1. Introduction and Project Setting

Dowling Lake is located in west central Douglas County, Wisconsin and is 153 acres in size. The mean depth is 7.2 feet and the maximum depth is 13 feet. Dowling Lake is connected to Amnicon Lake by a ¼ mile long channel which flows towards Amnicon Lake.

Amnicon Lake is located in west central Douglas County, Wisconsin and is 426 acres in size. The mean depth is 9.9 feet and the maximum depth is 31 feet. See Figure 1 for the general location as well as the watersheds for both lakes.

1.1 Goals of Project

This project was funded by a Wisconsin DNR Large-Scale Lake Management Planning Grant awarded to the Amnicon and Dowling Lake Management District. The following project summary is presented by Thatcher Engineering, Inc. (TEI) to the Amnicon and Dowling Lake Management District. The objectives of this project were to characterize existing lake conditions and to make recommendations to protect and improve both lake environments where feasible. There were three goals of this project:

1. Determine the current conditions of both lakes and associated watersheds and describe how the systems function.

2. Determine how the current trophic status for both lakes compares to realistic minimally impacted reference lake values.

3. Identify the primary contributing factors to both lakes eutrophic status, so the residents on the lake and within the watershed as well as users of the lake can prioritize and target those activities identified as most affecting the lake.

1.2 Background of Lakes and Surrounding Area

The drainage area or watershed for Amnicon Lake was calculated by TEI to include 2,615 acres. The drainage area for Dowling Lake was calculated by TEI to include 1,391 acres. See Figure 1 for a map showing the drainage areas for both lakes. The majority of both drainage areas are still undeveloped. The shorelines of both Amnicon and Dowling Lakes are characterized as highly developed, containing 2 and 3 tier development. Summer homes along the shorelines of both lakes became popular in the early 1900's and by the mid 1930's nearly 75 cottages were scattered along 3 sides of Amnicon Lake and nearly 50 cottages along Dowling Lake. Both lakes are currently the most highly developed per acre surface water of all lakes in Douglas County (approximately 300 lakes). Both Amnicon Lake and Dowling Lake support high quality sport fishing, particularly native muskellunge (musky), but also walleye, large-mouth bass and pan fish. The area has been able to retain much of its natural aesthetic beauty.

1.3 Previous Study Results

Previous studies of both lakes, which included acquiring water quality data, have been performed from at least 1978 to present. Based on these studies, the trophic status of Amnicon Lake in the late 1970's, through the 1980's to 1999, which is the last year water samples were analyzed prior to this project, has remained in the upper mesotrophic to lower eutrophic state. During this same time period (late 1970's to 1999), Dowling Lake has gone from lower eutrophic to near the middle of the eutrophic range.

2. Geologic Setting and Soils

Amnicon and Dowling Lakes are shallow drainage lakes of glacial origin, formed approximately 15,000 years ago during the last glacial retreat of the Superior Lobe (see Figure 2).

The central and southwestern part of Douglas County, including the area around Amnicon and Dowling Lakes, is characterized by unsorted glacial deposits typical of those found at the edge of a melting glacier. Properly termed glacial end moraine and ground moraine, these deposits consist of a heterogeneous mixture of boulders, gravel, sand, silt and red clay. The random disposition of these materials results in an irregular pattern of uplands interspersed with marshes and shallow lakes like Amnicon and Dowling.

Soils in the watershed reflect the random distribution of unsorted glacial material. Upland areas are dominated by Gogebic sandy loam, Pence sandy loam, Keweenaw loamy sand and Vilas sand. These soils are rapidly permeable and moderately to strongly acidic. Lowland areas are dominated by Greenwood peat and Seelyeville muck. Greenwood peat is a very poorly drained organic soil that ranges from strongly acid to extremely acid. Seelyeville muck is a deep organic soil that ranges from medium acid to neutral.

3. Watershed Features:

3.1 Drainage Area Delineation

Several previous studies have given estimates of the size of watershed or drainage area of Amnicon and Dowling Lakes. The drainage area is the land area that drains to the lake. We delineated the Amnicon Lake drainage area from a USGS 7.5 min quadrangle map, Amnicon Lake Quadrangle, Wisconsin. The calculated area of the Amnicon drainage area was 2,615 acres, which is slightly smaller than most of the other estimates. There is a sub drainage area for Dowling Lake (which ultimately discharges to Amnicon Lake via a channel), which we calculated to encompass 1,361 acres. See Figure 1 for a map showing both drainage areas.

3.1.1 Landscape and Cover of Watershed

The original forest in the Amnicon Dowling area was mature white pine mixed with hardwoods on the uplands and a mixture of black spruce, tamarack and sedge meadows on the lowlands. With the opening of a federal land office at Superior in 1855, European immigrants surged into Douglas County to cut timber, prospect for minerals and homestead. By the early 1900's, most of the marketable timber in the area was gone. The partial clearing of the land by logging encouraged a gradual influx of agricultural immigrants to further clear the land for farming. In fact, many influential groups and agencies strongly promoted this "cutover" area of northern Wisconsin as potential farmland. By the 1930's the number of farms in the county declined, which has continued to the present time.

Looking at the most current topographic map of the study area (1993), we calculated the number of acres for each of the four different land covers in both watersheds. These four different land covers were:

1. Medium Density Urban (MD Urban), up to ¼ acre lots

2. Rural Residential, greater than 1 acre lots

3. Wetlands

4. Forest

See Appendix 1 for a summary of this information. The drainage areas for both Amnicon Lake and for Dowling Lake are dominated by forests and wetlands. Of the 2,615 acres for the Amnicon drainage area, 1,918 acres or 73% consists of forests and wetlands. Of the 1,391 acres for the Dowling drainage area, 1,288 acres or 93% consists of forests and wetlands. Although the forest in the area have been clear cut several times in the last 100 plus years, the forests have grown back and current conditions are dominated by undeveloped land use.

3.1.2 Runoff Patterns in Relation to Sensitive Areas

Amnicon Lake has 3 inlets, a permanently flowing inlet from Dowling Lake and two intermittent feeder streams from adjoining marsh land off the north shore. Dowling Lake has at least five small seasonal inlets. Flow into the lake at these sites is highly variable. Surface flow into both lakes is generally slow because 1) most of the watershed is woodland or marsh and 2) there are many small depressional areas within the watershed that have no visible surface outlet.

Regarding stormwater runoff from impervious surfaces, the highest potential for impact to the lakes is where there are directly connected impervious surfaces to the lake. An example of this is a road adjacent to the shoreline, especially if there is a long paved driveway connected to this road. Also of concern are "manicured lawns" which can contribute excess sediment and nutrients to lakes as well. The best approach to minimize the amount of sediments and nutrients entering the lake in the near shore area is to disconnect all impervious surfaces from the lake. This can be accomplished by redirecting stormwater from impervious surfaces to a vegetated area before it enters the lake. A good method to minimize impacts from manicured lawns is to construct a buffer strip near the shoreline.

The most important and sensitive areas of both lakes in the near shore environment are the preferred spawning areas for walleye and for muskellunge. Since these are the most important areas to protect, care should be taken to minimize the amount of runoff entering these spawning areas, since excess sediment (silt and clay), nutrients and other contaminants (such as oil from the roads) can have an adverse effect on these areas. This is especially true for walleye spawning areas, since the preferred spawning habitat for walleyes are sand and rocky bottoms, which would be most effected by the addition of silt and clay. See section 7 for the discussion and the location of the spawning areas of both lakes.

3.2 Water Budget

The water budget for a lake is the volume of water entering a lake minus the volume of water leaving the lake, with the difference being the change in volume of water stored in the lake (can be seen as the lake level decreasing or increasing in a set period of time). In the last 25 years the lake levels in both lakes has remained approximately the same.

Water enters lakes as precipitation, surface water inflow (including inflow from a connected up-stream lake) and ground water inflow. Water leaves both lakes through evaporation and surface water outflow (including that to a connected downstream lake or river). Both lakes water budget was estimated, and are summarized below.

3.2.1 Amnicon Lake

The sources of water into Amnicon Lake are groundwater, surface water runoff, the inlet from Dowling Lake, the net of precipitation minus evaporation, the three small inlets and several intermittent feeder streams. All of the water leaves Amnicon Lake via the outlet to the Amnicon River at the southwest end of the lake.

In the "Amnicon & Dowling Lakes Feasibility Study Results; Management Alternatives", WDNR, 1981 (1981 WDNR Report) it stated that the inlet from Dowling Lake, the streams into Amnicon Lake and the outlet from Amnicon Lake (to Amnicon River) were gauged or measured from October 1978 through September 1979. It stated that this time period was a near normal water year. Therefore we will use their gauging estimates for this project. We will also utilize the Wisconsin Lake Modeling Suite (WiLMS) to calculate the annual hydraulic loading, which is the amount of water entering the lake and the nutrient loading (which will be discussed in Section 3.3). From this information we estimate the hydraulic loading (how much water enters the lake in one year) into Amnicon Lake at 7,147 acre-feet. The specific volumes are broken down below, along with the percentage of total volume:

- Combined ground water/surface water = 2,964 acre-feet (41% of total)

- Dowling lake inlet = 2,400 acre-feet (34% of total)
- Three permanent steams/intermittent streams = 1,600 acre-feet (22% of the total)
- Net of precipitation-evaporation = 183 acre-feet (3% of total)

The gauged amount of water leaving Amnicon Lake via the outlet was 6,900 acre-feet. The difference between the numbers (7,147 acre-feet and 6,900 acre-feet) is probably a combination of water leaking around and under the outlet culvert, the change in storage and measuring errors. The lake volume of Amnicon Lake is 4,120 acre-feet and 6,900 acre-feet of water leaves through the outlet to the Amnicon River every year. Therefore the residence time or exchange time of the lake is 7 months, meaning every 7 months an entire lake volume leaves through this outlet.

