddock Lake Precip. Volume (cfs)
January	1.36	0.24
February	1.09	0.21
March	2.39	0.42
April	3.34	0.60
May	2.99	0.52
June	4.05	0.73
July	4.22	0.74
August	3.96	0.69
September	3.57	0.64
October	2.45	0.44
November	2.55	0.46
December	1.82	0.32
Annual Total:	33.8	
Annual Average:		.48

* Average for 32 years of reporting.

5.1.4 Evaporation Impacts on Paddock Lake Levels

Evaporation rates from a lake surface can be estimated using values from literature sources. Two sources were used in this analysis: *Hydrology* (Wisler and Brater, 1967); and *Hydrology for Engineers* (Linsley, et.al., 1958). Monthly evaporation rates in cubic feet per second (cfs) for Paddock Lake were determined by the equation:

$$E(cfs) = .042 \times A \times E_{mo.} / D$$

where:
- A = surface area (acres)
- $E_{mo.}$ = monthly evaporation (inches)
- D = number of days in month
- E(cfs) = is lake surface monthly evaporation in cfs

The monthly evaporation figure (E) is estimated based on literature values for "pan evaporation" for the Paddock Lake area. Pan evaporation rates have been measured for different regions in the United States. Southeastern Wisconsin has a pan evaporation rate of 42 inches per year (Wisler and Brater, 1967). A correction factor is applied to the pan evaporation rate to determine the evaporation rate from the lake's surface. The correction factor is 0.7, thus the annual evaporation rate from Paddock Lake is:

$$E_{annual} = 42'' \times 0.7$$
$$= 29.4 \text{ in/year}$$

The monthly evaporation rate ($E_{mo.}$) is determined by pro-rating the percent of annual evaporation that occurs in each month. Thus, the equation for determining Paddock Lake's monthly evaporation rate in cubic feet per second (cfs) is:

$$E(cfs) = .042 \times 132 \text{ ac} \times E_{mo} / D$$

Table 5-3 shows the calculated average monthly and annual evaporation rates for Paddock Lake in cfs.

Table 5-3
Evaporation Rates for Paddock Lake

Month	Average Monthly Evaporation Distribution		Paddock Lake (cfs)
	%/month	inches	
January	1.69	0.50	0.09
February	2.54	0.75	0.14
March	4.24	1.25	0.21
April	8.47	2.49	0.44
May	15.25	4.48	0.77
June	12.71	3.74	0.66
July	13.56	3.99	0.69
August	13.14	3.86	0.66
September	10.17	2.99	0.53
October	10.59	3.11	0.54
November	5.08	1.49	0.27
December	2.54	0.75	0.13
Annual Total:	100.00	29.40	
Annual Average			0.43

5.1.5 Groundwater Impacts on Paddock Lake Levels

Subsurface water flows follow gradients in a similar manner to surface water flow. Groundwater flows from elevational high points to lower points, however, the speed and direction are greatly influenced by the type of soil or rock the water is flowing through. Sandy soils or highly fractured bedrock allow groundwater to flow relatively rapidly. Soils that are high in clay content slow groundwater flows, and can virtually block groundwater flow.

To assess the potential for groundwater contribution to Paddock Lake, well logs from nearby water supply wells were analyzed. The well logs describe the type of soils or rock encountered during the drilling of a well, and also report the depth of groundwater at the well. By locating the well on a topographic map, an approximate elevation of the groundwater at the well can be determined. Logs from 54 wells near and within the Village of Paddock Lake were analyzed. The wells were located on a 2-ft interval contour map and the elevation of each well was estimated to the nearest two feet. Seventeen of these wells are listed on Table 5-4 and their locations are shown on Figure 5-3 along with the elevation of groundwater found at each well. These elevations are only approximate because of several factors such as: 1) the well elevation was only approximated on the topographic map, and 2) the groundwater elevations shown were measured in different years (when the well was established) and the groundwater elevation can vary from year to year.

The level of water in the wells is then compared to the level of Paddock Lake. The USGS 7.5 minute map for Paddock Lake indicates a normal lake level of 794 feet above mean sea level (msl). With a maximum depth of 32 feet, the bottom of Paddock Lake is approximately 762 feet msl. Comparing this value with the surrounding groundwater elevations in the wells indicates that most of the wells have groundwater lower than the lake bottom by ten feet or more. Only wells #11 and #16 had groundwater at, or near the lake bottom elevation. This indicates that in general, groundwater around Paddock Lake is at a lower elevation than the lake itself, and thus groundwater does not contribute a significant amount of water to the lake.

