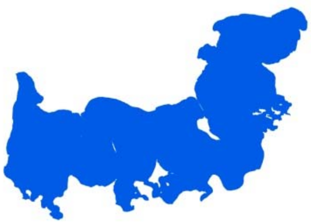
Deer Lake 31-0719-00 ITASCA COUNTY

Lake Water Quality

Summary



Deer Lake is located 10 miles north of Grand Rapids, MN in Itasca County. It is a large lake covering 4,094 acres (Table 1).

Deer Lake has some minor inlets and one outlet, which classify it as a groundwater drainage lake. Water enters Deer Lake from springs and ground-fed streams. The Deer River exits Deer Lake to the east and eventually drains into the Mississippi River.

Water quality data have been collected on Deer Lake since 1974 (Tables 2 & 3). These data show that the lake is oligotrophic (TSI = 37) with clear water conditions all summer and excellent recreational opportunities.

Deer Lake has an organized association that is involved in activities such as water quality monitoring and education.

Table 1. Deer Lake location and key physical characteristics.

Location Data	
MN Lake ID:	31-0719-00
County:	Itasca
Ecoregion:	Northern Lakes and Forests
Major Drainage Basin:	Mississippi R. – Headwaters
Latitude/Longitude:	47.375407/-93.655846
Invasive Species:	Purple Loosestrife

Physical Characteristics	
Surface area (acres):	4,094
Littoral area (acres):	900
% Littoral area:	23%
Max depth (ft), (m):	101.0, 30.8
Inlets:	2
Outlets:	1
Public Accesses:	2

Table 2. Availability of primary data types for Deer Lake.

Data Availability		
Transparency data		Good data set from multiple sites from 2001-2014.
Chemical data		Good data set from 2011-2014, but not enough for trend analysis.
Inlet/Outlet data		Good data set from the Deer Creek and Pokegama Lakes Diagnostic Study.
Recommendations		**For recommendations refer to page 22.**

Lake Map

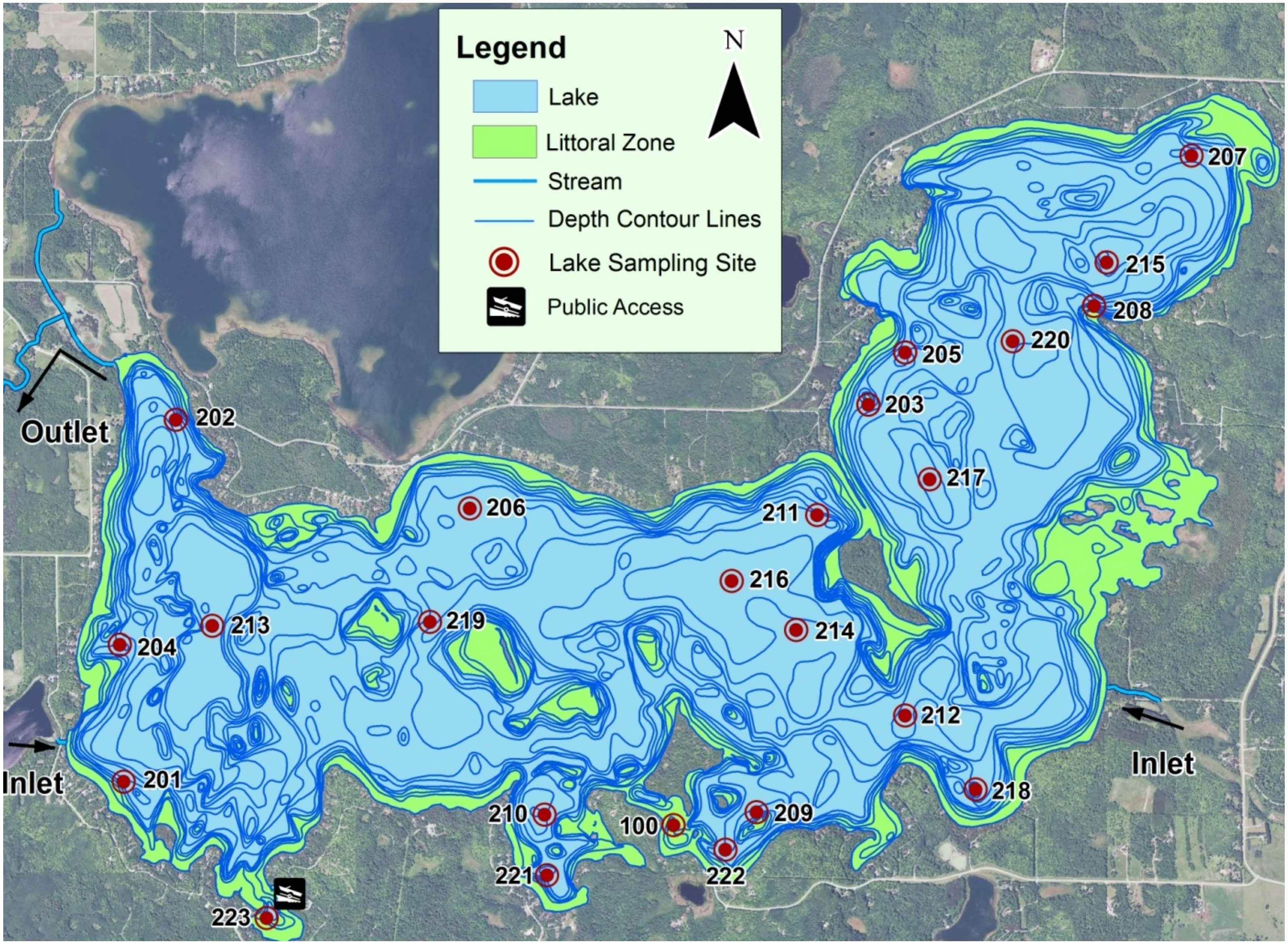


Figure 1. Map of Deer Lake with 2010 aerial imagery and illustrations of lake depth contour lines, sample site locations, inlets and outlets, and public access points. The light green areas in the lake illustrate the littoral zone, where the sunlight can usually reach the lake bottom, allowing aquatic plants to grow.

Table 3. Monitoring programs and associated monitoring sites. Monitoring programs include the Citizen Lake Monitoring Program (CLMP), A.W. Research Summer TSI (AWR), Clean Water Legacy Surface Water Monitoring (CWL), Deer Creek and Pokegama Lakes (DCPL), Itasca County Lake Assessment (ICLA), and MPCA Lake Monitoring Program Project (LMPP).

Lake Site	**Depth (ft)**	**Monitoring Programs**
100	10	ICLA: 1993,2001-2002; LMPP: 1991
201	20	CLMP: 1974,2006-2007
202	40	CLMP: 1975-1976,1991
203	20	CLMP: 1980
204	30	CLMP: 1986-1991, 1993-1994
205	20	CLMP: 1984-1990, 1992-2001
206	45	CLMP: 1989-2011
207	40	CLMP: 1992-1995,1997-1998,2000-2002,2004,2006-2010
208	40	CLMP: 1994-1995
209	30	CLMP: 2001-2013
210	45	CLMP: 2001-2013; DCPL: 2011-2013
211	75	CLMP: 2003-2013
212	80	CLMP: 2007
213*primary site	99	AWR: 2013-2014; DCPL: 2011-2013; ICLA: 1992-1993
214	75	AWR: 2013-2014; ICLA: 1992
215	100	AWR: 2013-2014; DCPL: 2011-2013; ICLA: 1992
216	85	CWL: 2013-2014; DCPL: 2011-2013
217	75	DCPL: 2011-2013
218	65	DCPL: 2011-2013
221	30	AWR: 2012-2014
222	27	AWR: 2012-2014
223	17	AWR: 2012-2014

Average Water Quality Statistics

The information below describes available chemical data for Deer Lake through 2014 (Table 4). Data for total phosphorus, chlorophyll *a*, and Secchi depth are from the primary site 213.