3.2.2 Dowling Lake

The sources of water into Dowling Lake are groundwater, surface water runoff, the net of precipitation minus evaporation and at least five small seasonal inlets. All of the water leaves Dowling through the Dowling Lake Outlet to Amnicon Lake. Again using gauged values for the 1981 WDNR Report and WiLMS, we calculated the annual hydraulic loading into Dowling Lake as 2,493 acre-feet. The specific volumes are broken down below, along with the percentage of total volume:

- Combined groundwater/surface water = 1,576 acre feet (63% of total volume)
- Five or so small seasonal inlets = 850 acre-feet (34% of total volume)
- Net of precipitation-evaporation = 67 acre-feet (3%)

The gauged amount of water leaving Dowling Lake via the outlet to Amnicon Lake was 2,400 acre-feet, which is very close to our calculated volume. The lake volume of Dowling Lake 1,113 acre-feet and 2,400 acre-feet of water leaves through the outlet every year. Therefore the residence time or exchange time of Dowling Lake is 5 ½ months, meaning every 5 ½ months an entire lake volume leaves through the outlet.

3.3 Nutrient Budget

Phosphorus and nitrogen are essential for plant growth and are the nutrients that usually limit algal growth in Midwestern lakes. High nutrient concentrations can cause high algal population (blooms) and can, therefore, be the cause of eutrophication (that is, accelerated aging and increased productivity) of lakes. Phosphorus concentrations greater than about 20 ug/L or parts per billion (ppb) generally indicate eutrophic conditions.

All lakes receive nutrients from a variety of sources. The challenge is to minimize the amount of phosphorus and nitrogen inputs to both lakes in order to minimize algae blooms. Based on the numerous studies performed on these lakes as well as other lakes in

Northern Wisconsin and Northern Minnesota, it is unlikely that nitrogen is the limiting nutrient to algal growth. It is most likely that phosphorus is the nutrient limiting algal growth, so phosphorus is the nutrient to focus on and manage for when considering management efforts to improve water quality. Below is a summary of the estimated phosphorus loading into both lakes, based on WiLMS modeling.

3.3.1 Amnicon Lake

The most likely total phosphorus loading into Amnicon Lake is 449 kg per year, based on WiLMS modeling. The largest source is from the Dowling outlet, at 109.5 kg/year. The next two largest sources of phosphorus are the streams/intermittent stream and septic tank loading, both at approximately 73 kg/year. See the two graphics in Appendix ___ for a summary of the loading total sources.

3.3.2 Dowling Lake

The most likely total phosphorus loading into Dowling Lake is 155.4 kg/year, based on the WiLMS modeling. The largest sources are the streams/intermittent streams into the lake, at 45 kg/year. The next two largest sources of phosphorus are from septic tanks and from the forested part of the drainage area both approximately 26 kg/year. See the two graphics in Appendix ____ for a summary of the loading totals and sources.

3.3.3 Internal Loading

Phosphorus that is deposited in the lake sediments is not permanently removed from the lakes and may be released back to the water column. The rate of phosphorus release from sediments is greatly increased when the sediment-water interface becomes anoxic.

Internal loading means the amount of phosphorus of the total phosphorus load that derives from the lake sediments. There are many factors that influence internal loading, including how stratified or mixed the lake is, and the thickness of anoxic water near the water/sediment interface. Five sediment samples were collected from Dowling and five from Amnicon (10 total) in June of 2003. Among the parameters analyzed was total phosphorus. The average total phosphorus in Dowling was 663ppm and the average total phosphorus in Amnicon was 574ppm. However, based on several studies performed, there is no confirmed correlation or connection between TP in sediments to trophic status.

We input values into the WiLMS Model to ascertain the estimated gross internal loading. Based on this work, we estimate 65 kg of the 155.4 kg of annual phosphorus in Dowling or 42% is due to internal loading. Similarly, we estimate 20 kg of the 449 kg of annual phosphorus in Amnicon, or 4.5%, is due to internal loading.

The internal loading value for Amnicon is in the low to normal range, but the internal loading estimate for Dowling (42% of the total loading) is extremely high.

3.4 Shoreland Inventory

The shoreland inventory looked at three areas; upland fringe, the shoreland and shallow water area by the shore. A photographic inventory of Amnicon and Dowling lakes was conducted. The objectives of the survey were to characterize existing shoreland conditions which will serve as a benchmark for future comparisons.

Each photograph had the shoreline and upland condition observed. The grading criteria was based on the presence of natural vegetation in the understory and natural vegetation along the shoreland. The levels that were looked at were 50% and 75% of natural vegetation currently growing. See Appendix ___ for pictures of the entire shoreline of both Amnicon and Dowling Lakes.

Table **1** below shows the results of the study. The criteria would be considered subjective, but follows protocols which are commonly used to create shoreland inventories. It shows that each lake has under half of the lots with greater than 50% natural shoreland and natural upland cover.

Table **1**. Summary of Upland and Shoreland conditions on Amnicon and Dowling Lakes.

Lake Name	**Natural Upland Condition**		**Natural Shoreland Condition**		**Total Lots Observed**	**Undevel Lots**	**Shoreland Structure**	
	>50%	**>75%**	**>50%**	**>75%**			**riprap**	**Wall**
Amnicon	**91** 44%	**78** 38%	**93** 45%	**83** 40%	**208**	53 25%	**13** 6%	**15** 7%
Dowling	**45** 46%	**25** 26%	**48** 49%	**31** 32%	**98**	11 11%	**6** 6%	**3** 3%

The more natural shoreland and natural upland vegetation there is, the lower the impact the lot on the lake. Below in Figure 3, you can see two graphics from the Wisconsin DNR. They depict the older cabins from when the northern lakes were first being developed versus the developments of today, which are year round homes with manicured and landscaped lawns. The combination added impervious area, along with the added vegetation and fertilizer contribute greatly to nutrient loading in Lakes.

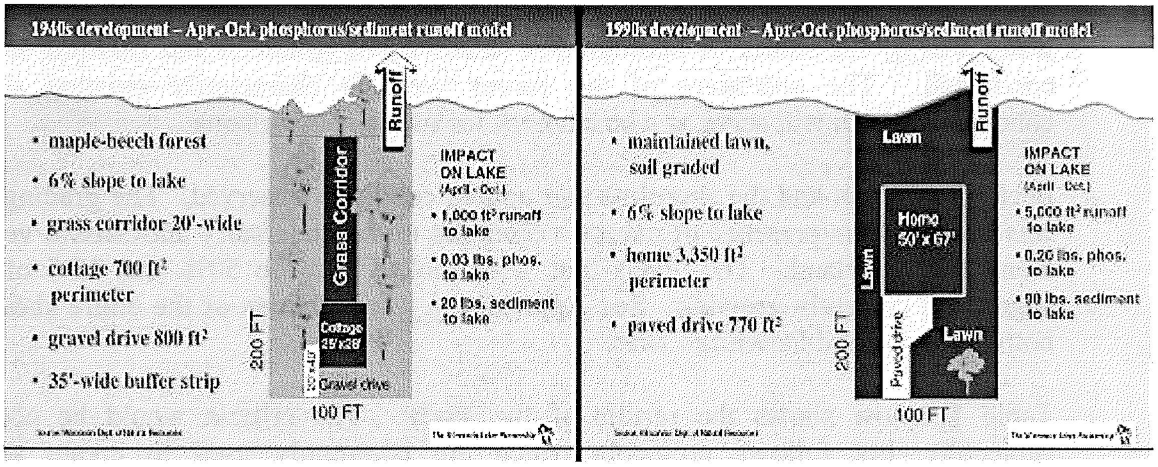

1940s development – Apr.-Oct. phosphorus/sediment runoff model
• maple-beech forest
• 6% slope to lake
• grass corridor 20'-wide
• cottage 700 ft² perimeter
• gravel drive 800 ft²
• 35'-wide buffer strip
Runoff
Grass Corridor
Cottage 25'x28'
Gravel drive
200 FT
100 FT
IMPACT ON LAKE
• 1,000 ft² runoff to lake
• 0.03 lbs. phos. to lake
• 20 lbs. sediment to lake
1990s development – Apr.-Oct. phosphorus/sediment runoff model
• maintained lawn, soil graded
• 6% slope to lake
• home 3,350 ft² perimeter
• paved drive 770 ft²
Runoff
Lawn
Home 50'x67'
Paved drive
200 FT
100 FT
IMPACT ON LAKE
• 5,000 ft² runoff to lake
• 0.20 lbs. phos. to lake
• 90 lbs. sediment to lake

Figure 3

The above photograph represents a lot with both 50% natural Upland vegetation and 50% natural shoreland vegetation. The photo below shows a site that does not meet either of the criteria.