The well logs for the seventeen wells analyzed also indicate that the soils at all of the sites contain a high degree of clay material to depths ranging between 70 to 120 feet. Water movement through this layer of soil would be very slow. Thus, it is likely that the Paddock Lake looses very little water to the ground.

Table 5-4
Well Logs Used in Paddock Lake Groundwater Analysis

I.D.	Well Location					G.W.	Installation Date			Ground Surface	G.W.
#	Tn	Ra	Sec	Q	Address	Depth	Mo	Dy	Yr	Elev.*	Elev.*
1	1	20	2	sw	Kenosha Co. Park	69	5	4	81	820	751
2	1	20	2	sw	24316 75th St.	70	8	20	86	824	754
3	1	20	2	sw	24327 74th St.	65	5	25	83	812	747
4	1	20	2	sw	7424 246th St.	70	4	25	82	822	752
5	1	20	2	sw	7006 245th Ave.	60	7	21	84	800	740
6	1	20	2	sw	24619 69th St.	62	12	12	85	810	748
7	1	20	3	se	24808 68th St.	70	3	7	86	820	750
8	1	20	3	se	6820 248th Ave.	75	11	4	87	818	743
9	1	20	3	ne	24511 68th St.	80	11	18	82	810	730
10	1	20	2	nw	24303 64th St.	55	12	3	86	802	747
11	1	20	2	nw	6159 248th Ave.	78	9	5	82	842	764
12	1	20	2	nw	6034 247th	70	5	22	83	822	752
13	1	20	2	nw	6056 241st Ave.	70	1	7	85	802	732
14	1	20	2	nw	6304 240th Ave.	60	7	2	81	801	741
15	1	20	2	nw		55	5	15	81	810	755
16	1	20	2	ne	23523 62nd St.	27	11	8	84	786	759
17	1	20	2	se	Village Hall	54				802	748

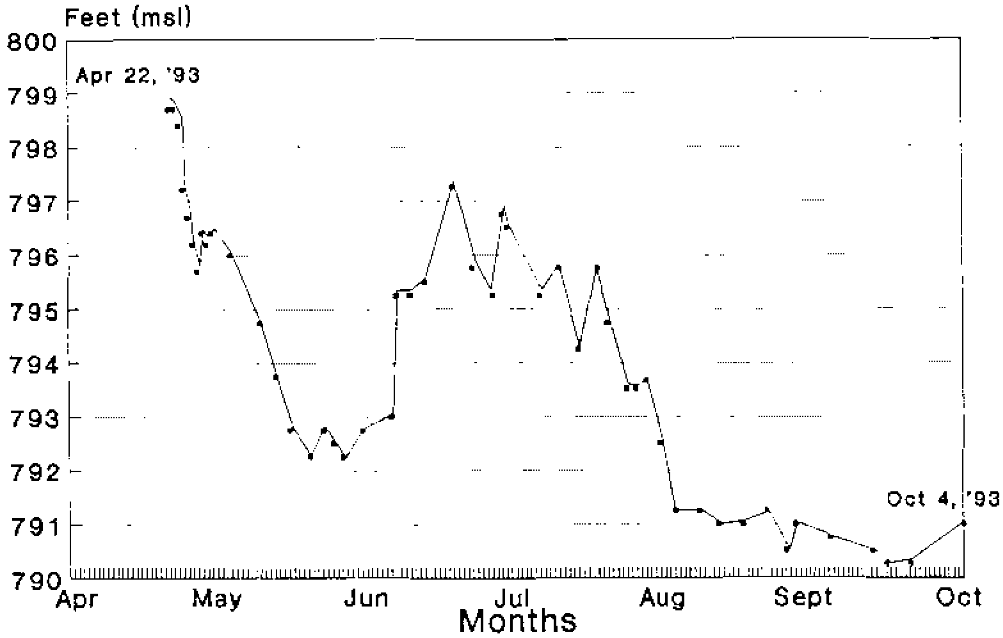
* Approximate feet above mean sea level.

5.2 RESULTS AND DISCUSSION OF WATER BUDGET ANALYSIS

Figure 5-4 shows the measured changes in Paddock Lake levels between April 22 and August 19, 1993. Precipitation in 1993 was unusually high and thus, the lake levels were also high. The Burlington weather station received about 1 1/2 times the normal precipitation through July of 1993 (28.49 inches verses 19.44 inches). Since the lake does not receive water from a consistent source (no perennial tributaries to the lake) the water level is, largely dependent on direct precipitation and evaporation.

