There is a steady release of phosphorus from the sediments from May 12, 2000 through September 5, 2000, a period of 116 days. The release rate is 507,685,000 µg P/day as shown by the slope of the line in Figure 25. We estimate that during the summer anoxic period in Lake Pleasant (~116 days), at least 5.89×10^{10} µg of P are released from the sediments to the water column. This is a conservative estimate based on the possibility of several days of phosphorus release unaccounted for at the beginning and end of the summer anoxic period as a result of sampling interval.

Table 22. Bathymetric summary of Lake Pleasant (Ostrofsky, personal communication)

Depth Interval (m)	Volume (m^3)	% of Total Volume
0.0 – 0.5	119,608	7.5
0.5 – 1.5	230,615	14.53
1.5 – 2.5	218,331	13.75
2.5 – 3.5	205,801	13.0
3.5 – 4.5	191,296	12.05
4.5 – 5.5*	172,714	10.9
5.5 – 6.5*	149,214	9.4
6.5 – 7.5*	117,932	7.4
7.5 – 8.5*	77,959	4.9
8.5 – 9.5*	47,607	3.0
9.5 – 10.5*	30,919	1.95
10.5 – 11.5*	16,461	1.04
11.5 – 12.5*	7,124	0.45
12.5 – 13.5*	2,122	0.13
TOTAL	1,587,703	100.00