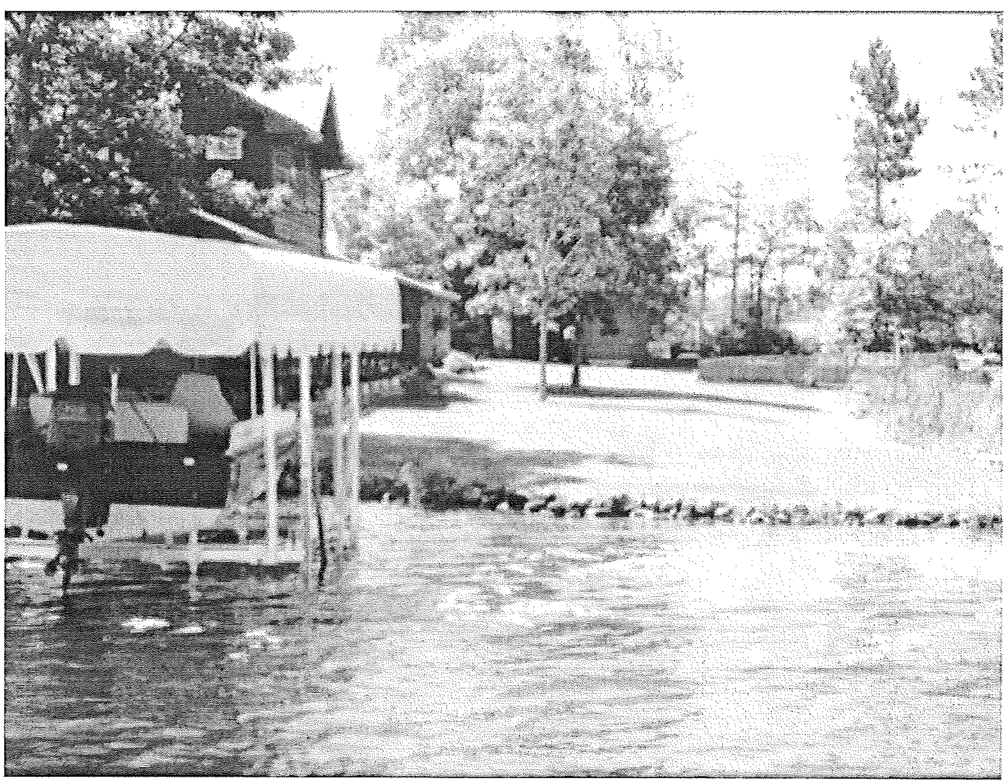


Table 2

Lake	County, State	Upland	Shoreline	Undev	Total Properties
Amnicon	Douglas, WI	44%	45%	25%	208
Dowling	Douglas, WI	46%	49%	11%	98
Round Lake	Polk, WI	27%	39%	14%	74
Big Bear Lake	Burnette, WI	82%	86%	13%	87
Upper Turtle Lake	Barron, WI	72%	76%	28%	309
Nancy Lake	Washburn, WI	77%	80%	19%	217
Bear Lake	Villas, WI	93%	84%	6%	115
East Rush	Chisago, MN	43%	43%	9%	192
Comfort	Chisago, MN	62%	50%	0%	100
Orchard	Dakota, MN	47%	53%	4%	109
Weaver	Hennepin, MN	47%	44%	5%	111

*Highlighted lakes above are lakes near or in urban areas of the Twin Cities.

Amnicon and Dowling lakes are both comparative to lakes near urban areas such as the lakes near the first tier suburbs in the Twin Cities area. Looking at several lakes in northern Wisconsin it is seen that a large portion of the lakes have about the same amount of development percentage wise, but more of these structures are probably older cabins or the owners have chosen a more natural look, with more native cover. The lakes selected to compare have roughly the same number of lots as Amnicon and Dowling.

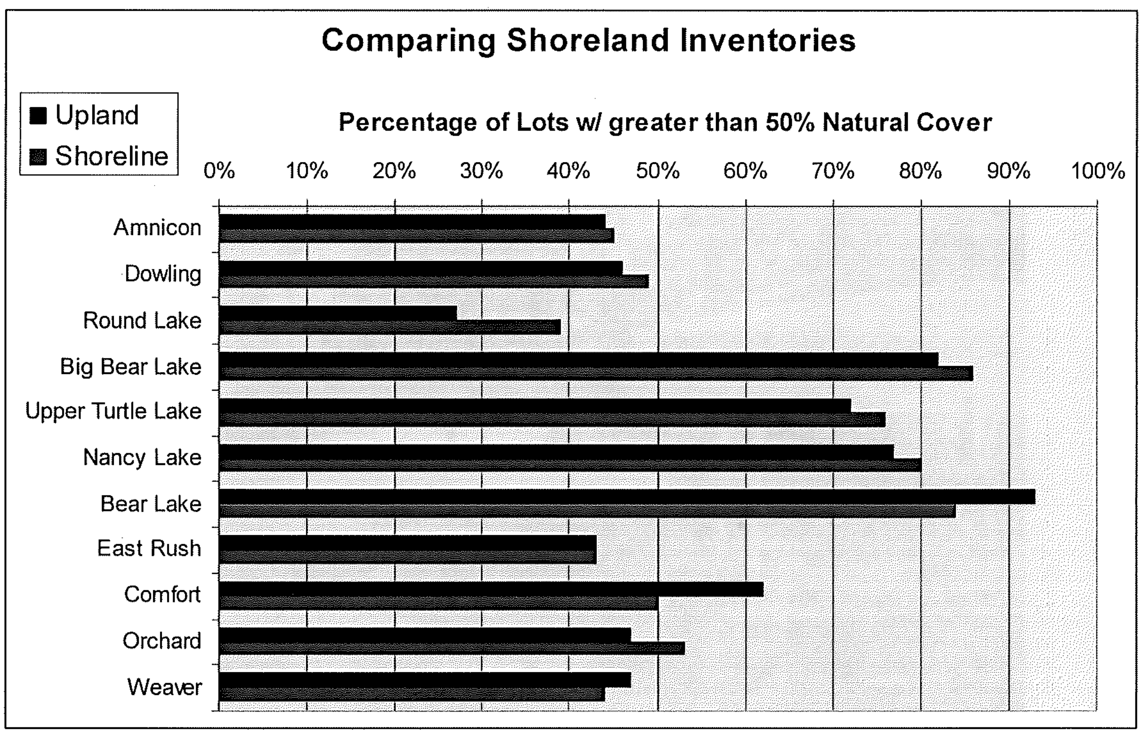


Figure 4

3.5 Ground Water and Onsite Treatment Systems

Septic Systems are generally not designed to remove nutrients. Once the soil retention capacity of the soil is exceeded for phosphorus, septic systems can and often do discharge high concentrations of phosphorus to the ground water. However, as discussed in Section 3.3, the estimated phosphorus load contributions of septic tanks and related onsite treatment systems, is only 16% to 17% of the total load. These percentages are on the high side of the normal range, but not the leading culprit in phosphorus loading to the lakes. For details on how we arrived at our estimates for septic tank loading, see Appendix ____.

3.6 Watershed Synopsis

The watershed area that drains to Amnicon Lake is dominated by wilderness areas composed of forests and wetlands which encompass 73% of the watershed. Similarly, the watershed area that drains to Dowling Lake is dominated by forests and wetlands with over 92% of the watershed coming from forests and wetlands.

Concerns have been raised about the water quality coming into both lakes. As will be discussed in detail in Section 4.3, results of water testing indicate the water coming into Amnicon is typical for the region, with the largest source of nutrients into Amnicon coming from the Dowling outlet. The results of water testing for Dowling indicate the water coming into the lake are on the high side of normal for the region, with the largest source of nutrients into the lake coming from the permanent and intermittent streams.

As previously stated, Amnicon is slightly mesotrophic to eutrophic and Dowling is considered eutrophic. Knowing that most of the watershed is undeveloped forests and wetlands, the following questions come to mind:

1.) What happens if the phosphorus loading to both lakes is reduced and how much would the phosphorus have to be reduced in order to bring both lakes up to mesotrophic status?

2.) How could this be accomplished, knowing that most of the watershed is undeveloped land?

Question 1, will be addressed in section 5.2 Loading Reduction Feasibility Analysis and question 2, will be addressed in section 5.2 and in section 7, Lake Management Ideas and Recommendations.

4. Lake Features and Statistics

4.1 Amnicon Lake

Amnicon Lake is a 426 acre stained drainage lake located in West Central Douglas County. The lake is relatively shallow with an average depth of 9.9 feet and a maximum depth of 31 feet. There are three state owned islands within the lake basin. The measured watershed is 2,615 acres which includes the 154 acres of Dowling Lake. Surface drainage consists of three inlets, two small intermittent streams from adjacent wetlands and the permanent inlet from Dowling Lake. Amnicon Lake is the headwaters of the Amnicon River, which drains into Lake Superior. As previously discussed, approximately three quarters of the watershed drainage into Amnicon is from forests and poorly drained wetlands.

4.2 Dowling Lake

Dowling Lake is a 154 acre drainage lake located upstream from Amnicon Lake. Dowling Lake is a shallow lake with an average depth of 7.2 feet and a maximum depth of 13 feet. There is one state owned island within the lake basin. The measured watershed is 1,391 acres. Surface drainage consists of at least 5 small seasonal inlets from small depressional poorly drained wetlands. Dowling Lake drains into Amnicon Lake from an outlet on the northwest side of the lake.

4.3 Lake Water Quality Summary

Water quality is described by a set of measurements or indicators of measurable physical, chemical, and biological factors. The factors that were looked at were Dissolved Oxygen (DO), Temperature, water clarity (as measured with a Secchi Disk), Total Phosphorous, and Chlorophyll a.

4.3.1 Dissolved Oxygen and Temperature

The growing season (May through September) DO and Temperature profiles for both Amnicon and Dowling Lakes for 2003 and 2004 are shown in the following sections. By examining the profiles, we can learn a great deal about the lake. The main thing that can be determined from the profiles during the growing season is whether or not the lakes are thermally stratified or mixed.

Dissolved oxygen is the amount of oxygen available for aquatic life to use in the water. Without oxygen, or with limited oxygen, aquatic organisms may have difficulty surviving. Lack of oxygen is a major cause of fish kills. Amnicon and Dowling are classified as weak dimictic to polymictic lakes, which means during the growing season months and winter, lakes will slightly stratify, however they also easily resist stratifying in summer and instead continually mix.

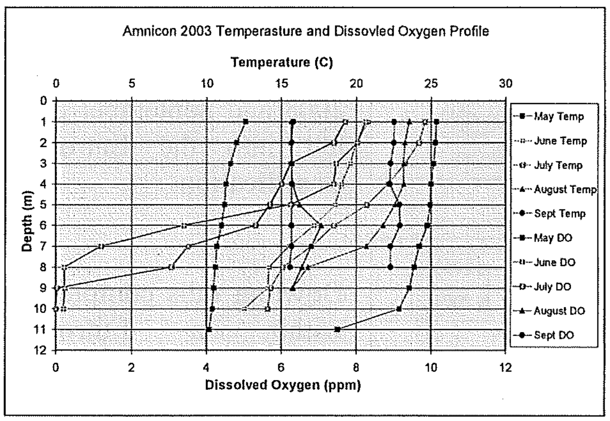
Thermally stratified means that the water column is segregated into discrete layers of water based on their temperature. The water near the surface that is warmed by the sun is less dense that the cooler water below it and “floats” forming a layer called the epilimnion. Since this water is frequently mixed by the wind, it is usually the approximate temperature of the air and is saturated with oxygen.