Figure 5-5 shows the relative importance of each water component to and from Paddock Lake for an average year. Direct precipitation to the lake and evaporation from the lake play a significant role in the net change in lake levels from year to year. Surface runoff from the watershed contributes about 36 percent of the water to the lake on an average annual basis. The surface outlet from Paddock Lake accounts for about 43 percent of the water leaving the lake on an average annual basis. This means that the only practical approaches to controlling the lake levels are: 1) to control the surface outlet flow to retain the spring runoff water in the lake (build a dam at the outlet) or 2) add "make up" water during low level periods (from a high capacity well). These options are discussed in more detail in the next section.

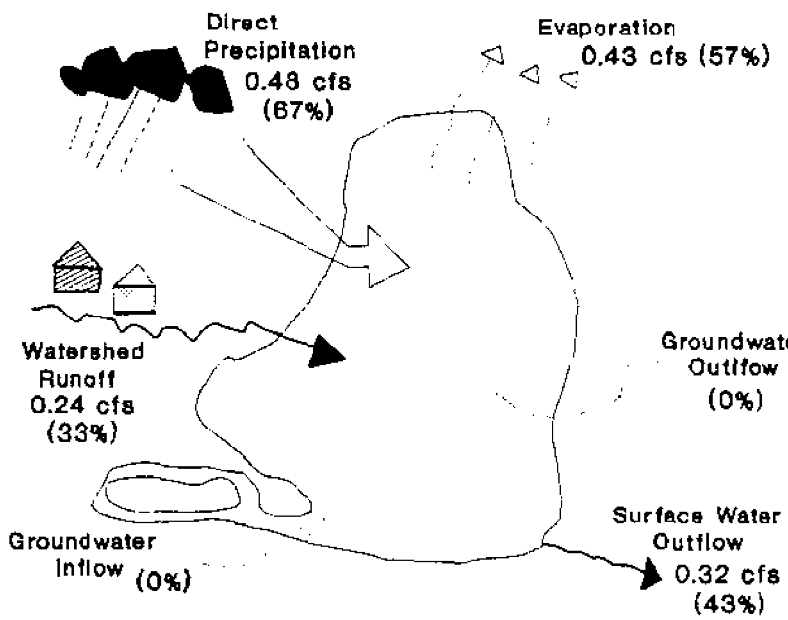
Fig 5-4: 1993 Measured Lake Levels
Paddock Lake*



* Average Lake Level Assumed = 794.5'msl

Source: Lake Volunteer & WCC, 1993

Fig. 5-5: Average Annual Paddock Lake Water Budget



6.0 RECOMMENDATIONS FOR A LAKE MANAGEMENT PLAN

6.1 WATER QUALITY MONITORING/WATER QUALITY TRENDS

Data analyzed in this document do not indicate clear trends in water quality in Paddock Lake over the past several decades. Secchi disk measurement, dissolved oxygen levels, and phosphorus concentrations did not show significant changes or trends over the period data was collected. It should be noted, that only very large changes in the lake's water quality would have been shown, given the amount of water quality data available.

The lake has had a trophic status in the mesotrophic range since the early 1950's. Phosphorus concentrations in the water are very low compared to other lakes in southeastern Wisconsin, however the lake still supports a nuisance level of macrophytes.

Recommendation:

The Village of Paddock Lake or the Paddock Lake Rehabilitation and Protection District (PLRPD) should become involved in DNR's Self-Help Monitoring and the Expanded Self-Help Monitoring programs. These programs train and provide equipment for local citizen volunteers to collect water quality data. Involvement in these programs will provide valuable, long-term, data to help measure changes in the lake's quality and to measure progress from the various management efforts that may take place in the future. Mr. Bob Wakeman of the DNR's Milwaukee Office can provide you with guidance on becoming involved with these programs.

The Village of Paddock Lake or the Paddock Lake Rehabilitation and Protection District (PLRPD) may wish to consider contracting with the U.S. Geological Survey for a more comprehensive monitoring program.

6.2 LAKE LEVEL CONTROL

As stated in Section 5.0 there are two potential alternatives to improving the control of lake levels: construction of a dam at the outlet, or installation of a high capacity well to supply "make up" water to the lake. Both options have "pros" and "cons" and are discussed below.