Minnesota is divided into 7 ecoregions based on land use, vegetation, precipitation and geology. The MPCA has developed a way to determine the "average range" of water quality expected for lakes in each ecoregion. For more information on ecoregions and expected water quality ranges, see page 12. Deer Lake is in the Northern Lakes and Forests Ecoregion.

Table 4. Water quality means compared to ecoregion ranges and impaired waters standard.

Parameter	Mean	Ecoregion Range[1]	Impaired Waters Standard[2]	Interpretation
Total phosphorus (ug/L)	9.6	14 – 27	> 30	Results are better than the expected range for the Northern Lakes and Forests Ecoregion.
[3]Chlorophyll *a* (ug/L)	1.9	4 – 10	> 9	
Chlorophyll *a* max (ug/L)	9.2	< 15		
Secchi depth (ft)	18.8	8 – 15	< 6.5	
Dissolved oxygen	*See page 9*			Dissolved oxygen depth profiles show that the lake mixes in spring and fall (dimictic).
Total Kjeldahl Nitrogen (mg/L)	0.39	<0.4 – 0.75		Indicates insufficient nitrogen to support summer nitrogen-induced algae blooms.
Alkalinity (mg/L)	120.5	40 – 140		Indicates a low sensitivity to acid rain and a good buffering capacity.
Color (Pt-Co Units)	NA	10 – 35		No data available.
pH	8.3	7.2 – 8.3		Indicates a hard water lake. Lake water pH less than 6.5 can affect fish spawning and the solubility of metals in the water.
Chloride (mg/L)	2.5	0.6 – 1.2		Slightly above the expected range for the ecoregion, but still considered low level.
Total Suspended Solids (mg/L)	1.4	<1 – 2		Indicates low suspended solids and clear water.
Conductivity (umhos/cm)	228.8	50 – 250		Within the expected range for the ecoregion.
TN:TP Ratio	34.2	25:1 - 35:1		Within the expected range for the ecoregion, and shows the lake is phosphorus limited.

[1]The ecoregion range is the 25th-75th percentile of summer means from ecoregion reference lakes
[2]For further information regarding the Impaired Waters Assessment program, refer to http://www.pca.state.mn.us/water/tmdl/index.html
[3]Chlorophyll *a* measurements have been corrected for pheophytin
Units: 1 mg/L (ppm) = 1,000 ug/L (ppb)

Water Quality Characteristics - Historical Means and Ranges

Table 5. Water quality means and ranges for primary sites.

Parameters	Primary Site 213	Site 214	Site 215
Total Phosphorus Mean (ug/L):	**9.6**	**5.9**	**9.6**
Total Phosphorus Min:	3	5	5
Total Phosphorus Max:	20	7	15
Number of Observations:	36	10	35
Chlorophyll *a* Mean (ug/L):	**2.0**	**1.7**	**2.3**
Chlorophyll-a Min:	<1	<1	<1
Chlorophyll-a Max:	9.2	4	8
Number of Observations:	24	9	24
Secchi Depth Mean (ft):	**18.8**	**20.0**	**18.8**
Secchi Depth Min:	11.6	18.0	10.7
Secchi Depth Max:	51.2	24.9	28.5
Number of Observations:	36	11	31

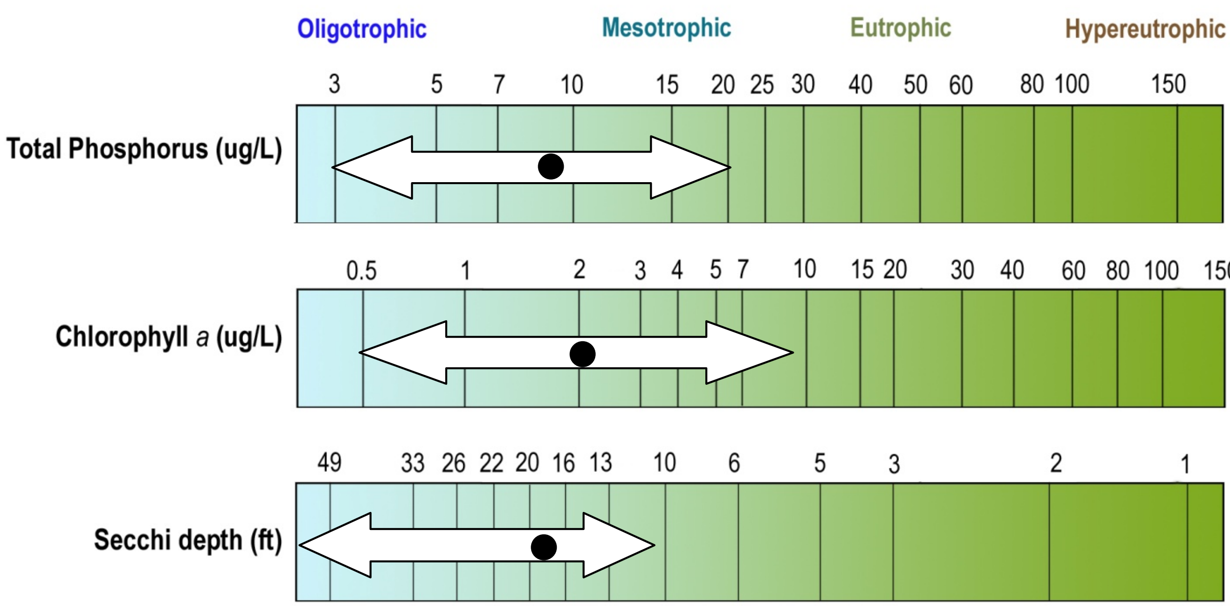


Figure 2. Deer Lake total phosphorus, chlorophyll a and transparency historical ranges. The arrow represents the range and the black dot represents the historical mean (Primary Site 213). Figure adapted after Moore and Thornton, [Ed.]. 1988. Lake and Reservoir Restoration Guidance Manual. (Doc. No. EPA 440/5-88-002)

Transparency (Secchi Depth)

Transparency is how easily light can pass through a substance. In lakes it is how deep sunlight penetrates through the water. Plants and algae need sunlight to grow, so they are only able to grow in areas of lakes where the sun penetrates. Water transparency depends on the amount of particles in the water. An increase in particulates results in a decrease in transparency. The transparency varies year to year due to changes in weather, precipitation, lake use, flooding, temperature, lake levels, etc.

The annual mean transparency in Deer Lake ranges from 12.2 to 19.3 feet (Figure 3). The annual means hover fairly close to the long-term mean. For trend analysis, see page 10. Transparency monitoring should be continued annually at site 206 in order to track water quality changes.