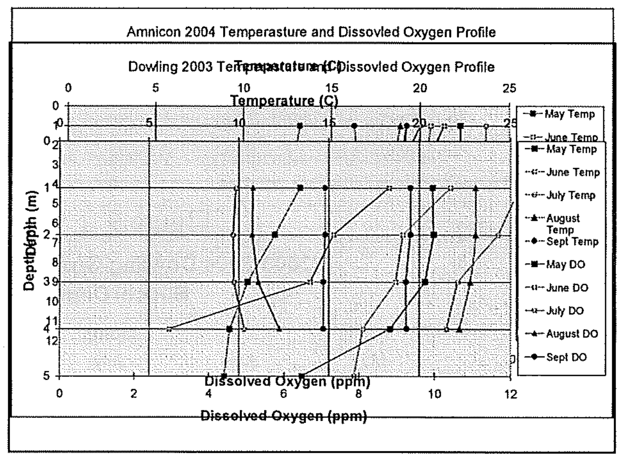
Below this eplimnion layer, is a region called the metalimnion, where water temperatures quickly decrease with depth. Water in this layer is isolated from gas exchange with the atmosphere. The oxygen level in the metalimnion usually declines with depth in a manner similar to the decrease in water temperature.

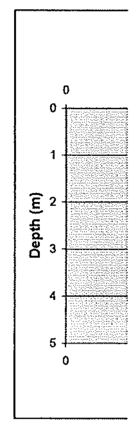
Below the metalimnion is a layer of cold dense water called the hypolimnion. This layer is completely cut off from exchange with the atmosphere and light levels are very low. In a thermally stratified lake, once the lake stratifies in the summer, oxygen concentrations on the hypolimnion progressively decline due to decomposition of plant and animal matter and respiration of benthic (bottom-dwelling) organisms.

A lake that stratifies twice (throughout summer and during winter) is termed a dimictic lake. A lake that rarely stratifies or does not stratify, due to constant mixing of the lake column, is termed a polymictic lake.

Below are the graphs for Amnicon and Dowling Lakes for the 2003-2004 summers.







Temp and DO 2003 and 2004

Figure 7 and 8 Dowling Water Temp and DO 2003 and 2004

4.3.2 Secchi Disc

Water clarity was measured with the use of a secchi disc. This is done by lowering the secchi disc over the side of a boat until the disc is no longer visible. Water clarity tests the amount of suspended particulate in the water as well as staining. Lakes with secchi disc readings between 6.5 and thirteen feet are said to be in the Mesotrophic range. Below are the secchi disk readings collected in 2003-2004.

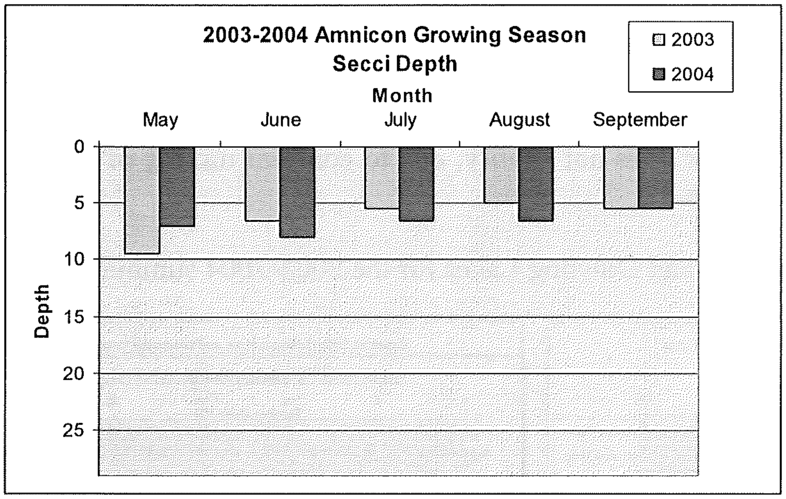


Figure 9

The general secchi disc reading for a lake to be classified as Eutrophic is 6.5 feet. The 2003 average secchi disc reading was 6.4, and the 2004 average was 6.7. The averages are on the border of being classified as Eutrophic. July through September in 2003 and September 2004 fell into the Eutrophic classification.

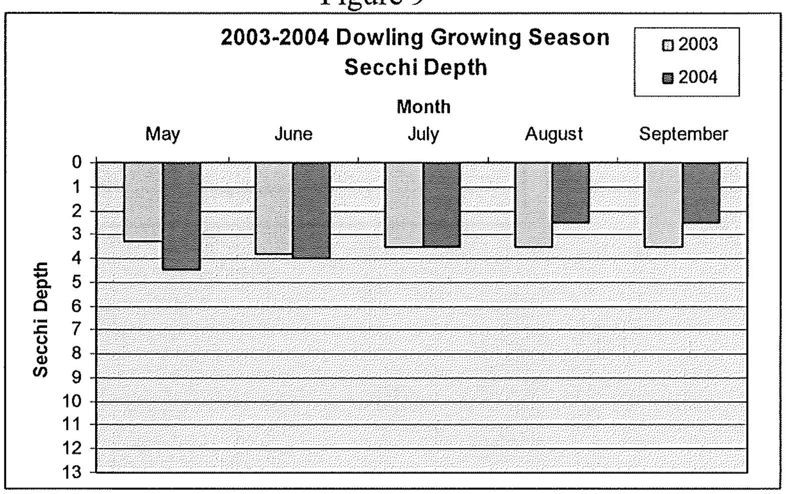


Figure 10

Dowling falls completetly within a Eutrophic classification when looking at the secchi disc readings for 2003 and 2004. In 2003 there was not much of a decline in visibility through the end of summer, but in 2004 visibility decreased in August and September.

4.3.3 Total Phosphorous

Phosphorous is an essential nutrient for plant growth and commonly is the limiting nutrient effecting biological growth in Amnicon and Dowling Lakes. Measurements of 2003-2004 Phosphorous can be seen below. Total Phosphorous concentrations greater than 17 to 20 ppb indicate eutrophic conditions.

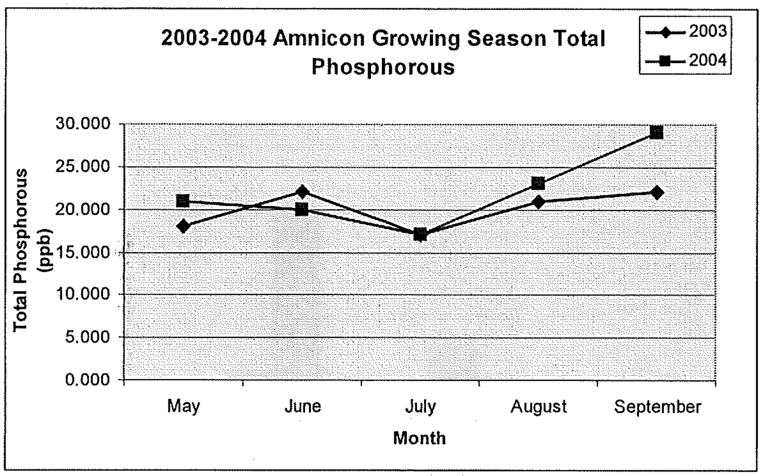


Figure 11

Total Phosphorous readings in Amnicon Lake are in the upper range of Mesotrophic for most of 2003 to 2004, with a spike in September of 2004. There is a slight dip in both data sets for the month of July, this may be due to algae using the readily available orthophosphate.

Total Phosphorous readings in Dowling Lake are in the Eutrophic range for 2003 to 2004, with a spike in August of 2004. There is a slight dip in both data sets for the month of July, this may be due to algae using the readily available orthophosphate.

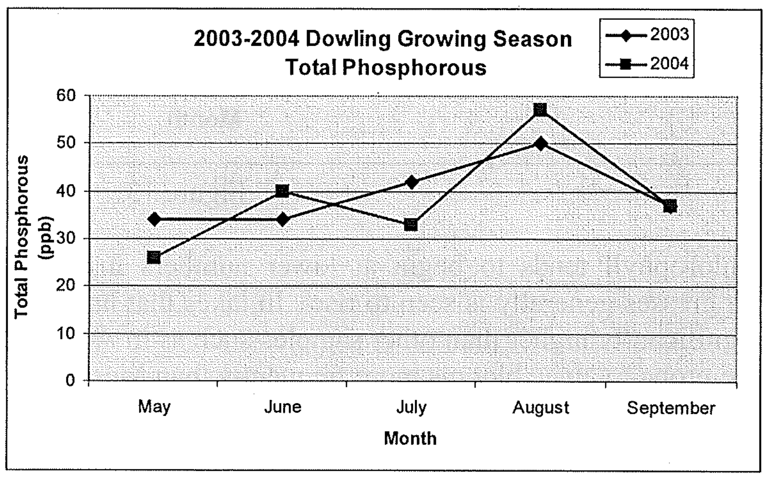


Figure 12

4.3.4 Chlorophyll a

Chlorophyll a is a photosynethic pigment that can be found in algae and other green plants. Its concentration can be used as a measurement of the amount of algae that is within a water body. Some algae is needed, but excess algae can choke out other organisms. Chlorophyll a levels greater than 7 to 10 ppb indicate eutrophic conditions. Amnicon