* denotes layers of hypolimnion based on summer temperature data

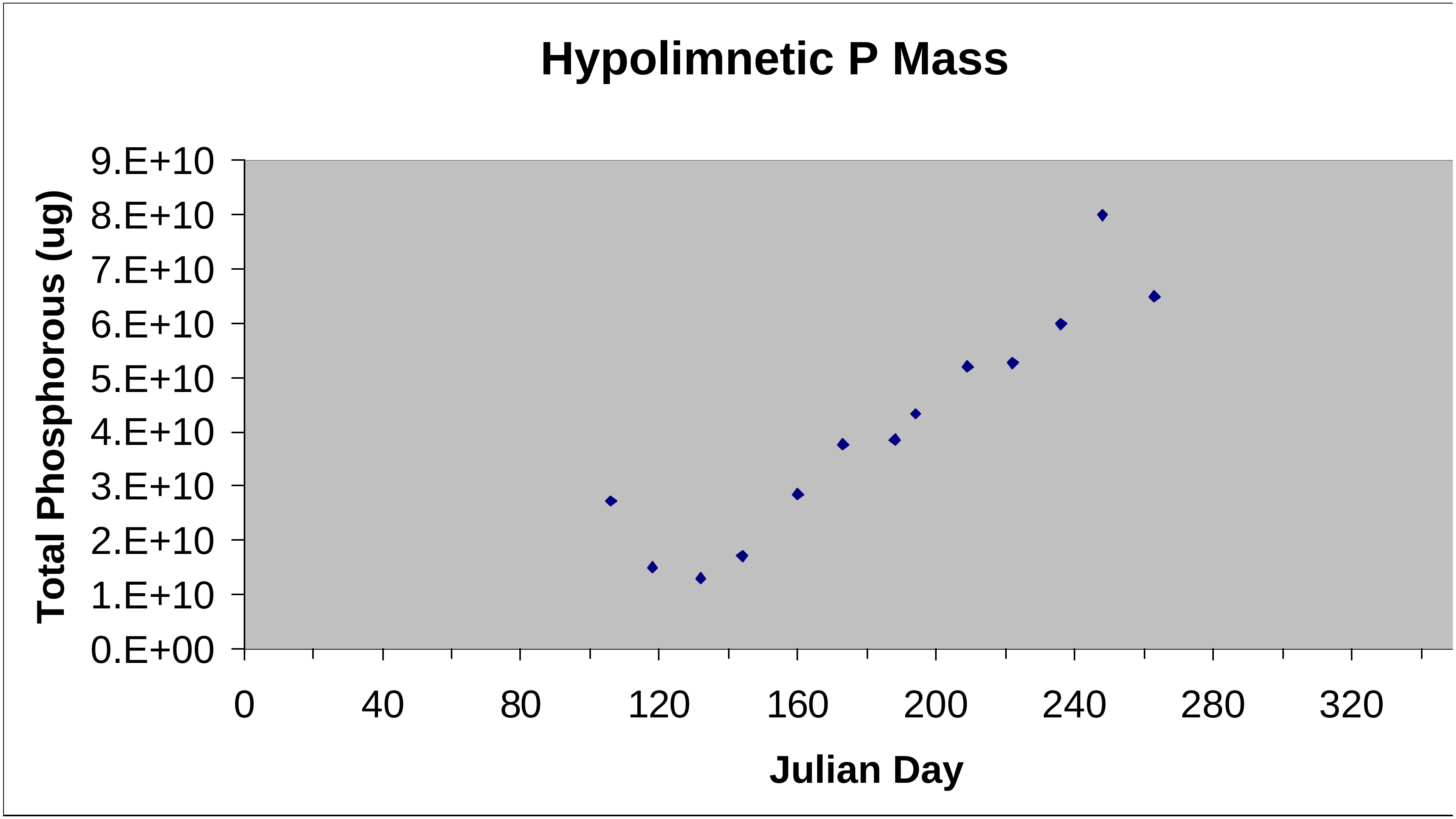

Figure 25. Total summer phosphorus mass in the hypolimnion of Lake Pleasant as a function of time (Ostrofsky, n.d.)

7.2.5 Other Sources

Several other possible sources of phosphorus inputs to Lake Pleasant have been identified. These include leaching of untreated human sewage from septic systems located too close to the lake, direct run off from the east side of the lake where no riparian buffer or wetlands exist to filter pollutants, and excrement from waterfowl. Areas of the lake have been identified as receiving untreated human sewage from septic systems that are located too close to the lake to provide adequate filtration. These areas are conspicuous each summer due to dense algae blooms and duckweed growth. Waterfowl are probably not a significant contributor of phosphorus to the lake. The lack of mowed lawns to the water's edge seems to reduce the number of waterfowl, particularly Canada geese that use Lake Pleasant as compared to other area lakes. Finally, while impacts from run off are obvious along the eastern lakeshore, attempts to measure phosphorus inputs in direct runoff were not included in this study. It would not be difficult to estimate P loading from run off as a product of the area draining directly into the lake and the amount of precipitation falling on that area during the budget year. This problem would be restricted to the eastern lakeshore as the remainder of Lake Pleasant's shoreline is protected by adequate riparian buffers and wetlands.

7.3 Phosphorus Outflows

7.3.1 Surface Outflow

Lake Pleasant Outlet drains the lake into the receiving French Creek watershed. Phosphorus that enters the lake leaves either by way of the Outlet or through sedimentation that occurs as a result of inorganic material settling with phosphorus bound to it, death of organisms that have utilized the phosphorus or by precipitation through chemical reaction with $CaCO_3$. In comparison to surface outflow, very little phosphorus is expected to be lost through groundwater seepage (Wetzel 2001). This is especially true in Lake Pleasant where the clay layer associated with the ancestral glacial lakebed acts as a barrier to groundwater outflow to the south.

The average discharge rate for the Lake Pleasant Outlet is estimated to be 2 cfs or an annual discharge of 1.78×10^9 L (approximately equal to groundwater input to the lake). We estimate total P lost from the lake by way of the Outlet to be 2.4185×10^{11} μg P.

7.3.2 Sedimentation

Total phosphorus inputs to a lake must equal total phosphorus outflows. Phosphorus leaves a lake either by way of a direct surface outflow (Lake Pleasant Outlet) or by sedimentation to the lake bottom. This process causes phosphorus to become inactivated through binding to sediments, deposited in the sediments as part of dead organisms or by precipitation as a result of contact with $CaCO_3$. Sedimentation is calculated by determining the total phosphorus entering a lake from all inputs and subtracting the total phosphorus leaving the lake by way of the Outlet. The difference is the amount of phosphorus trapped in the sediments. It is assumed that very little, if any, phosphorus leaves the lake by way of groundwater seepage.

We estimate total sedimentation of P during the budget year to equal 4.565×10^{10} µg P.

7.4 Phosphorus Budget

A summary of the phosphorus budget for Lake Pleasant for the period November 4, 2001 to November 5, 2002 is given in Table 23. Internal loading data was collected April 16, 2000 to September 20, 2000. The P load components only of the P budget are shown in Figure 26.