6.2.1 Dam Re-construction or Relocation

The current structure at the lake outlet is not functional. There is no way to control the lake level for different times of the year. A small dam at the outlet would allow the Village or District to maintain higher lake levels during the times of the year when needed. However, if water levels were lowered in the Spring (perhaps because of high water shore damage), it could aggravate lower water levels in the summer (during periods of low precipitation and high evaporation). Water levels that are high affect a relatively few riparian landowners. Low water conditions affect a high percentage of the lake's recreational users. High water problems can be minimized by proper shoreline protection. Cost estimates for a small outlet structure appropriate for Paddock Lake are estimated in Table 6-1.

Table 6-1
Construction Costs Estimate for Paddock Lake Outlet Structure[1]

Item	Unit	Quantity	Unit Price ($)	Total Cost ($)
Excavation	day	0.5	$ 700	$ 350
Form work	day	1.0	$ 700	$700
Concrete (labor)	day	0.5	$ 700	$ 350
Concrete (material)	cubic yard	3.0	$ 200	$ 600
Rebar/steel (labor)	day	1.0	$700	$ 700
Rebar/steel (material)	lb	440	$ 1.25	$ 550
Backfill	day	0.5	$ 700	$ 350
Riprap	sq. yard	40	$ 30	$ 1,200
			Sub Total:	**$ 4,800**
Mobilization/Demobilization (10%)				$ 480
Overhead/Profit (25%)				$ 1,300
Contingencies (25%)				$1,300
			Total:	**$ 7,880**

[1] Assumptions:
1. dewatering effort is minor
2. engineering costs not included
3. crew consists of 2 laborers and 1 equipment operator

"Pros" and "Cons" of a Lake Outlet Structure

Pros:

- Lake level control may help in other areas of lake management such as macrophyte management, and winter ice shore erosion problems.
- Operation and maintenance costs are relatively low.
- Possible cost share funds (50% up to $200,000 maximum) available for dam repairs from DNR. The potential for this source of funding is dependent upon DNR's evaluation of the current structure and its' "hazard" rating.
- Allows for lake level management for navigation (pier access) and flood control.

Cons:

- Ownership of property at dam site will require land purchase and/or easement agreements
- long-term liability and legal responsibilities for owner of dam
- Cost share funding requires DNR dam inspection, and following DNR directives for repairs
- The control structure will not allow water to be added to the lake during the summer; it will only allow a greater amount of spring runoff to be retained for the summer months.

6.2.2 High Capacity Well

A high capacity well (or wells) would provide the only reliable and consistent source of "make up" water to the lake during the summer months. Well logs of the area show that there is a layer of clay soil generally from the surface to 80-100 feet in depth. At depths between 100-150 feet, a sand/gravel layer is found. This is the layer where most of the local wells draw water from. This deep layer of clay indicates that the drawdown resulting from groundwater pumping of a high capacity well, will not likely draw down the lake level.

The evaporation analysis indicated that during the months of June, July, and August, the lake looses an average of 310 gallons per minute (gpm) to evaporation. The well supplying the make up water would need a minimum capacity of this rate to just maintain the lake levels during these months. A well capacity in the 500 - 1,000 gpm would likely be needed to provide an adequate volume of water to the lake. To add three inches (vertically) to the lake, it is estimated that a well pumping at 1,000 gpm would require about ten days of continuous pumping. However, the strategy for using the well would be to <u>maintain</u> desirable lake levels before the lake levels drop to an undesirable level.

Costs for the installation of a high capacity well were estimated based on a similar well construction project in Sauk County, Wisconsin. In that case, a 10 inch diameter, 150 foot deep well with a pumping capacity of 450 gpm was installed at a cost of about $28,000. A larger capacity well (500 gpm) may cost between $30,000 - $35,000 to install. Operation costs are also a factor in this alternative. To estimate this cost it was assumed that the well would be pumping continuously (to maintain a desired lake level) during the months of June, July, and August. The electrical cost of pumping during this period is estimated to be about $5,000.

<u>"Pros" and "Cons" of a High Capacity Well</u>

Pros:

- A high capacity well allows for more flexibility in controlling the water levels in the summer months.

- The addition of "clean" groundwater to the lake may decrease summer phosphorus concentrations and result in a reduction of algae blooms and some macrophyte growth.

<u>Cons:</u>

- Relatively high initial costs and continual operational costs.

- The technical feasibility must be further explored.