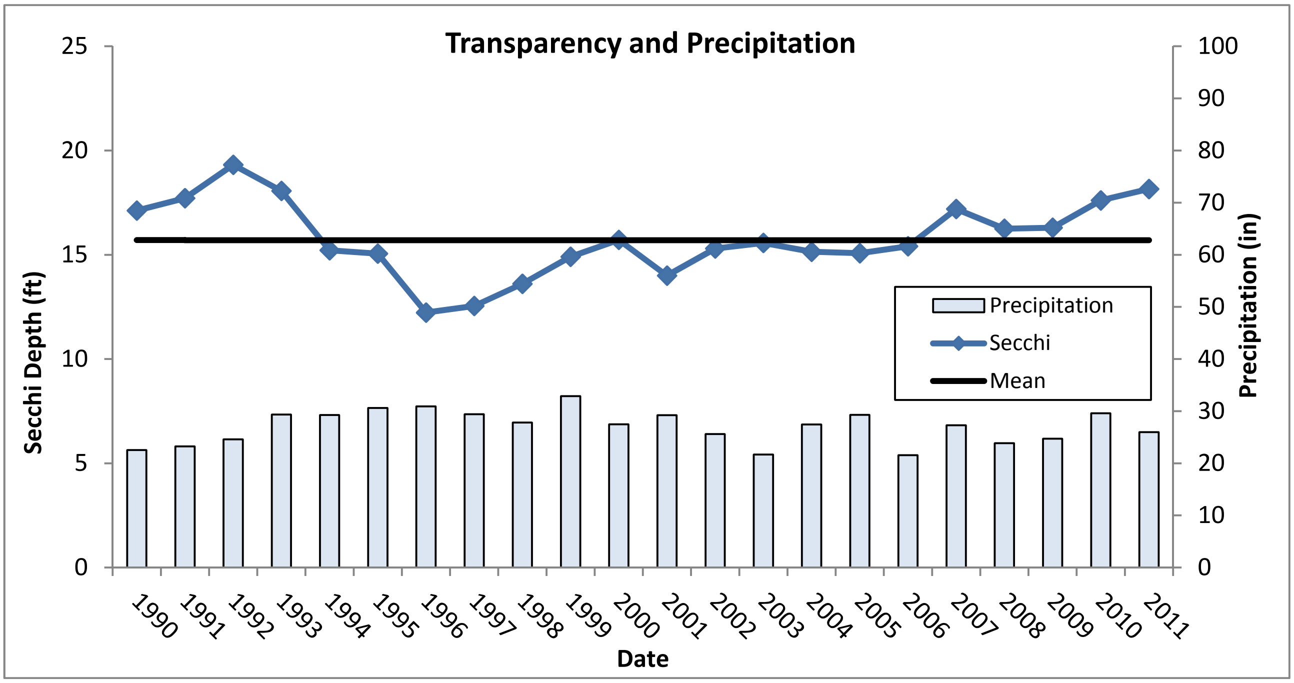


Figure 3. Annual mean transparency compared to long-term mean transparency.

Deer Lake transparency ranges from 2.9 to 14.0 ft at site 206. Figure 4 shows the seasonal transparency dynamics. The maximum Secchi reading is usually obtained in early summer. Deer Lake transparency is high in May and June, and then declines through August. The transparency then rebounds in October after fall turnover. This transparency dynamic is typical of a Minnesota lake. The dynamics have to do with algae and zooplankton population dynamics, and lake turnover.

It is important for lake residents to understand the seasonal transparency dynamics in their lake so that they are not worried about why their transparency is lower in August than it is in June. It is typical for a lake to vary in transparency throughout the summer.

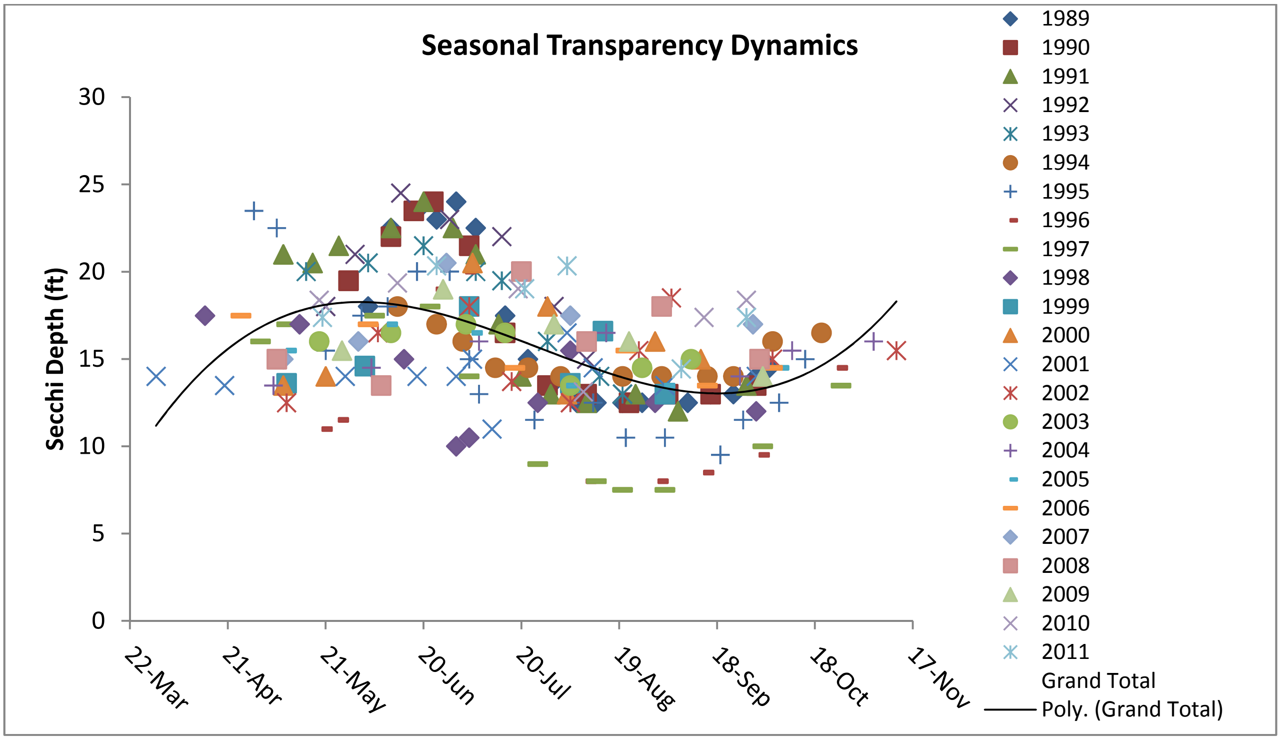


Figure 4. Seasonal transparency dynamics and year to year comparison (Site 206). The black line represents the pattern in the data.

User Perceptions

When volunteers collect Secchi depth readings, they record their perceptions of the water based on the physical appearance and the recreational suitability. These perceptions can be compared to water quality parameters to see how the lake "user" would experience the lake at that time. Looking at transparency data, as the Secchi depth decreases the perception of the lake's physical appearance rating decreases. Deer Lake was rated as being "crystal clear" 49% of the time by samplers at site 206 between 1989-2011 (Figure 5).

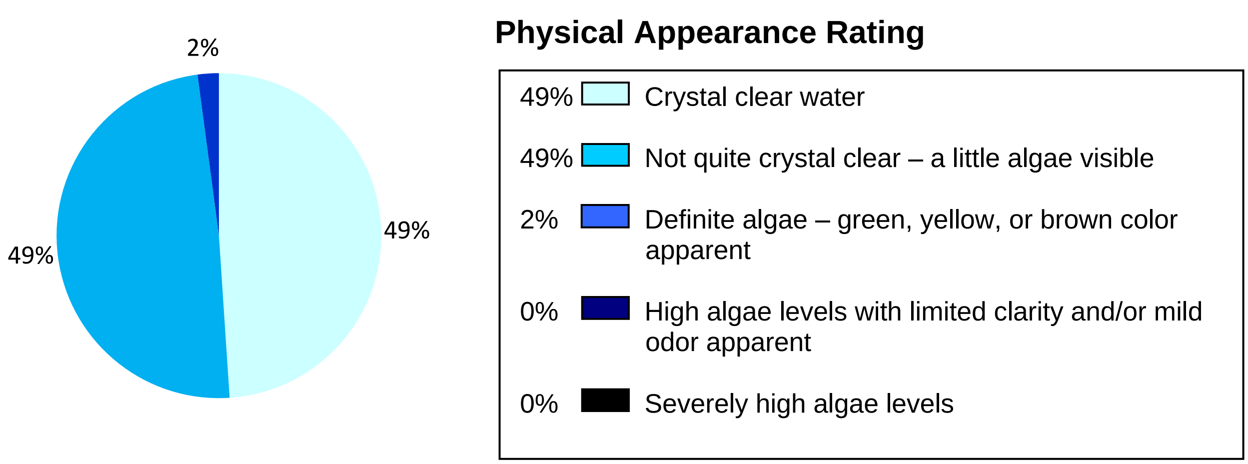


Figure 5. Deer Lake physical appearance ratings by samplers.