Table 23. Summary phosphorus budget for Lake Pleasant

Source	Mass of P (mg)	% of Total
Groundwater	2.030×10^{11}	65.0
Sediment Release	5.889×10^{10}	18.9
Precipitation	1.495×10^{10}	4.8
Streams	1.183×10^{10}	3.8
Dry Deposition	2.342×10^{10}	7.5
Total P Load	**3.121×10^{11}**	**100.0**
Outlet	2.419×10^{11}	77.5
Sedimentation	7.019×10^{10}	22.5
Total P Loss	**3.121×10^{11}**	**100.0**

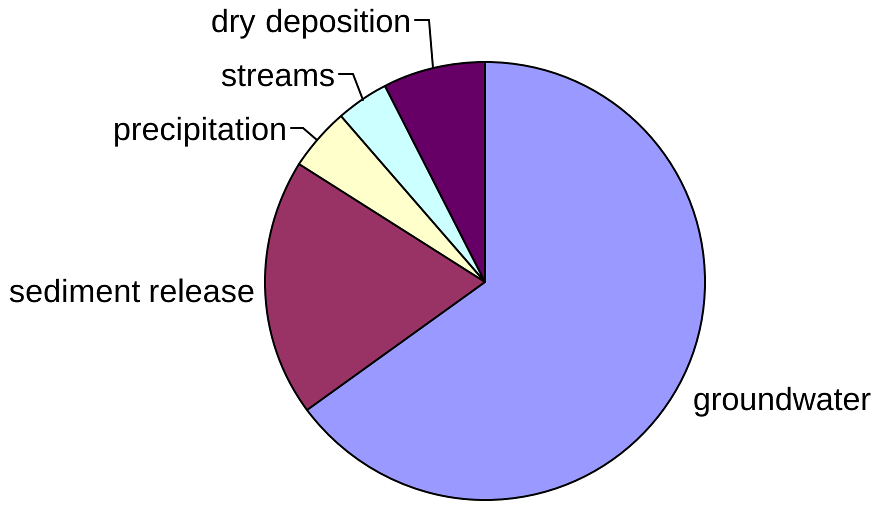

Figure 26. Summary of phosphorus sources to Lake Pleasant

8. TROPHIC STATE ANALYSIS

Trophic state is an absolute scale that describes the biological condition of a water body in terms of the total weight of living biological material (biomass) in a water body at a specific location and time. The trophic state is understood to be the biological response to forcing factors such as nutrient additions, but the effects of nutrients can be modified by factors such as season, grazing, mixing depth, etc. (Carlson and Simpson, 1996).

The Carlson Trophic State Index (TSI) is a tool that was developed to characterize trophic conditions and is based on the statistical relationship between phosphorus loading and concentration, chlorophyll a, and transparency measured by Secchi disk. Interpretation of calculated TSI values is presented in Table 24.

Table 24. Carlson's Trophic State Index (Harper 1992)

TSI	Secchi disc depth (m)	Total Phosphorus (µg/L)	Chlorophyll (µg/L)
0	64	0.75	0.04
10	32	1.5	0.12
20	16	3	0.34
30	8	6	0.94
40	4	12	2.6
50	2	24	6.4
60	1	48	20
70	0.5	96	56
80	0.25	192	154
90	0.12	384	427
100	0.06	768	1183

Oligotrophy refers to a state of low productivity and low nutrients. Mesotrophic conditions are characterized by moderate amounts of nutrients and productivity. Eutrophic refers to a state of increased nutrients and increased photosynthetic productivity. TSI values are interpreted within ranges of trophic state: <20, ultra-oligotrophic conditions; values of 30-40, oligotrophic conditions; 45-50, mesotrophic conditions; 53-60, eutrophic conditions; and >70, hyper-eutrophic conditions (Harper, 1992). TSI values are based on a logarithmic relationship: every increment of 10 on the TSI scale is representative of a 100-fold increase in algal biomass.

8.1 Methods for Trophic State Calculation

Based on historical data from other lakes, it is suggested that an index calculated from phosphorus values in the winter and spring and from chlorophyll or transparency during the growing season would be most accurate (Harper, 1992). Total phosphorus in the spring, summer chlorophyll a, and summer Secchi disk visibility were used to estimate the trophic state of Lake Pleasant for 2001- 2002.

8.1.1 Total Spring Phosphorus

Total phosphorus values were collected during the period of spring turnover (3/27/02, 4/1/02, and 4/10/02), as determined by isothermal temperature profiles, from the sampling location, center, using the same methods described in section 4.2.1 (Table 25).