- Permits and legal requirements associated with a high capacity well.

- Potential impacts on area water supply wells must be investigated.

- Concentrations of elements in the groundwater (iron or silica for example) could cause a decrease in water quality conditions.

Recommendation:

The Village of Paddock Lake or the Paddock Lake Rehabilitation and Protection District (PLRPD) should first pursue the potential for dam reconstruction at the lake's outlet. If dam reconstruction is successfully completed, a determination of the need for a high capacity well should be based on the satisfaction of the residents with dam's control of mid-summer lake levels.

6.3 REDUCE NONPOINT SOURCES OF POLLUTION TO PADDOCK LAKE

The calculations made in this study show that the major sources of phosphorus and sediment, to the lake are most likely from watershed runoff. Determining the significance of the lake bed sediment as a phosphorus source is discussed in the next section (6.4). Because of the relatively small watershed area to Paddock Lake, significant control of nonpoint pollution may be achieved. However, because the watershed is virtually fully developed, there is very little open land available to locate structural nonpoint source control practices. Because of this limitation, the recommendations for Paddock nonpoint source pollution control should include both structural and non-structural approaches.

Structural practices should be focused on the two subwatersheds identified to have the largest contribution of phosphorus to the lake: U1 and U4. Subwatershed U1 includes about seven acres of commercial land use along U.S. Highway 50. There are several culverts which discharge stormwater along the southeast shore Paddock Lake from this commercial area. Subwatershed U4 includes about 13 acres of undeveloped lands (agricultural) in the northwest portion of the watershed. Land for a small nonpoint source control structure may be available to control runoff from this area.

Recommendations:

Several steps are recommended to address the nonpoint source control needs for Paddock Lake.

1. *The Village should apply to DNR for selection into the Wisconsin's Nonpoint Source Pollution Abatement Program - Priority Lakes. This program provides funding for planning, designing, and constructing best management practices for control of nonpoint source pollution. Mr. Bob Wakeman or Jim D'Antuono of DNR's Milwaukee office should be contacted to obtain information on this program.*

   Upon being accepted into the program, structural control measures should be focused on the subwatersheds U1 and U4. Structural controls may include such things as: a wet pond/sediment basin, runoff infiltration areas, and grass swale drainage systems.

2. *The Village and\or the PLPD should apply for a follow up Lake Planning Grant to develop a local information/education program for non-structural; source controls of nonpoint source pollution. Potential components of the program could include:*

   - *Develop of a "citizen's handbook" explaining what homeowners can do to minimize nonpoint source pollution from their property.*

   - *Develop posters or handouts addressing specific nonpoint source control issues such as: pet waste control, lawn fertilizer/pesticides, automobile oil disposal, etc. These could be used at local stores that sell lawn care products, automobile supplies, etc.*

   - *Develop a program to involve school classes in some aspects of water quality and nonpoint source control such as: water quality testing, impacts of pollution on Paddock Lake, etc.*

6.4 LAKE TROPHIC STATUS MANAGEMENT

A potential significant source of phosphorus which was not quantified, and outside of the scope of this study is the contribution from lake bed sediments. Because of the contribution of the past unsewered development around the lake, phosphorus concentrations in these sediments may be quite high. Since the Village installed a sanitary sewer system (in 1967) what was once a major source of phosphorus (poorly functioning septic systems) has likely been controlled. Determining the potential phosphorus available to the lake from the bottom sediments will provide an important piece of information in managing Paddock Lake's trophic conditions.

In 1993, Paddock Lake funded the development of an aquatic plant management plan. This plan provides a clear management approach to control aquatic plants to minimize the nuisance conditions for boaters and swimmers while maintaining the valuable function the plants provide for fish habitat. The PLRPD has also applied for, and received funding from the Wisconsin Waterways Commission to help purchase a mechanical weed harvester to replace their current machine.

Recommendations:

1. *The Village of Paddock and/or the PLRPD should pursue a follow up Lake Planning Grant to determine the significance of lake bed phosphorus contribution to the lake's nutrient content and trophic status.*

   If the phosphorus contribution from lake bed sediment is determined to be significant, the Village may wish to consider treating the sediments with a phosphorus inactivation treatment (such as alum). This treatment will only have long-term benefits if the other phosphorus sources to the lake (from nonpoint sources) are also controlled.

2. *The Village should adhere to the plant management recommendations contained in the "Paddock Lake Plant Management Plan" prepared in August of 1993.*