As the Secchi depth decreases, the perception of recreational suitability of the lake decreases. Deer Lake was rated as being "beautiful" 58% of the time from 1989 to 2011 (Figure 6).

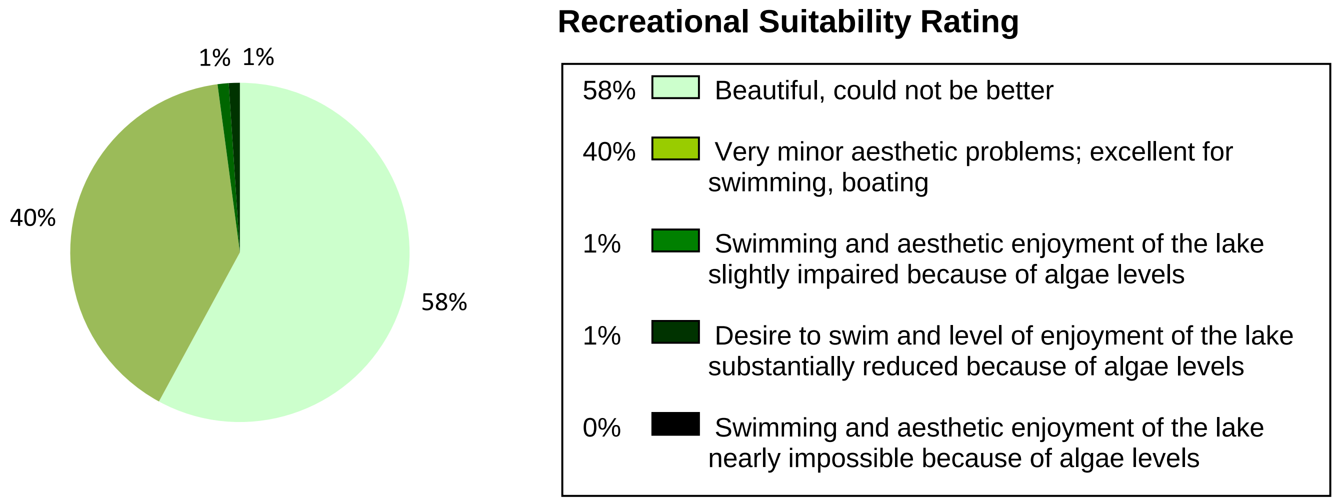


Figure 6. Recreational suitability rating, as rated by the volunteer monitor.

Total Phosphorus

Deer Lake is phosphorus limited, which means that algae and aquatic plant growth is dependent upon available phosphorus.

Total phosphorus was evaluated in Deer Lake at site 213 in 1992-1993, 2011-2014. The data do not indicate much seasonal variability. The majority of the data points fall into the oligotrophic range (Figure 7).

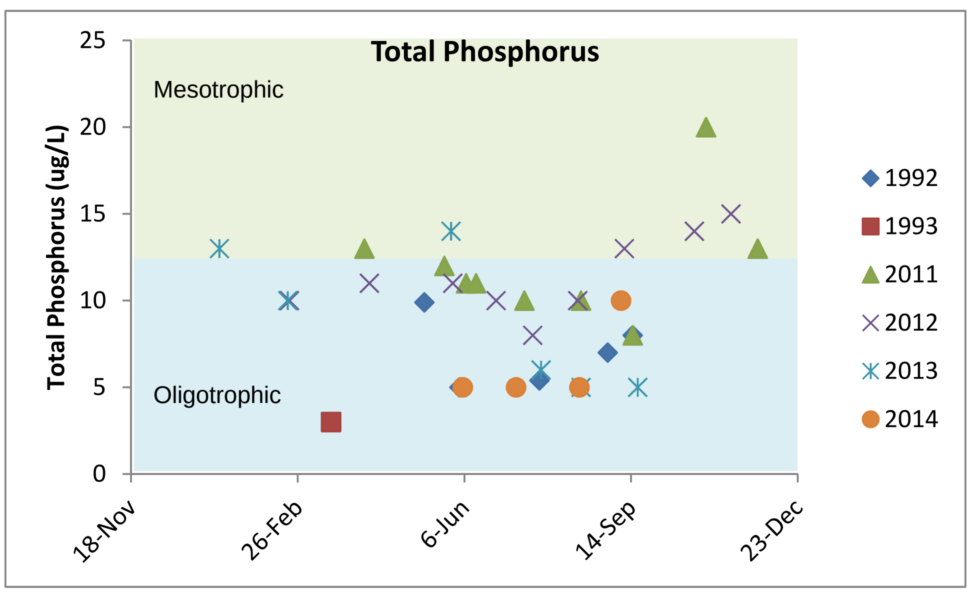


Figure 7. Historical total phosphorus concentrations (ug/L) for Deer Lake site 213.

Phosphorus should continue to be monitored to track any future changes in water quality.

Chlorophyll *a*

Chlorophyll *a* is the pigment that makes plants and algae green. Chlorophyll *a* is tested in lakes to determine the algae concentration or how "green" the water is.

Chlorophyll *a* concentrations greater than 10 ug/L are perceived as a mild algae bloom, while concentrations greater than 20 ug/L are perceived as a nuisance.

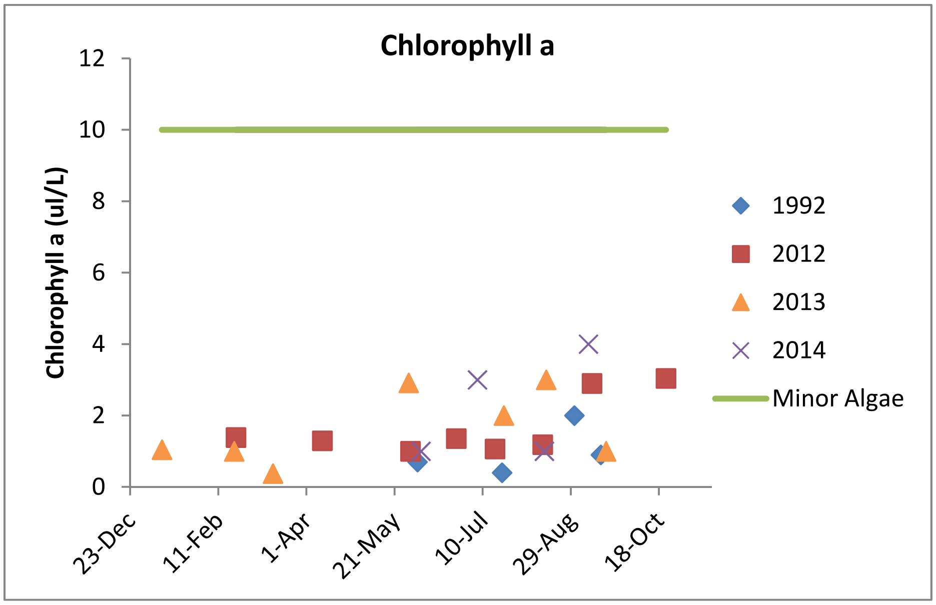
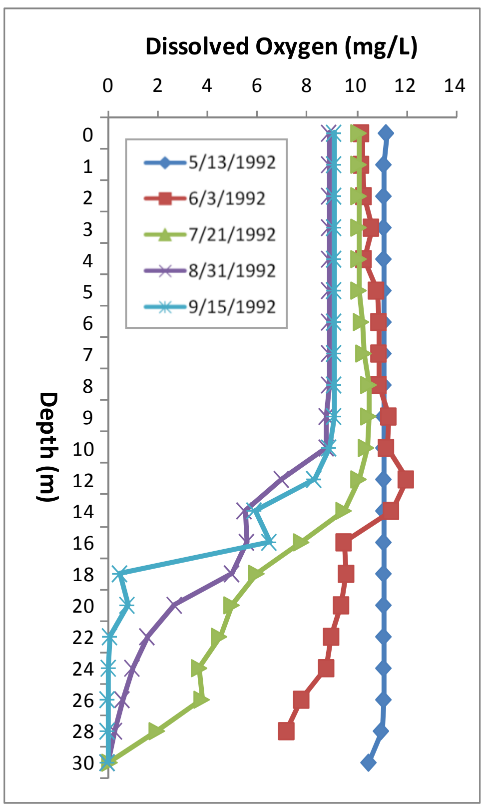