Table 25. Total phosphorus concentrations in Lake Pleasant during spring turnover

Depth (m)	Total Phosphorus (mg/L)		
	3/27/02	4/1/02	4/10/02
0.5	130	<30	30
1.5	30	140	70
2.5	<30	70	160
3.5	60	<30	280
4.5	30	160	180
5.5	30	80	60
6.5	50	120	310
7.5	30	30	230
8.5	50	140	60
9.5	40	60	270
10.5	40	80	60
11.5	60	180	150
12.5	50	<30	300

These values were averaged and used in the following calculation:

$$TSI = ((14.42)\ (\ln \text{Total phosphorus } (\mu g/L)) + 4.15$$

where: TSI = Carlson trophic state index
ln = natural logarithm

8.1.2 Chlorophyll a

Chlorophyll a samples were collected from the center of the lake by Dr. Milt Ostrofsky in summer 2000 (Ostrofsky, personal communication). An integrated sample was taken from the photic zone (depth at which the illumination level is 1% of surface illumination) and is representative of the average concentration of healthy phytoplankton. Photic zone depth can be estimated as two times the Secchi disk depth. (EPA 1997b). The average chlorophyll a value during summer 2000 was 6.6 μg/L.

The chlorophyll a results were used to determine the TSI for the summer months.

TSI = (9.81) (ln Chlorophyll a (μg/L)) + 30.6

where:

TSI = Carlson trophic state index
ln = natural logarithm

8.1.3 Secchi disk

A Secchi disk is a 20cm diameter black and white disk that is used to determine water clarity. The disk, attached to non-stretchable rope marked with pre-measured increments, was lowered into the water and the depth at which it was no longer seen was noted. The disk was raised until it became visible again – the Secchi disk depth was recorded as a value midway between these two points (EPA 1990a). Secchi disk depth is a measure of transparency based on the amount of inorganic suspended solids and algae present. The mean summer secchi disk depth during July-August, 2002 was 2.9m.

Summer secchi disk readings were used to calculate CSI values for Lake Pleasant with the following equation:

TSI = 60 – (14.41(ln Secchi disk (meters))

where: TSI = Carlson trophic state index
ln = natural logarithm

8.2 Trophic Index Results

An index value of 71 was generated using total phosphorus as an indicator (Table 26). Secchi disk and chlorophyll a derived values generated a TSI value of 45 and 49, respectively.

The Secchi disk and chlorophyll a values agree with Wellington's trophic state estimation calculated from data collected on August 28, 1991 (Wellington, 1991). Wellington's TSI value of 49.6, characterized the lake as mesotrophic-borderline eutrophic. The phosphorus-derived estimate of 71 appears to disagree with the others.

Table 26. Calculation of the Trophic State Index (TSI) for Lake Pleasant, 2002

Parameter	Measured Value	Calculation	TSI
Total spring phosphorus	100 µg/L	TSI = (14.42(ln 100)) + 4.15	71
Secchi disk	2.9 m	TSI = 60 – (14.41(ln 2.9))	45
Chlorophyll a	6.6 µg/L	TSI = (9.81(ln 6.6)) + 30.6	49

Chlorophyll a and Secchi disk measurements usually agree in lake assessments (Carlson, 1977). Chlorophyll a derived TSI values are the most free from suppositions. The number derived from chlorophyll a is best for estimating algal biomass and should be given priority in the event that the three derived values don't agree (Carlson, 1977). Phosphorus TSI's depend on the assumptions that phosphorus is the limiting nutrient, and that all forms of phosphorus present effect the algal biomass. Even with the inferences, the phosphorus derived TSI is relatively stable seasonally, and can give a more accurate predictor of maximal eutrophic conditions when algal biomass is unusually low. Given this, the chlorophyll a estimation classifies Lake Pleasant as mesotrophic-borderline eutrophic.

8.3 Evaluation of the Potential for Eutrophic Conditions

Excessive algae growth can be indicative of eutrophication and its effects (Harper 1992). Eutrophication can be a natural progression in lakes. However, it is often associated with an accelerated form of nutrient enrichment due to increased inputs to a waterbody as a result of human activities. Increases in phosphorus and nitrogen, normally limiting in aquatic systems, will result in increased production of plants, particularly algae. Algae can shift balances in the ecosystem by competition with other species for space and light and can decrease lake visibility. As algae dies off, decomposition can lower the DO and adversely affect the respiration of aquatic life.

Eutrophic conditions were documented in the lake during the summer of 1991. Fishing was reported to be uncharacteristically poor during that year and a large green algae bloom was observed in October before fall turnover (Wellington 1991).