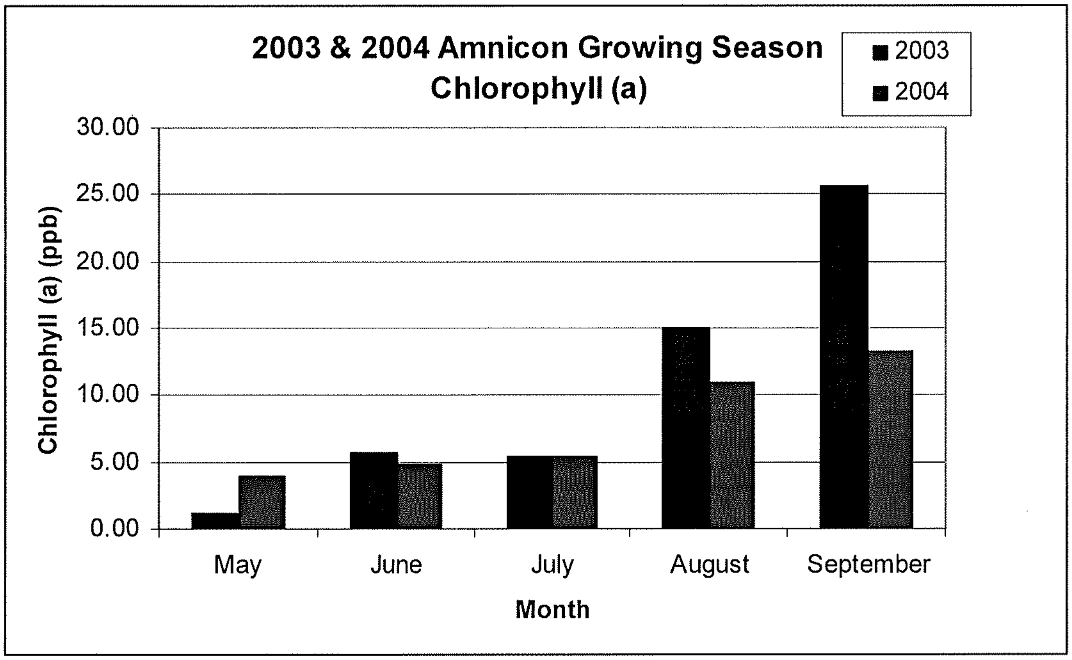


Figure 13

Chlorophyll tends to begin at lower numbers in spring, and as the growing season progresses generally is seen to rise. In lakes that have algae blooms, a spike may appear significantly higher than other samples such as in August 2004. Lakes that are Eutrophic are prone to algae blooms more frequently than Mesotrophic lakes.

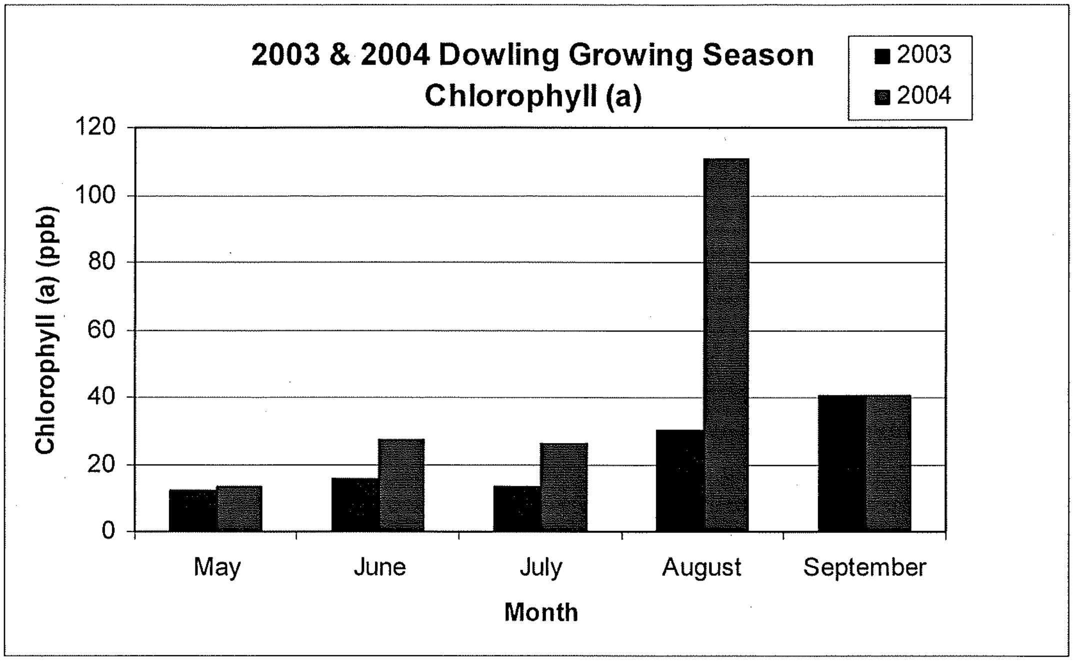

2003 & 2004 Dowling Growing Season
Chlorophyll (a)
2003
2004
120
100
80
60
40
20
0
Chlorophyll (a) (ppb)
May
June
July
August
September
Month

Figure 14

4.3.5 Historic Trophic State Index Summary

Water Clarity, Total Phosphorous, and Chlorophyll a have mathematical formulas that allow them to be placed on a similar scale called the Trophic State Index. This was first created by Carlson in 1977. The equations that were originally used were then modified to better suit Wisconsin Lakes, by the Wisconsin DNR. Using the equations created by the WDNR in 1993, the data collected was averaged for the entire year that data was collected. The data displayed below represents years in which three or more sampling dates were in the data set.

When looking at the assembled lake data, only years with more than three points through the five month growing season were included. This was due to the fact that if only two data points existed in the year in months such as May and September, readings would be lower and skew the results positively, and if two points existed in July and August, the data would be skewed negatively. Therefore it was decided to use years with data in three or more of the five months (May through September).

Currently Amnicon Lake is clearly in the Eutrophic region to on the border between eutrophic and mesotrophic. However historical data places it in similar levels historically when recalculated using the 1993 modified equations, and has not noticeably deteriorated in over 25 years. However, the current data indicates that with cutting back on phosphorous loading, the lake may show improvement in TSI.

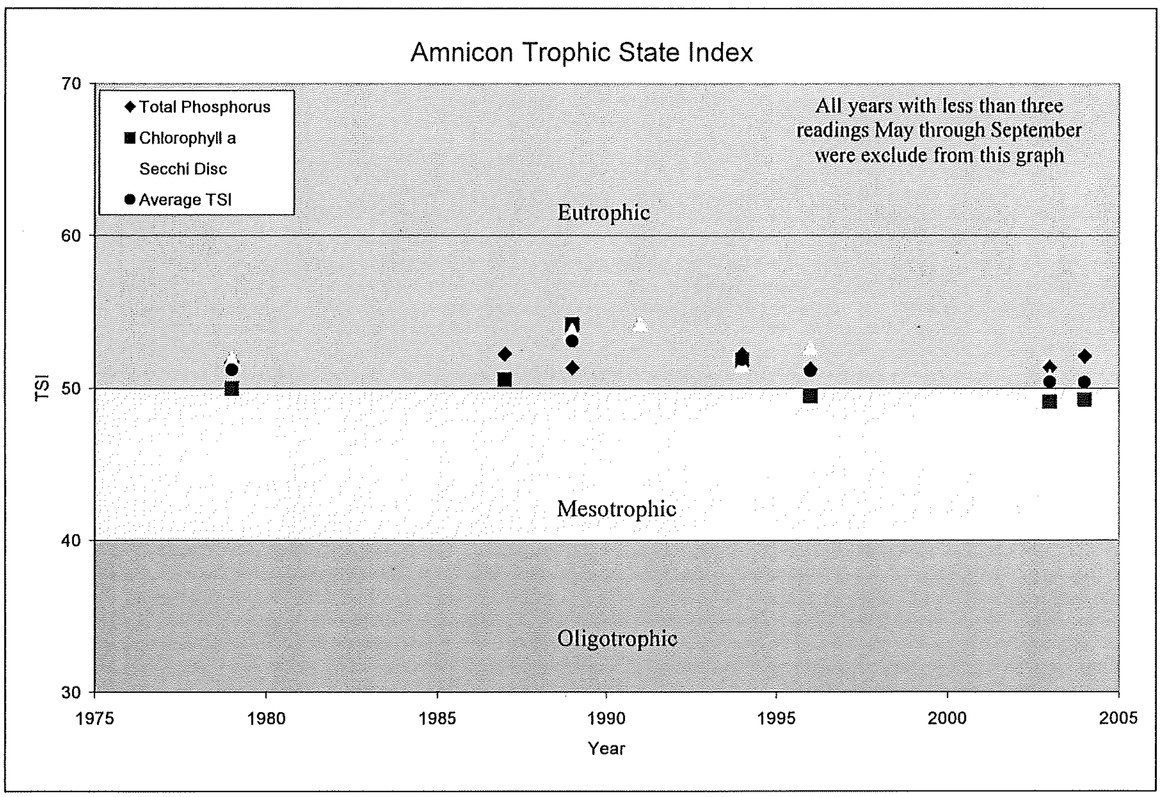


Figure 15

Dowling Lake shows a consistent rise in every year monitored in the data set. The graphbelow includes trend lines with R values. R values are indicaters that refer to the accuracy of the trend line. The closer to one, the more accurate the equation will be. After sorting through years that did not meet the criteria, only five to six points were left for each measure. Based on this, Dowling appears to be consistently worsening in water quality over the last 25 years.