Figure 8. Chlorophyll *a* concentrations (ug/L) for Deer Lake at site 213.

Chlorophyll *a* was evaluated in Deer Lake at site 213 in 1992, 2012-2014 (Figure 8). Chlorophyll *a* concentrations remained well below 10 ug/L in all years, indicating no algae blooms. There was not much variation over the years monitored and chlorophyll *a* concentrations remained relatively steady over the summer.

Dissolved Oxygen



Dissolved Oxygen (DO) is the amount of oxygen dissolved in lake water. Oxygen is necessary for all living organisms to survive except for some bacteria. Living organisms breathe in oxygen that is dissolved in the water. Dissolved oxygen levels of <5 mg/L are typically avoided by game fisheries.

Deer Lake is a deep lake, with a maximum depth of 101 feet. Dissolved oxygen profiles from data collected in 1992 at site 213 show stratification developing mid-summer (Figure 9). The thermocline occurs at around 12-13 meters (39 - 42.5 feet). Oxygen is sufficient for fish until September, when the hypolimnion goes anoxic.

Figure 9. Dissolved oxygen profile for Deer Lake.

Trophic State Index (TSI)

TSI is a standard measure or means for calculating the trophic status or productivity of a lake. More specifically, it is the total weight of living algae (algae biomass) in a waterbody at a specific location and time. Three variables, chlorophyll a, Secchi depth, and total phosphorus, independently estimate algal biomass.

Phosphorus (nutrients), chlorophyll *a* (algae concentration) and Secchi depth (transparency) are related. As phosphorus increases, there is more food available for algae, resulting in increased algal concentrations. When algal concentrations increase, the water becomes less transparent and the Secchi depth decreases. If all three TSI numbers are within a few points of each other, they are strongly related. If they are different, there are other dynamics influencing the lake's productivity, and TSI mean should not be reported for the lake.

The mean TSI for Deer Lake falls into the oligotrophic range (Figure 10). There is good agreement between the TSI for phosphorus, chlorophyll *a* and transparency, indicating that these variables are strongly related (Table 6).

Oligotrophic lakes (TSI 0-39) are characteristic of extremely clear water throughout the summer and sandy or rocky shores. They are excellent for recreation. Some very deep oligotrophic lakes are able to support a trout fishery.

Table 6. Trophic State Index for Deer.

Trophic State Index	Site 213
TSI Total Phosphorus	37
TSI Chlorophyll-a	37
TSI Secchi	35
TSI Mean	37
Trophic State:	Oligotrophic

Numbers represent the mean TSI for each parameter.

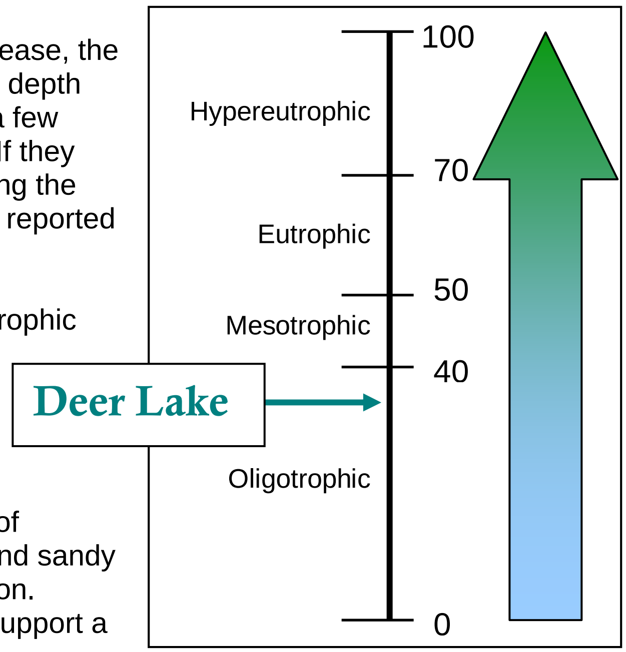


Figure 10. Trophic state index chart with corresponding trophic status.

Table 7. Trophic state index attributes and their corresponding fisheries and recreation characteristics.

TSI	Attributes	Fisheries & Recreation
<30	Oligotrophy: Clear water, oxygen throughout the year at the bottom of the lake, very deep cold water.	Trout fisheries dominate
30-40	Bottom of shallower lakes may become anoxic (no oxygen).	Trout fisheries in deep lakes only. Walleye, Cisco present.
40-50	Mesotrophy: Water moderately clear most of the summer. May be "greener" in late summer.	No oxygen at the bottom of the lake results in loss of trout. Walleye may predominate.
50-60	Eutrophy: Algae and aquatic plant problems possible. "Green" water most of the year.	Warm-water fisheries only. Bass may dominate.
60-70	Blue-green algae dominate, algal scums and aquatic plant problems.	Dense algae and aquatic plants. Low water clarity may discourage swimming and boating.
70-80	Hypereutrophy: Dense algae and aquatic plants.	Water is not suitable for recreation.
>80	Algal scums, few aquatic plants	Rough fish (carp) dominate; summer fish kills possible

Source: Carlson, R.E. 1997. A trophic state index for lakes. *Limnology and Oceanography*. 22:361-369.

Trend Analysis

For detecting trends, a minimum of 8-10 years of data with 4 or more readings per season are recommended. Minimum confidence accepted by the MPCA is 90%. This means that there is a 90% chance that the data are showing a true trend and a 10% chance that the trend is a random result of the data. Only short-term trends can be determined with just a few years of data, because there can be different wet years and dry years, water levels, weather, etc, that affect the water quality naturally.

Deer Lake had enough data to perform a trend analysis on transparency (Table 8). The data was analyzed using the Mann Kendall Trend Analysis.

Table 8. Trend analysis for Deer Lake.