8.3.1 Nutrient Ecoregion Assessment

The USEPA has identified several ecoregions throughout the U.S. in an attempt to provide comparative nutrient criteria for water bodies. Water quality values from one lake in an ecoregion can then be compared to a calculated reference value from other lakes, etc. in the same region. The reference value is meant to represent background values of the region. Lake Pleasant lies within Subregion 61: the Erie Drift Plains (Figure 27):

> Once largely covered by a maple-beech-birch forest, much of the Erie Drift Plain is now in farms, many associated with dairy operations. The Eastern Corn Belt Plains, which border the region on the west, are flatter, more fertile, and therefore more agricultural. The glaciated Erie Drift Plain is characterized by low rounded hills, scattered end moraines, kettles, and areas of wetlands, in contrast to the adjacent unglaciated ecoregions to the south and east that are hillier and less agricultural. Areas of urban development and industrial activity occur locally (from USEPA website).

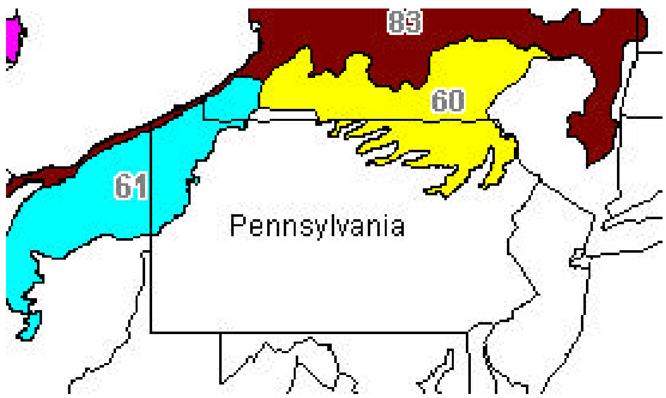

Figure 27. Map of Ecoregion VII, subregion 61, the Erie Drift Plains (from USEPA website)

Historical records spanning a decade were compiled for lakes in subregion 61. Parameters included were TKN (mg/L), NO2 + NO3 (mg/L), TN (mg/L), TP (µg/L), Secchi (m), Chlorophyll a (µg/L, by various methods). The 25th percentiles from each of the seasonal distributions (summer, spring, fall, and winter) of median values were selected. The median value from the four seasonal 25th percentiles was then calculated and recorded as the reference condition for the ecoregion (Table 27).

Lake parameters that fall above this calculated value are considered to have values that have been affected by outside inputs or that have been impaired in comparison to background values. Since the reference values are 25th percentiles and are meant to represent the waterbodies within the ecoregion, 75% of the lakes in the region (in theory) will show concentrations of parameters that exceed these criteria. One exception must be noted – the 75th percentile was used in determining the reference condition for Secchi disk depth because increased Secchi disk depth is associated with increased water clarity.

Table 27. Lake eutrophication parameters for Ecoregion VII, sub-ecoregion 61: the Erie Drift Plains (from USEPA website)

Parameter	No. of Lakes	Reported values		25th Percentiles based on all seasons data for the Decade	Reference Lakes **
	N ++	Min	Max	P25* all seasons +	P75 all seasons
TKN (mg/L)	35	0.36	1.48	0.51	
NO2 + NO3 (mg/L)	34	0.02	0.30	0.025	
TN (mg/L) - calculated	NA	0.38	1.78	0.54	
TN (mg/L) - reported	7	0.63	1.75	0.85 zz	
TP (µg/L)	42	6.25	202.50	28.25	
Secchi (meters)	16	0.31	1.75	1.52	
Chlorophyll *a* (µg/L) - F	3 z	12.73	28.49	12.73 zz	
Chlorophyll *a* (µg/L) - S	3 z	23.05	90.93	23.05	
Chlorophyll *a* (µg/L) - T	3 z	28.77	114.58	28.77	

The total phosphorus reference value of 28.25µg/L is clearly exceeded by Lake Pleasant values (see Figure 23). The mean total phosphorus value for the sampling point, center, in the lake for 230 samples taken between 11/4/01 and 9/16/02 is 126µg/L. The min is <30µg/L for 13 samples that fell below detection limits, and the max is 590µg/L.

Mean of total N from 11/4/01 (13 samples) is 1.38mg/L, also above the TN reference value but within the range of reported values for the region. Lake Pleasant min and the max were 1mg/L and 2.2mg/L respectively.