All years with less than three readings May through September were exclude from this graph

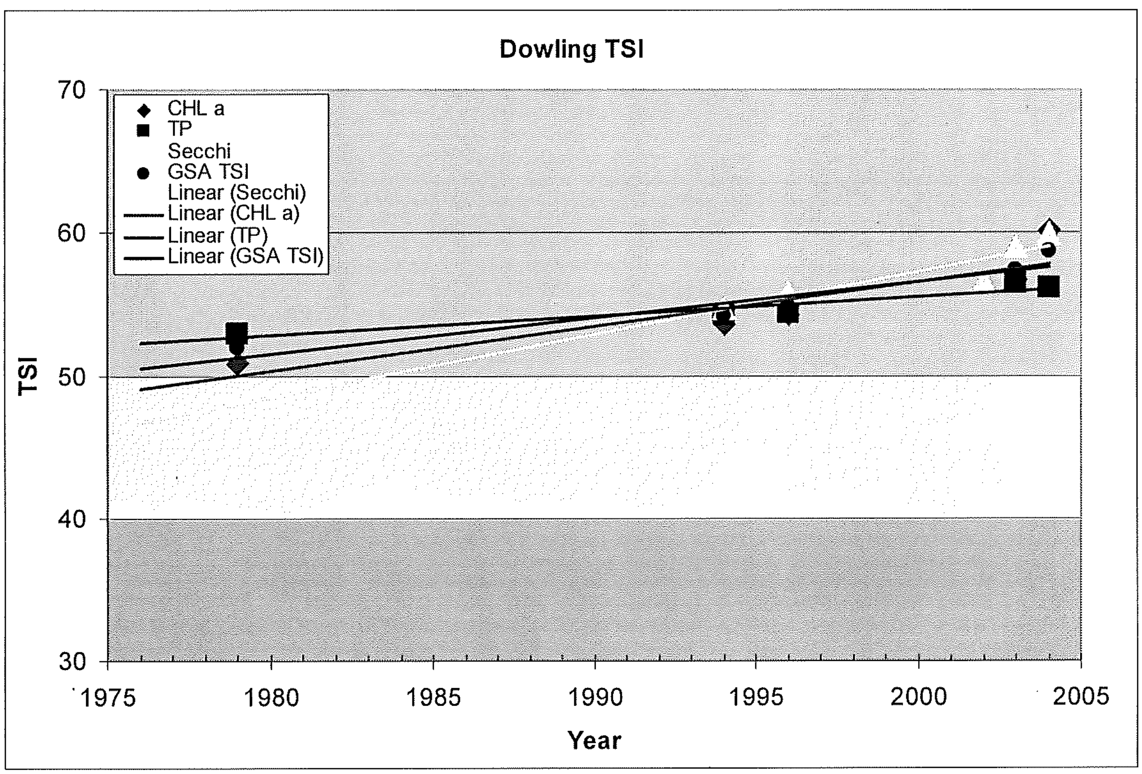


Figure 16

4.4 Aquatic Plant Status

Aquatic plants are an essential part of a healthy lake and fish population. Amnicon and Dowling Lakes have abundant and diverse macrophyte plant populations that provide habitat and food for the fish populations, and also help protect the shoreline. The lakes also have large populations of algae.

There are many types of algae, but the most notable is the blue-green algae or cyanobacteria. This is the algae that are generally responsible for the algae blooms that occur in late summer and are most associated with poor water quality. Algae blooms are generally allowed to occur due to elevated levels of available phosphorous. The larger problem created by algae blooms is the rapid decomposition of the algae which decreases the dissolved oxygen in the water.

Macrophyte plants come in three types; floating, emergent, and submergent. Floating macrophytes float on top of the water with no root system in the soils and sediments of the lake. Emergent macrophytes are water plants such as wild rice and cat tails. Submergent macrophytes like those in the water milfoil family may be entirely under the water or only slightly above the waters surface. The macrophyte plant population competes with the algae for nutrients and light. A large macrophyte population helps to limit the amount of algae by consuming phosphorous and other nutrients that contribute to algae blooms.

Macrophytes have many positive effects on water quality, but can also create a nuisance. Floating plants like duckweed thrive in nutrient rich, still waters, and can reproduce and grow quickly in such conditions. Other plants such as the submergent water milfoils can easily break off when hit by propellers and spread a dense mat of plant matter quickly throughout the water body. Milfoils and other submergent macrophytes have less food value than most of the floating and emergent macrophytes, but have the most value as habitat.

Amnicon and Dowling lakes have large amounts of macrophyte vegetation. The populations are diverse, both lakes having more than fifteen known species of macrophyte. Below are tables with the most recent species found in Amnicon and Dowling Lakes.

At last count Amnicon had 26 different macrophytes growing in its waters. The population of the macrophytes is reported to be large enough to inhibit use of the lake in some areas. A large diverse macrophyte population is healthy for a lake but may need to be managed. A management strategy must look at removing the nutrient source, not the plants themselves. This is because removal of excessive plant growth will free nutrients, and may destabilize sediment as well.

Dowling Macrophytes
American Elodea
Arrowhead
Bulrush
Burreed
Common Cattail
Filimenting Algae
Floating Leaf Pondweed
Horsetail
Moss
Pickerelweed
Richards Pondweed
Spikerush
Variable Pondweed
Wild Rice
Wort
Yellow Water Lily

Amnicon Macrophytes	
American Elodea	Raccoons Tail
Arrowhead	Ribbonlead Pondweed
Bulrush	Richards Pondweed
Burreed	Sedge
Common Cattail	Small Pondweed
Common Elodea	Spiral Pondweed
Eel Grass	Stonewart
Floating Leaf Pondweed	Water Marigold
Hornwart	Water Milfoil
Horsetail	Water Shield
Large Leaf Pondweed	Whilestem Pondweed
Moss	White Water Lily
Pickerelweed	Wild Rice

Table 3

Dowling Lake had sixteen species found during the last complete survey and in 2004 while completing a fish survey the WDNR noted in the 2004 report from the Wisconsin DNR, that Dowling had Purple Loosestrife fairly widespread along the shoreline. The report also noted native macrophyte species that were observed were the yellow water lily, arrowhead and spikerush sp., common and floating-leaf bur-reed, pickerel weed, watersheild, horsetail, elodea, and bushy floating, and large-leaf pondweed. Judging by this, Dowling may be more diverse than the report from 1997 indicates. Dowling also has a high macrophyte population and due to the same concerns as in Amnicon, nutrient removal needs to be looked at before the removal of the vegetation.

4.5 Zooplankton and Other Invertebrates

Zooplankton and benthic communities are essential components of lake ecosystems. Zooplankton are small crustaceans that can feed on algae. Zooplankton samples were collected from Amnicon Lake in 1986 and in 1987 (Ryan, November 1993). The species found in both samples reflect a common lake zooplankton community and suggest a normal diverse benthic community.

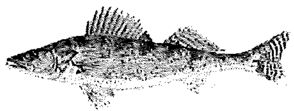
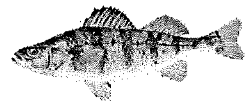
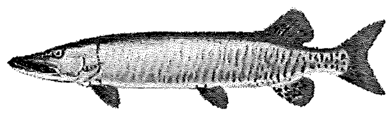
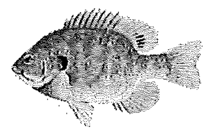
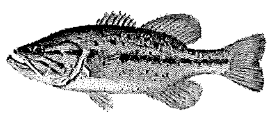
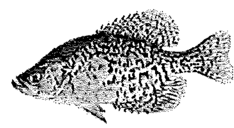
4.6 Fishery Status

Judging the status of a fishery is difficult. Studies that are done to count the number of fish can be positively or adversely affected by the time of year, water and weather conditions, and the area and species targeted. While the data presented below is accurate in the sense that it represents an actual count, but conditions present on the day of the study may cause an inaccuracy that could not be avoided.

Amnicon and Dowling Lakes were consistently stocked until 1970's with walleye and Muskellunge. From 1972-1978, Dowling shows that it was continued to be stocked with Musky and Amnicon was continually stocked with Musky from 1972-2001, only missing a couple of years. See Appendix XXX for the historical stocking information including the years, species, and numbers stocked. According to WDNR records, Amnicon received its first walleye stocking in 30 years in 2002, and again in 2003 with a total of more than 800,000 fry being introduced to the lake. Dowling has not had any Wisconsin DNR stocking in recent years.

Amnicon is designated by the WDNR as an A2 class Musky lake with a class 2 reproduction ranking; Dowling has an A2 classification as well, but is labeled a class 1 reproduction class. A class 1 reproduction class indicates that the population is completely sustained by natural reproduction; Class 2 indicates that is partially or mostly sustained by natural reproduction. An A2 class musky lake offers the most consistent Musky fishing, but may have very few large trophy fish.

To make better sense of the data currently available, it will be looked at in three sections, game fish (walleye, bass, muskellunge), pan fish (crappie and bluegill), and baitfish (white sucker and common shiner).

Game Fish	**Panfish**
 **Walleye**	 **Yellow Perch**
 **Muskellunge**	 **Bluegill (Sunfish)**
 **Largemouth Bass**	 **Black Crappie**

Photos by Virgil Beck

Figure 15

4.6.1 Game Fish

The most recent study done on Amnicon was in 1999, when there was a Wisconsin treaty lake walleye population count performed. This count differs in technique from when the Wisconsin DNR performs population count. The WDNR uses fyke nets to catch and mark fish followed with shocking to recapture. The company that performs the treaty assessment uses shocking for capture and recapture. To have the most accurate numbers, it is advisable to acquire a copy of the WDNR's records upon completion to have a greater detailed picture of the fish quantity in Amnicon. The walleye count at that time was found to be 4.3 adult walleye per acre. This is above the Wisconsin state average of 3.7 adult walleye per acre and well above the 3.0 fish per acre management goal. The DNR will be performing a population study in the spring of 2006 in Amnicon. At this time the population seems to be steady. The musky population is also steady on the lake. The population of largemouth bass is growing which is expected in a mesotrophic lake.

Amnicon Game Fish	1999	1997	1992
Walleye	17.84		3.91
Muskellunge	1.97	3.51	3.62
Largemouth Bass	0.55	0.74	0.88

Table 4

The game fish present in Dowling are muskellunge, walleye, and largemouth bass. The 2003 walleye per hour was 5.68 versus 37.61 in 1991. The most recent walleye population count was in 1991. However, the 1991 figure is skewed high because it was performed during spawning and specifically targeting walleye. The walleye population at the time was found to be 7.24 adult fish per acre. The state average is 3.7 adult fish per acre and the management goal is to maintain populations above 3.0 adult. The muskellunge population is thought to be high given that Dowling is classified as a high density musky lake. The report from the WDNR by Cordell Manz says that the 5.68 fish per hour supports that Dowling has a large population of musky. 1977 was the last time that Dowling had a musky population count. It was found that the estimated musky population was 1.8 fish per acre with the state average at the current time .42 fish per acre. Largemouth bass appear to be increasing in numbers over the years but the lake has not had an assessment to ascertain their actual numbers.