Lake Site	Parameter	Date Range	Trend	Probability
213	Total Phosphorus	2012-2014	Insufficient data	-
213	Chlorophyll *a*	2012-2014	Insufficient data	-
206	Transparency	1990-2011	No trend	-
206	Transparency	2000-2011	Improving	95%
207	Transparency	1992-2010	Improving	95%
210	Transparency	2001-2014	Improving	99%
211	Transparency	2003-2014	Improving	90%

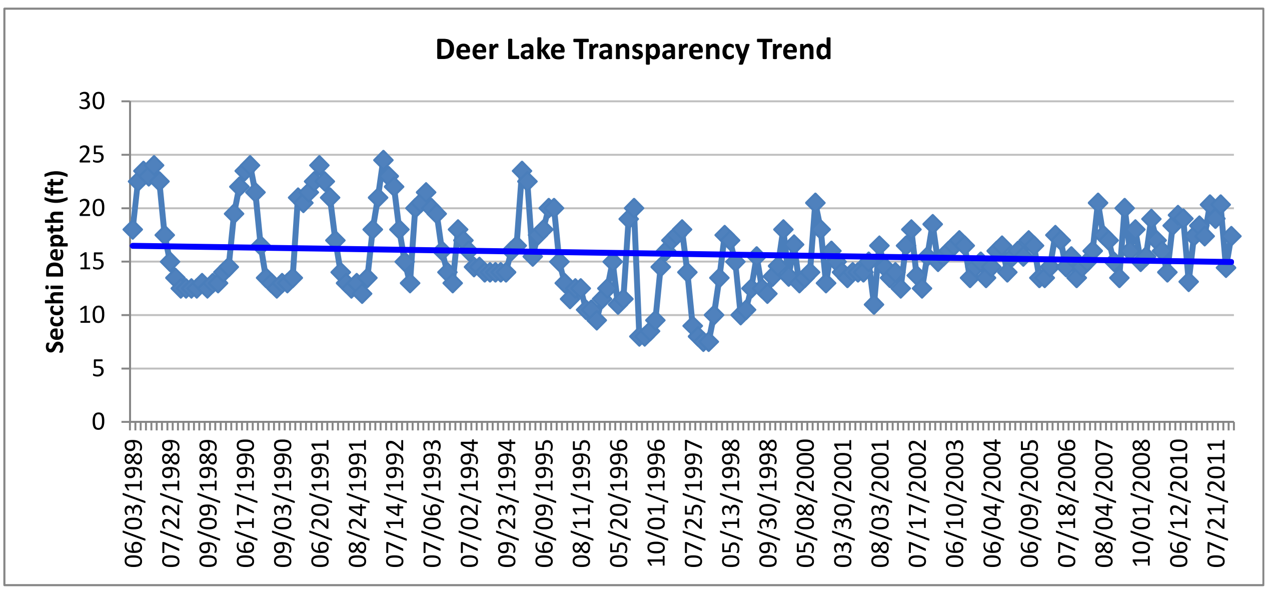


Figure 11. Transparency (feet) trend for site 206 from 1989-2011.

Deer Lake shows evidence of an improving transparency trend in the short-term (since 2000) and no trend in the long-term data set (Table 8, Figure 11). From the long-term data set (Figure 11), it looks like the transparency declined in the mid-1990s, but the recovered in the 2000s. Since 1994, the annual maximum transparency hasn't reached 23 feet. Transparency monitoring should continue so that this trend can be tracked in future years.

Ecoregion Comparisons

Minnesota is divided into 7 ecoregions based on land use, vegetation, precipitation and geology (Figure 12). The MPCA has developed a way to determine the "average range" of water quality expected for lakes in each ecoregion. From 1985-1988, the MPCA evaluated the lake water quality for reference lakes. These reference lakes are not considered pristine, but are considered to have little human impact and therefore are representative of the typical lakes within the ecoregion. The "average range" refers to the 25th - 75th percentile range for data within each ecoregion. For the purpose of this graphical representation, the means of the reference lake data sets were used.

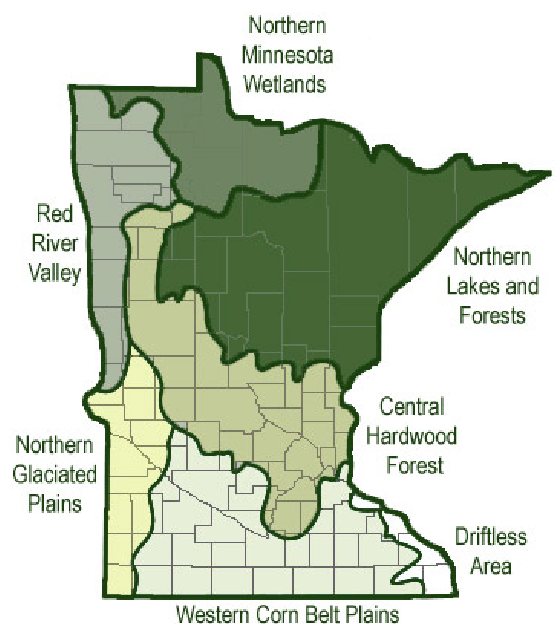
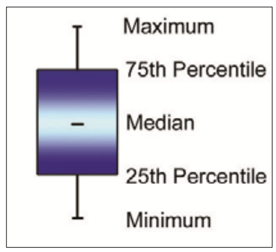


Figure 12. Minnesota Ecoregions.

Deer Lake is in the Northern Lakes and Forest Ecoregion. The mean total phosphorus, chlorophyll *a* and transparency (Secchi depth) for Deer Lake are better than the ecoregion ranges (Figure 13).