Because Lake Pleasant exceeded these reference values, it can be inferred that nutrients are present in the lake at levels greater than regional background levels.

The chlorophyll a value for Lake Pleasant was 6.6µg/L taken at the center sampling point during summer 2000 (Ostrofsky, personal communication). This value is below the reference values provided in the table above.

The Secchi disk mean is 2.5m for 37 samples taken from 11/4/01 to 11/20/02. This is greater clarity than even the maximum reported for the region. Despite exceeding the nutrient reference values, the clarity and primary productivity of Lake Pleasant appears to be less affected by these constituents than other lakes in the region.

8.3.2 Potential for Eutrophication Conditions based upon Phosphorus Inputs and Retention

As a component of Management Objective 1: Principal Study Component 1 (section 1.2.1), phosphorus levels were evaluated to determine the potential for the lake to develop eutrophic conditions. The EPA has set phosphorus limits for lake water at

25µg/L and for streams entering lakes at 50µg/L. Exceedance of these values implies that the lake is at an increased risk for the development of eutrophic conditions.

8.3.2.1 Concentrations within the lake

If >10% of the samples for P in the lake at the sampling point center, fall above 25µg/L, then the lake will be considered to be at an increased risk for eutrophication. A total of 230 samples were collected from the center point of the lake at depths ranging from the lake surface to the bottom, between 11/4/01 and 9/16/02, and were analyzed for total phosphorus.

94% of samples from the center sampling point contained >25 µg/L total phosphorus (see Figure 23). Based upon the above threshold value, the lake is considered to be at risk for the development of eutrophic conditions.

8.3.2.2 Concentrations in water entering the lake

If >10% of the samples for P at surface inflow points fall above 50µg/L, then the lake will be considered to be at an increased risk for eutrophication. A total of 20 samples were collected from the sampling locations, unt1 and unt2, between 11/4/01 and 10/02/02, and were analyzed for total phosphorus.

Sixteen of the 20 samples, or 80% contained >50 µg/L total phosphorus (see Table 21). The lake is considered to be at risk for the development of eutrophic conditions due to phosphorus inputs that exceed EPA guidelines.

9. DISCUSSION AND MANAGEMENT RECOMMENDATIONS

9.1 Hydrologic Alterations

The Lake Pleasant watershed has the special characteristic of being able to transmit most of the water falling on the watershed into ground water that moves through carbonate rich sediments to the lake and wetlands. This is the primary alkalinity source providing the buffering ability of the watershed that allows the rare, alkalinity-dependent species to thrive here. Therefore, practices that encourage the current flow rate of groundwater to the lake, at a minimum, should be maintained.

Increased development, agriculture, and gravel mining may drastically alter the hydrologic balance in the Lake Pleasant watershed. Currently, only a small fraction (less than 5 percent) of precipitation in the watershed reaches the lake via surface flow. Development that increases the percentage of impervious surfaces in the watershed may increase overland flow and decrease groundwater infiltration. Increased development may also negatively impact the quality of the water entering the lake via both surface and groundwater pathways. Increases in surface water flow to the lake will reduce the fraction of water in the lake that has traveled through the carbonate-rich glacial materials, thus decreasing the pH of the water, the mineral content, and the related benefits to the lake's ecology. Increases in agriculture may increase the evapotranspiration occurring in the watershed, which will decrease the groundwater flow and associated constituents to the lake.

In contrast to the effects of increased development and agriculture, an increase in gravel mining activities may increase the flow of groundwater to the lake. As long as the water table remains several feet below the ground surface, precipitation falling on the unvegetated gravel surface will percolate rapidly downward to the water table. Very little evaporation and no transpiration or surface runoff will occur under these circumstances. Therefore, virtually all of the precipitation reaches the groundwater and begins moving toward the lake. However, gravel mining may result in accumulation of large areas of surface water (i.e., ponds), and consequently, water will be lost from the lake's hydrologic system through evaporation. While gravel mining may encourage the flow of groundwater to the lake, it removes the beneficial carbonate-rich glacial sediments. While it does not appear that a critical point has been reached in terms of removal of this carbonate reservoir, a full analysis of the existing extent of carbonate laden glacial sediments has not been performed.