Dowling Game Fish	1991	2003
Walleye	37.61/hr	5.68/hr
Muskellunge	0.85/hr	6.82/hr
Largemouth Bass	1.71/hr	21.59/hr

Table 5

The fish populations in Amnicon seem to be holding steady to slightly increasing. The walleye and musky catch per unit effort (CPUE) in 1999 may be deceptive since walleye was the targeted fish and the nets were placed in walleye spawning areas. This may also have effected the largemouth bass count. Looking at the 1997 count in comparison shows that the population is more likely holding steady. The pan fish populations seem to be holding steady to slightly increasing. This seems to indicate that overall, Amnicon has a healthy steady fishery that should continue current management practices. The 2006 count should be anticipated to get the most accurate and current information.

The most recent fish study in Dowling was from the fall of 2003. Most all populations seem to be healthy and thriving save for the walleye which decreased sharply. It was noted by the WDNR surveyors' that the number of walleye that was sampled may have been affected by the water condition, or the timing. In a 2004 report by Cordell Manz, from the Wisconsin DNR noted, "Despite low catch rates for walleye in 2004 it is recommended that Dowling Lake continue to be managed for walleye, musky, and pan fish species." With the history the lake has had for natural reproduction, and knowing that lakes with natural reproducing populations have higher populations than lakes that continually stock and struggle with natural reproduction, an assumption can be made that the walleye population is not as low the sample would indicate.

4.6.2 Pan fish

Amnicon is not known as a pan fish lake, though it has adequate population. Crappies, bluegill, and perch are commonly found, though few are of adequate size to harvest. Crappies provide more of an opportunity than the bluegill or perch though both population have a higher average size than Dowling. Amnicon's catch per effort/ catch per hour is said to be lower than most lakes in the area as far as pan fish are concerned

Amnicon Panfish	1999	1992
Black Crappie	9.81	4.85
Bluegill	10.77	11.56
Yellow Perch	35.19	27.44

Table 6

Dowling is not considered a lake with a high density of pan fish. While the numbers in fish per hour greatly increased over the 1991 survey, the numbers were still below regional averages for the numbers being caught and do not seem to have size that is desirable for harvest. The black crappie population has also increased and has a slightly better size than the bluegills making them better for harvest, but still not in abundant numbers. There is also a growing population of yellow perch, but again not in a size that would be desirable to harvest.

Dowling Panfish	1991	2003
Black Crappie	6.00/hr	31.03/hr
Bluegill	66.00/hr	100/hr
Yellow Perch	3.42/hr	13.64/hr

Table 7

4.6.3 Bait Fish

The bait fish population in Amnicon Lake seems to be holding steady when looking at the white sucker population. The white sucker fish per hour total in 1992 was 5.68, but in the spring of 1999 was 6.71. This indicates there may have been a slight increase in the population, but could also be holding steady with fish slightly more active in the 1999. The common shiner population never was seen significantly high, however fyke netting is not an accurate method for documenting the bait fish population due to the smaller size of most bait fish.

The bait fish population is also increasing in Dowling judging by the comparison of the recent survey compared a much older survey with a similar method. The white sucker fish per hour total in 1977 was 0.44, but in the fall of 2003 was more than eight fish per hour. In 1977 the common shiner was seen in the shocking at a rate of 0.44 fish per hour and in 2003 was found at the rate of 3.45 fish per hour. Seine netting is the best method to count bait fish, but there was insufficient historical data to make a good comparison.

Amnicon Bait Fish	1999	1992
White Sucker	6.71	5.68
Common Shiner	0.16	0.62

Table 8

Dowling Bait Fish	1977	2003
White Sucker	0.44/hr	8.62/hr
Common Shiner	0.44/hr	3.45/hr

Table 9

5. Loading Reduction Feasibility Analysis

Both Amnicon and Dowling Lakes are generally located in the Northern Lakes and Forests Ecoregion (see Appendix____), which in general consists of sandy glacial outwash deposits. Based on additional research of ecoregions and considering that the soils in the area are generally silt and clay, not sand, we used the "Laurentian Mixed Forest Province" instead of the Northern Lakes and Forests in our models. The main difference between the two is the estimated total phosphorus (TP) inflow. The TP inflow for Northern Lakes and Forests Ecoregion is 28 ug/L and for Laurentian Mixed Forest Province Ecoregion the estimated inflow if 83 ug/L. As stated previously, both lakes are currently classified as eutrophic (although Amnicon has higher water quality than Dowling).

Based on WLMS models, Minnesota Lake Eutrophication Analysis Procedure (MnLEAP) and ecoregion values for the area, the predicted and observed TP values for Amnicon are 28 and 20 respectively. The predicted and observed TP values for Dowling are 33 and 39 respectively (See Appendix ____). The observed Chlorophyll a and Secchi depth are slightly worse than predicted in Amnicon and much worse than predicted in Dowling.

To determine how the response in water quality (TP, Chlorophyll a and Secchi Depth) varies with respect to changes in loading, we utilized WiLMS to simulate water quality conditions if TP loading was reduced and then what would happen if TP loading was increased. Each of the three water quality indices (TP, Chlorophyll a and Secchi Depth) were correlated to the Wisconsin Trophic State Index (TSI). A Wisconsin TSI of under 50 was considered mesotrophic and 50 and over was considered eutrophic.

5.1 Amnicon

We considered three TP loading scenarios for Amnicon. In the first scenario we removed the surface runoff for the residents around the lake (medium density urban) and the rural part of the watershed (rural) (Scenario 1). In the second scenario we removed all septic tank loading of TP in addition to removing MD Urban and Rural loading (Scenario 2). In the third scenario we increased the total TP loading by 25% (Scenario 3). The table below summarizes the expected Wisconsin TSI's for TP, Chlorophyll a and Secchi Depth for all three scenarios:

Scenario	TSI-TP	TSI-Chlorophyll a	TSI-Secchi Depth
1	50	50	52
2	49	49	50
3	53	52	52

Table 10

As shown above in Scenario 2, by reducing all TP from human activity (surface runoff from medium density urban and rural and septic tanks), mesotrophic status can be attained. This is theoretically the maximum that can be accomplished by Best Management Practices (BMP's).

5.2 Dowling

We considered four TP loading scenarios for Dowling. In the first scenario we eliminated the surface runoff TP from medium density urban and rural residents (Scenario 1). Secondly we removed all septic tanks loading of TP in addition to removing MD urban and rural loading (Scenario 2). Thirdly we reduced the total external TP loading by 50% (Scenario 3). Finally we increased the total TP loading by 25% (Scenario 4). The table below summarizes the expected Wisconsin TSI's for TP, Chlorophyll a and Secchi Depth for all four scenarios:

Scenario	TSI-TP	TSI-Chlorophyll a	TSI-Secchi Depth
1	54	53	55
2	53	52	54
3	50	50	52
4	57	55	57

Table 11

As shown above, even by reducing all TP loading by 50% in Scenario 3, Dowling lake is still only on the border of becoming Mesotrophic. This modeling indicates that employing BMP's alone would not be enough to bring Dowling Lake to Mesotrophic status.

As discussed in Section 3.3.3, significant internal loading is suspected in Dowling Lake. Based on WiLMS Modeling, we estimate 65 kg of the total phosphorus load of 155.4 kg (or 42%) comes from internal loading. If the external phosphorus loading to Dowling is reduced (as discussed above), phosphorus release from the sediment could have a larger effect on phosphorus concentration. If external phosphorus loading was reduced, phosphorus release from sediments would not be expected to decrease immediately. Therefore, the internal loading would be higher (relative to external loading) for several years and may result in higher in-lake phosphorus concentrations then expected given the lower external phosphorus loading.

6. Feasibility Studies

As summarized in the above section, reducing or eliminating all phosphorus loading from human activity (septic tank loading, surface water runoff from lawns and impervious surfaces) would definitely increase water quality in both lakes. Per scenario 2 for Amnicon Lake, this could theoretically bring Amnicon to Mesotrophic Status. However, eliminating all phosphorus loading due to human activity in Dowling would still leave the lake eutrophic (scenario 2). In fact reducing all external loading to Dowling by 50% would still leave Dowling classified as eutrophic (scenario 3). In addition, based on the modeling performed, we estimate 42% of the loading in Dowling is from internal loading.

Therefore, it is logical that since limiting external loading to Dowling would not greatly change the water quality, we should evaluate in-lake solutions. Three possible restoration solutions were considered; Biomanipulation, Dredging and Alum Addition. Biomanipulation is adjusting the fish species composition in a lake as a restoration technique. After reviewing the fishery data and discussing both lakes with the DNR fish biologists, at this time biomanipulation does not make sense. Specifically, according to Cordell Manz, the pan fish population is relatively low in both lakes and the game fish population, especially bass is increasing. Since the typical biomanipulation strategy is to increase the predators and decrease the pan fish, biomanipulation probably would not work. At this time the DNR would not recommend adjusting the fish population in either lake. However, a comprehensive fish survey is scheduled for 2006 in Amnicon Lake. Once this work is completed, we recommend reviewing the data and reevaluate whether biomanipulation makes sense. Below is a discussion of the other two possible restoration solutions.

6.1 Dredging

Dredging is used to remove sediments, vegetation and debris from a water body. Dredging may be a solution to many problems a water body has, but may also have high costs, both monetary and biological. It is important to define the main reason for a dredging project when determining the feasibility of a project. The assumption made in this report is that the main reason to consider dredging is to develop defined channels for lake property owners to have lake access from their shoreline, but also as a possible means of improving the water quality.