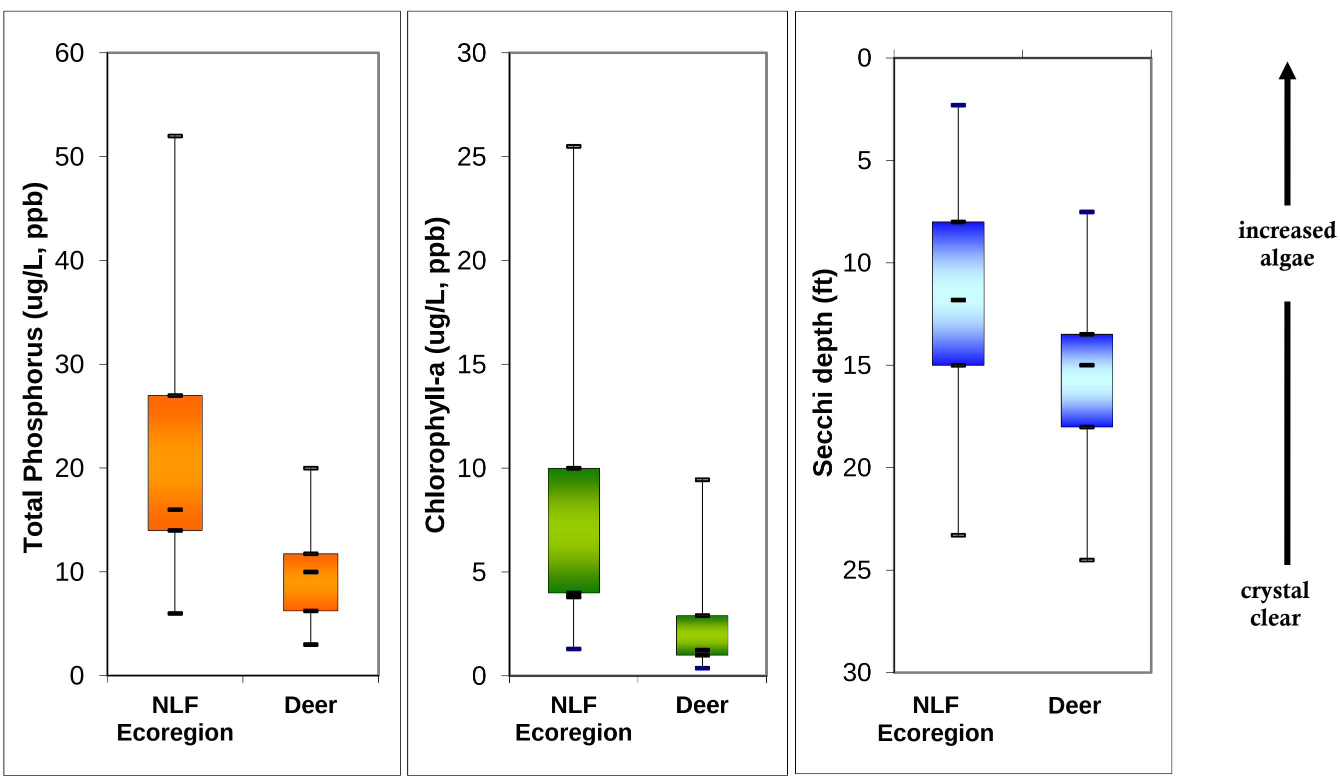


Figure 13. Deer Lake ranges compared to Northern Lakes and Forest Ecoregion ranges. The Deer Lake total phosphorus and chlorophyll *a* ranges are from 36 data points collected in May-September of 2011-2014. The Deer Lake Secchi depth range is from 207 data points collected in May-September of 1989-2011.

Lakeshed Data and Interpretations

Lakeshed

Understanding a lakeshed requires an understanding of basic hydrology. A watershed is defined as all land and water surface area that contribute excess water to a defined point. The MN DNR has delineated three basic scales of watersheds (from large to small): 1) basins, 2) major watersheds, and 3) minor watersheds.

The Mississippi River Headwaters Major Watershed is one of the watersheds that make up the Upper Mississippi River Basin, which drains south to the Gulf of Mexico (Figure 14). Deer Lake is located in minor watershed 7010 (Figure 15).

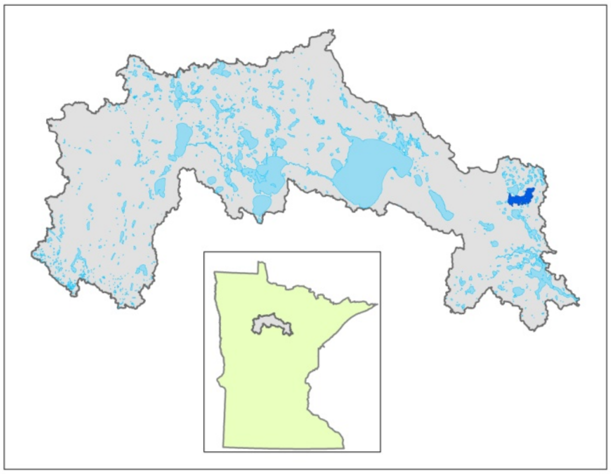


Figure 14. Upper Mississippi River Major Watershed.

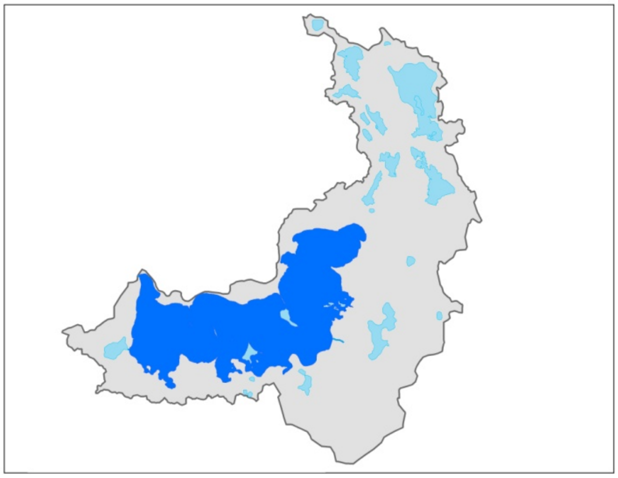


Figure 15. Minor Watershed.

The MN DNR also has evaluated catchments for each individual lake with greater than 100 acres surface area. These lakesheds (catchments) are the “building blocks” for the larger scale watersheds. Deer Lake falls within lakeshed 701000 (Figure 16). Though very useful for displaying the land and water that contribute directly to a lake, lakesheds are not always true watersheds because they may not show the water flowing into a lake from upstream streams or rivers. While some lakes may have only one or two upstream lakesheds draining into them, others

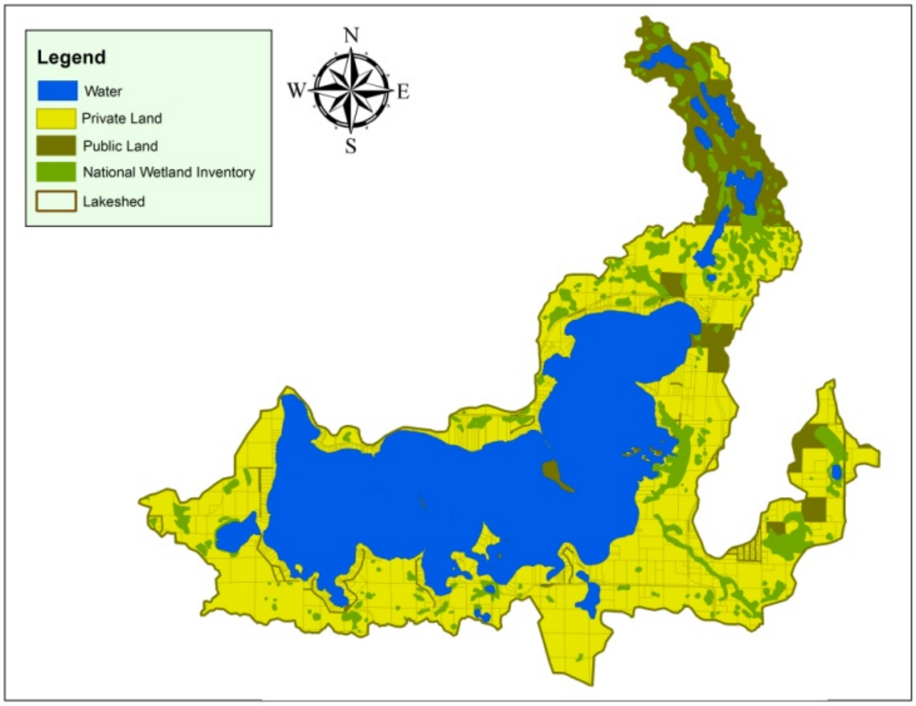


Figure 16. Deer Lake lakeshed (701000) with land ownership, lakes, wetlands, and rivers illustrated.

may be connected to a large number of lakesheds, reflecting a larger drainage area via stream or river networks. For further discussion of Deer Lake 's watershed, containing all the lakesheds upstream of the Deer Lake lakeshed, see page 18. The data interpretation of the Deer Lake lakeshed includes only the immediate lakeshed as this area is the land surface that flows directly into Deer Lake.

The lakeshed vitals table identifies where to focus organizational and management efforts for each lake (Table 9). Criteria were developed using limnological concepts to determine the effect to lake water quality.

KEY
- Possibly detrimental to the lake
- Warrants attention
- Beneficial to the lake

Table 9. Deer Lake lakeshed vitals table.