Recent gravel mining operations have resulted in several large surface impoundments (figure 28) that represent areas of the water table that have been exposed to the

Figure 28. Gravel mining operation showing surface ponds in the Lake Pleasant watershed

atmosphere. This study has shown degraded water quality in these ponds with respect to temperature, various depositional pollutants, and altered chemistry. The ponds are also at increased risk of rapid eutrophication and will serve as sources for groundwater nutrients, heavy metals, algae, and invasive exotic species. As stated previously, they also pose a significant threat to an altered hydrologic budget for the watershed through increased evaporation of surface water. This poses a significant threat to the lake and adjacent wetlands that depend on stable water levels. These ponds and gravel pit areas should be further restored to more ecologically viable wetlands and surrounding riparian areas with a mix of vegetation that will promote pollutant filtration and root retention of water.

Another threat to water quantity in the lake and wetlands is the practice of drawing water from the Lake Pleasant Outlet for irrigation. A large potato farming operation south of the lake relies on water from the outlet for irrigation during periods of low rainfall. These periods correspond with lowered water levels in the lake and stressed aquatic communities. Because the Outlet and associated wetlands are closely, hydrologically linked to the lake, extraction of water downstream of the lake has the ability to dramatically lower the lake level. This was observed during the summer of 2002 when drought conditions lowered the lake level and concurrent commencement of irrigation caused an additional rapid and noticeable drop in lake level (personal observation). Due to slow recharge of the lake during times of little or no surface runoff, water levels remained low through the fall of 2002. Alternative irrigation practices should be explored, including impounding water during wetter months to offset the need to draw water during summer. More protective designations for Lake Pleasant and the Outlet should be sought, including “Exception Value” to more accurately reflect the status of sensitive wetlands and rare plant species found there.

Finally, it should be pointed out that the former glacial lake bed south of the lake should be better defined in order to develop a richer understanding of the lake's hydrology. Additional gravel mining in areas south of the lake should be avoided. If the clay layer representing the former glacial lakebed is perforated, it could drastically alter the amount of groundwater flowing out of Lake Pleasant. This would have deleterious effects on the lake water levels and surrounding wetlands.

Continued monitoring of the watershed’s hydrologic budget is recommended. Long-term, seasonal monitoring is necessary to document trends in lake and groundwater levels. Established staff gages and wells can be utilized. Also, pH and alkalinity monitoring, as well as monitoring for other beneficial macronutrients like calcium, should be implemented to document any impacts to water chemistry from carbonate depletion. The east side of Lake Pleasant should be better studied hydrologically. This region was determined to contribute a relatively small percentage of the overall groundwater to the lake and was not included in this study in order to conserve funding. A thorough analysis of the remaining carbonate-rich glacial deposits should be conducted before any additional gravel mining permits are considered for the watershed. If possible, because of the potential for unknown or unforeseen impacts to hydrology, additional gravel mining should be avoided in the Lake Pleasant watershed.

9.2 Water Quality

Lake Pleasant has good water quality and appears to be less eutrophied than other lakes in the region. pH and alkalinity levels indicate there is sufficient buffering capacity for the acidic atmospheric inputs to the region. However, further gravel mining in the watershed should be avoided in order to maintain this alkalinity-producing capacity. Water temperatures and oxygen levels are sufficient to allow stocked rainbow trout to survive through the summer, although most are undoubtedly caught during the spring and winter months. Despite these conditions, several impacts and potential threats were documented during this study.

9.2.1 Heavy Metals

Arsenic, mercury, and other heavy metal concentrations were found to be relatively high in the sediments of Lake Pleasant. Some arsenic can be derived locally from natural weathering of bedrock and parent soil material. This is supported by elevated arsenic levels found in monitoring wells. However, other likely sources of arsenic include atmospheric deposition as a result of industrial emissions and coal-burning power plants to the north and west of the region. A regional effort by state, federal, and international governments, environmental agencies, and conservation organizations will be required to abate the effects of atmospheric deposition. Widespread support of Great Lakes' basin initiatives is necessary to deal with these regional issues.

Mercury levels were also found to be elevated in Lake Pleasant sediments. The likely source of mercury is atmospheric deposition. Fish tissue analysis seems to indicate that these metals do not appear to be bioaccumulating in the food web. However, more analysis should be done on a wide range of species including benthic mollusks, fish, reptiles and amphibians, mammals, and birds.