Dredging can improve the ability to navigate waterways, provide deeper channels for fish in winter, and remove nutrients and plant life from the body of water. Removing sediments that are rich in nutrients may help reduce the amount of macrophyte vegetation and algae. Deeper water may also affect dissolved oxygen and water temperature positively. This is due to creating a larger epilimion layer at the beginning of winter, reducing the chance that the lake may become anoxic and causing winter fish kills. Approximately 42% of the loading to Dowling Lake is from internal loading. Based on our research, if 50% of the total loading is due to internal loading from sediments, there may be some benefit in dredging (assuming the underlying sediments are lower in phosphorus concentrations). If internal loading is less than 50% of the nutrient budget, dredging may be of limited value.

Dredging may not be a permanent solution for the lake access problem, and will most likely not be a long term solution for plant growth and available nutrients which contribute to the plant growth. Erosion from the surrounding area needs to be further examined to determine the rate of sedimentation to the lake because having to repeatedly dredge would not be cost effective. This is especially true since both lakes are considered drainage lakes.

Disturbing the thriving Macrophyte vegetation would allow invasive plants to more readily establish themselves along with increasing the amount of available phosphorous that contributes to algae blooms. In 1993, Dan Ryan from the Wisconsin DNR stated, "Disturbance of the Macrophyte stands should be kept to an absolute minimum." This is still true given the high amount of phosphorus in the water and in the sediment. Sediment samples were collected in Amnicon and Dowling lakes in 2003. Five sediment samples from each lake were analyzed for lead, mercury and oil and grease. (See Appendix ____) Based on the results, the oil and grease levels are fairly high (ranged from 4,000 to 6,000 ppm). This oil and grease could be due to historic outboard motor use, runoff from roads or possibly other sources. This oil and grease level should be considered when contemplating dredging. High levels of lead, mercury and petroleum may affect the cost of removal and disposal of the dredged sediments and could be cost prohibitive. The approximate cost to remove the bottom 1 foot of Dowling would be $1.5 million and to remove 3 feet from Dowling would be $4.5 million. This is using a rate of $6/cubic yard, which is at the low end of the price range.

Amnicon and Dowling Lakes are designated by the Wisconsin DNR as a Priority navigable waterway, and as an Area of Special Natural Resource Interest (ASNRI). Both Lakes are an ANSRI because of the naturally reproducing Muskellunge and Walleye, and Amnicon also has natural areas of Wild Rice. Dredging could endanger these areas of special interest. An Exemption would have to be applied for because of the ANSRI designation. A WDNR permit as well as approval by the Corps of Engineers would also be required prior to dredging being allowed.

Given the nature of the fishery, the current type of vegetation and the danger of exotic plant species such as, Purple Loosestrife and Eurasian Water Milfoil, several additional factors need to be examined before dredging can be recommended. The factors include but are not limited to the likelihood that the WDNR permits would be issued for dredging, a study to determine the yearly sediment loading into the lakes and a study to investigate the nutrient and pollutant make up of the sediments to be dredged.

6.2 Alum Addition

The addition of Alum or Aluminum Sulfate can significantly reduce the total phosphorus level in a lake. Without getting into a discussion of the technical details of the chemical interactions that reduce the phosphorus level, suffice it to say Alum ties up or reduces available phosphorus in the sediments into the water column. There are several things to consider before recommending Alum addition. The type of phosphorus present in the sediments is more important then the density of the sediments. For instance, calcium-bound phosphorus is more inert than iron or Aluminum bond phosphorus. Therefore, iron-bound or Aluminum-bound phosphorus is more likely to be exchangeable than calcium-bound phosphorus. Amnicon and Dowling Lakes are fairly soft lakes (lots of calcium and magnesium in the water). Prior to adding Alum, the water and sediments should be tested to determine the exchangeable phosphorus in the sediments and the hardness, buffering capacity, alkalinity and ph of the water.

Before considering dredging or alum addition, the sediment should also be analyzed at the surface and at depth to determine the pre-settlement (approximately 150 years ago) phosphorus conditions of the water column. This could be accomplished by collecting and analyzing sediment cores, specifically looking at the diatom community, which would give you the phosphorus concentrations in the water column at that time. It should also be possible to determine the accumulation rate in the lake(s), specifically the sedimentation rate and the soil erosion rate. Once this is completed, the pre-settlement conditions will be known, so we will know how good we can expect the lake(s) to get.

If it appears Alum addition would be effective after testing is completed, it could be done say once every five years, or perhaps the dosing could be increased to three times in five years. This could all be determined through a feasibility study. Regarding cost, a general rule of thumb for alum treatment is $1000 per lake acre. So for Dowling Lake, the approximate cost would be $154,000.

7. Lake Project Ideas for Protecting Both Lakes

The work performed for this project has given us a snapshot of lake conditions in 2003 and 2004. Compared to the last 25 years, Amnicon has remained stable, barely mesotrophic to eutrophic. Dowling has gotten progressively worse over the same time period, remaining eutrophic. The stage of eutrophication of both lakes is at a level where the possibility exists for significant water quality problems in the future. Phosphorus is a critical nutrient in the eutophication of the lakes and all available measures should be employed to reduce or eliminate all controllable sources of phosphorus to both lakes. The following details how both lakes can be protected. The sections are broken up into three sections: Best Management Practices, Recommended Lake Projects and Lake Monitoring.

7.1 Best Management Practices (BMP's)

This study has shown that the main contributor of phosphorus load is from the watershed, not from human activities. However, the education of homeowners around the lake with respect to septic system and lawn maintenance and shoreline protection is crucial. This is because near shore activities are of greater significance in term of phosphorus loading due to the relatively natural undeveloped condition of the watershed. Minimizing the phosphorus loading that we can control will prevent the lakes from getting worse.

This is especially true considering the extremely high degree of development surrounding both Amnicon and Dowling Lakes. It is encouraged that land owners develop and maintain vegetative, shoreline buffer zones of 20 feet or more if possible. Buffer zones help reduce and interrupt nutrient runoff from associated yards and groundwater that would otherwise enter the lake, thus improving water quality and helping reduce the number of large algae blooms (which are common occurrences on Dowling Lake).

Buffer zones that allow the growth of trees, shrubs, and grasses also help to prevent erosion from wave and ice action that can occur, which is responsible for the destruction of important spawning and rearing habitat for fish species. Rip-rapping of shoreline areas is also discouraged unless native plants are planted along with the rip-rap, because of its similar nature to be detrimental to habitat important for spawning and rearing of fish species, through the wave action it usually generates along the shorelines. Buffer zones also enhance the appearance of the lakeshore by giving it a more natural profile. It is also recommended that home owners avoid activities such as excessive fertilization of lawns, clearing shoreline areas of aquatic plants to make "swimming beaches", dumping raked leaves or lawn clippings into the lake, high speed boating in shallow lake areas, and other similar activities. We recommend that the Lake District implement an information and education effort to advise residents of land use activities that could contribute nutrients to the lake system. Dumping leaves, ashes, animal waste, lawn clippings, excessive lawn fertilization, etc. are examples of practices that should be discouraged.

We also recommend that lake shore residents have their soil tested, so they do not use too much fertilizer. We recommend using phosphorus-free-fertilizer, the one with an "O" in the middle for the NPK (nitrogen-phosphorus-potassium) ratio.

We also recommend inspecting and repairing septic systems. Many individual septic systems are not working properly, or are improperly connected to tile lines. Maintain systems with periodic pumping and good use practices.

7.2 Recommended Lake Projects

Below are lake projects that can be completed to improve the lake quality on both lakes.

7.2.1 Shore Protection and Habitat Enhancement

In the spring of 2002 work was done to the shoreline of Amnicon on the west part of the north shore, adjacent to Tri-Lakes Road. The work was done by Ashland, Bayfield, Douglas and Iron (ABDI) County Land Conservation Department. The installation of large rock, rip-rap, fill, geotextile liner and native plants were done in an effort to reduce erosion of shoreline next to the road to protect the shoreline and increase habitat for animals. The plan for this work was designed by the USDA, Natural Resources Conservation Service (NRCS). This project accomplished two goals, reducing sediment loading into the lake and protecting walleye spawning area. Essentially the north shore from the Campground to Finn Point on the east is the preferred walleye spawning area on Amnicon Lake. See Appendix ___ for a map showing the preferred walleye spawning areas on Amnicon Lake.

We recommend a similar project as the above project for areas within the rest of the walleye spawning area on Amnicon Lake. In addition, in this same area we recommend that lakeshore owners "disconnect impervious surfaces", either driveways, manicured lawns, or roads, to the lake. This can be accomplished be redirecting stormwater to vegetated areas or possibly installing impervious "green" driveways.

Another project we recommend is to develop a prevention and control strategy for alien species near both lakes. For instance, purple loosestrife was noted along Dowling. There would be a benefit to removing or controlling this plant, in order to allow native species to again take hold and flourish.

7.3 Lake Monitoring

Both Amnicon and Dowling Lakes are high quality resources with excellent fisheries. There is some indication that any significant increase in the trophic level of both lakes may be manifested in the critical decrease of fisheries habitat in late winter. Specifically, low dissolved oxygen levels can reduce suitable living space to a few feet in the epilimnion during late winter. Therefore, we recommend dissolved oxygen testing in December, January, February and March to check for the possibility of winterkill. Dissolved oxygen conditions should be correlated with ice-on days and snow cover.

In addition, it is important to monitor both lakes during the growing season (May-September) to check the conditions of the lake. Dissolved oxygen and temperature profiles should be collected at the "deep hole" of both lakes at least once a month during the growing season. Secchi disk readings should also be taken at the same time.

The Self-Help Monitoring Program through the Wisconsin Lakes Partnership of the WDNR was utilized in Dowling Lake in 2001 and 2002. No monitoring records from the program were found for Amnicon at least back to 1995. In our opinion, the lake monitoring efforts need to be reenergized, so if the lake conditions are noticeably improving due to BMP's or lake projects, this can be observed. Similarly if the condition of the lakes is noticeably changing, the WDNR will be notified, so restorative measures may be taken.