Another source of heavy metals in the Lake Pleasant watershed continues to be State Route 1001, Lake Pleasant Road that borders the lake on the east (Figure 29). Analysis by Fidorra (2003) concluded that roadside sediments adjacent to Lake Pleasant contained elevated levels of heavy metals. The research further concluded that winter application of deicing materials promoted the migration of these toxic metals to Lake Pleasant via runoff (Fidorra, 2003). These conditions are further exacerbated by the absence of shoreline vegetation. Immediate restoration of the

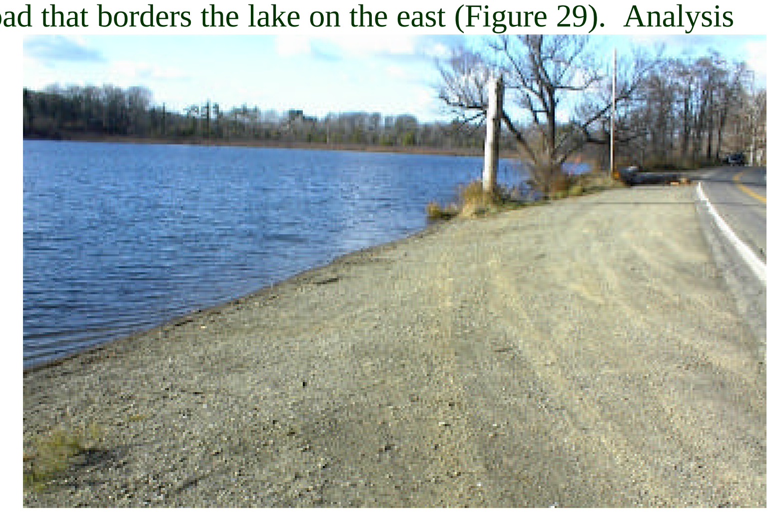

Figure 29. Degraded Lake Pleasant shoreline and State Route 1001, Lake Pleasant Road

eastern Lake Pleasant shoreline is recommended to help abate the threats of pollutants from roadway runoff. An adequate riparian buffer is needed to protect Lake Pleasant from polluted runoff and increased sedimentation. Ultimately, partners in the conservation of Lake Pleasant, including Western Pennsylvania Conservancy, PA Fish & Boat Commission, PA Department of Transportation, Venango Township, and local residents should work to reroute State Route 1001, or redirect traffic so that the section of roadway along Lake Pleasant can be removed. This will enable increased buffer restoration and can be accomplished while providing fishing and pedestrian access to the shoreline. A blueprint for this work, including cost estimates, has already been developed as part of the long-range vision of Lake Pleasant Conservation Area Master Site Plan.

Finally, malfunctioning on-lot septic systems may also contribute heavy metals to Lake Pleasant. Impacts to the lake are evident from some properties and others are probable given the proximity of several residences to the water's edge. While it is difficult to measure actual impacts, dye testing should be done on all properties to assess potential for impacts. Upgrades to septic systems, routine cleaning, and new alternative "green" systems should be employed throughout the watershed. While there are increased costs associated with these practices, many grant or subsidy programs exist to help defray costs to landowners. In addition, it is assumed that through education, many residents will support these practices due to a sense of ownership and pride in a healthy Lake Pleasant.

Lake sediments, groundwater, and surface water should continue to be monitored for heavy metals of concern. This monitoring should occur every 5-10 years unless conditions worsen and more frequent monitoring is necessary. Tissue sampling should also occur at the same frequency to document bioaccumulation of metals in the food web.

9.2.2 Nutrients

Nutrient levels appear to be relatively high in Lake Pleasant. This puts the lake at an increased risk for rapid, human-induced eutrophication if additional nutrient inputs are not controlled. Eutrophication will lead to increased primary productivity and algae growth, foul odors, nuisance and potentially unsafe conditions for boaters, swimmers, and anglers, increased oxygen debts and prolonged anoxia leading to fish kills, and impacts to Lake Pleasant's natural communities. Sources of additional nutrients include atmospheric deposition, on-lot septic systems and greywater discharges, roadway runoff, and agricultural runoff.

Impacts from deposition, septic systems, and roadway runoff can be addressed as described above. Agricultural impacts from the existing dairy farm are probably minimal in comparison due to the filtering of runoff by wetlands prior to entering the lake. The farming operation is undoubtedly the source of increased nutrient input in the spring due to the timing of fertilizer application and plowing coincident with increased stream discharge beyond the filtering capacity of riparian wetlands. Lake Pleasant would benefit from fencing of livestock from UNT 2, increases in riparian buffers to UNT 2 and the wetlands, and improved nutrient management planning and fertilizer application.