Lakeshed Vitals		**Rating**
Lake Area	4,094 acres	descriptive
Littoral Zone Area	900 acres	descriptive
Lake Max Depth	101 feet	descriptive
Lake Mean Depth	40.8 feet	Beneficial to the lake
Water Residence Time	17.5	Possibly detrimental to the lake
Miles of Stream	0 miles	descriptive
Inlets	Minor tributaries	Warrants attention
Outlets	1	Beneficial to the lake
Major Watershed	7 - Mississippi River-Headwaters	descriptive
Minor Watershed	7010	descriptive
Lakeshed	701000	descriptive
Ecoregion	Northern Lakes and Forests	descriptive
Total Lakeshed to Lake Area Ratio (total lakeshed includes lake area)	3:1	Beneficial to the lake
Standard Watershed to Lake Basin Ratio (standard watershed includes lake areas)	4:1	Beneficial to the lake
Wetland Coverage (NWI)	7.3%	Beneficial to the lake
Aquatic Invasive Species	None	Beneficial to the lake
Public Drainage Ditches	0	Beneficial to the lake
Public Lake Accesses	2	Warrants attention
Miles of Shoreline	20.96 miles	descriptive
Shoreline Development Index	2.34	Warrants attention
Public Land to Private Land Ratio	1:5	Warrants attention
Development Classification	Recreational Development	Warrants attention
Miles of Road	28.52 miles	descriptive
Municipalities in lakeshed	None	Beneficial to the lake
Forestry Practices	None	Beneficial to the lake
Feedlots	1	Possibly detrimental to the lake
Sewage Management	Individual Waste Treatment Systems (septic systems and holding tanks)	Warrants attention
Lake Management Plan	Yes, 1998-2000	Beneficial to the lake
Lake Vegetation Survey/Plan	DNR, 2000	Beneficial to the lake

Land Cover / Land Use

The activities that occur on the land within the lakeshed can greatly impact a lake. Land use planning helps ensure the use of land resources in an organized fashion so that the needs of the present and future generations can be best addressed. The basic purpose of land use planning is to ensure that each area of land will be used in a manner that provides maximum social benefits without degradation of the land resource.

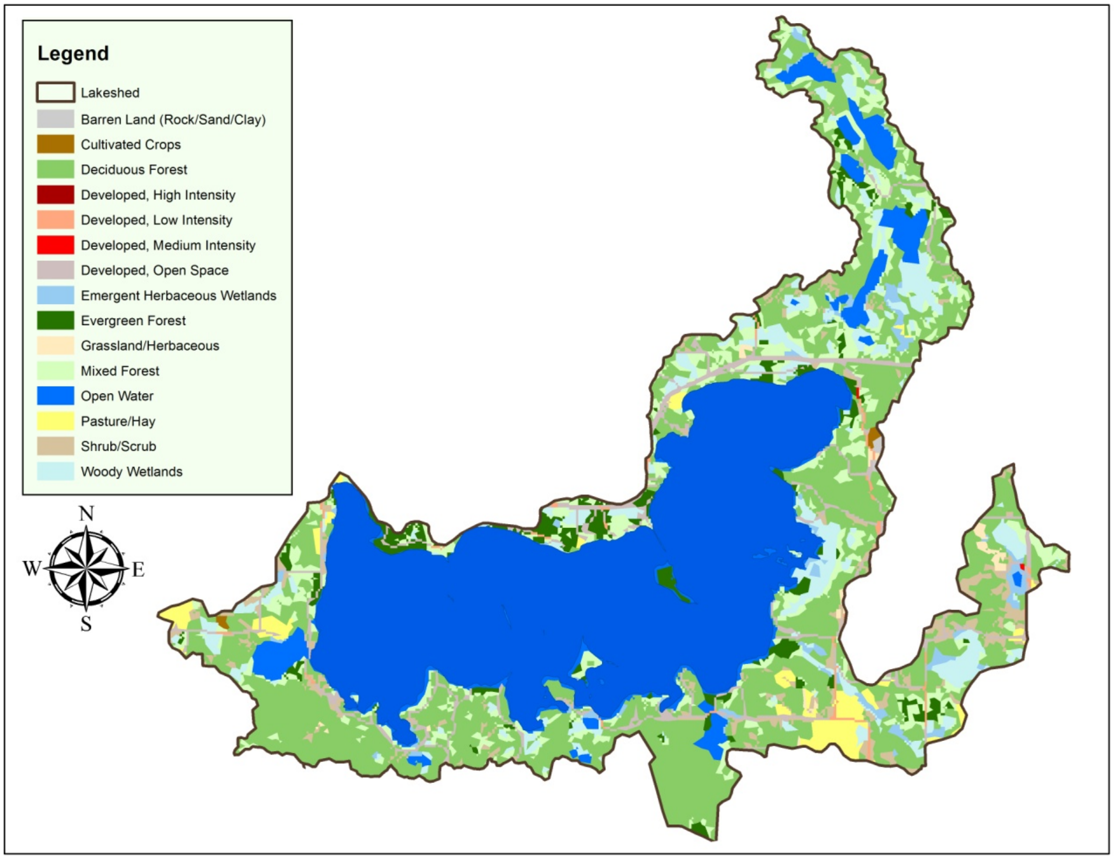


Figure 17. Deer Lake lakeshed (701000) land cover (NLCD 2011).

Changes in land use, and ultimately land cover, impact the hydrology of a lakeshed. Land cover is also directly related to the land's ability to absorb and store water rather than cause it to flow overland (gathering nutrients and sediment as it moves) towards the lowest point, typically the lake. Impervious intensity describes the land's inability to absorb water, the higher the % impervious intensity the more area that water cannot penetrate in to the soils. Monitoring the changes in land use can assist in future planning procedures to address the needs of future generations.

Phosphorus export, which is the main cause of lake eutrophication, depends on the type of land cover occurring in the lakeshed. Figure 17 depicts the land cover in Deer Lake 's lakeshed.

The National Land Cover Dataset (NLCD) has records from 2001 and 2011. Table 10 describes Deer Lake's lakeshed land cover statistics and percent change from 2001 to 2011. Overall, there was not much change over this decade or from 1990-2000 (Table 11).

Table 10. Deer Lake's lakeshed land cover statistics and % change from 2001 to 2011 (Data Source: NLCD).

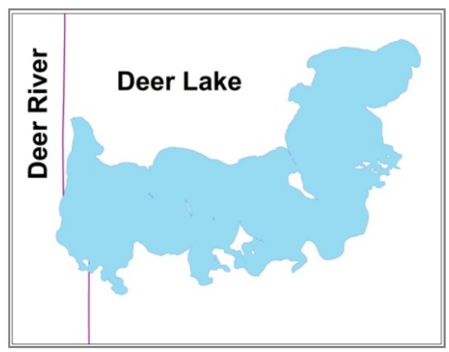
Land Cover	2001 Acres	Percent	2011 Acres	Percent	% Change 2001 to 2011
Barren Land (Rock/Sand/Clay)	4.68	0.04	9.19	0.08	0.0403
Cultivated Crops	12.24	0.11	12.81	0.11	0.0051
Deciduous Forest	3191.63	28.50	3247.23	29.00	0.4960
Developed, High Intensity	0.00	0.00	0.20	0.00	0.0018
Developed, Low Intensity	54.09	0.48	56.10	0.50	0.0179
Developed, Medium Intensity	1.58	0.01	3.03	0.03	0.0129
Developed, Open Space	421.11	3.76	417.70	3.73	-0.0305
Emergent Herbaceous Wetlands	169.35	1.51	174.40	1.56	0.0451
Evergreen Forest	358.89	3.21	361.75	3.23	0.0255
Grassland/Herbaceous	26.82	0.24	44.56	0.40	0.1584
Mixed Forest	984.37	8.79	982.47	8.77	-0.0172
Open Water	4642.89	41.47	4644.79	41.48	0.0161
Pasture/Hay	230.95	2.06	229.44	2.05	-0.0136
Shrub/Scrub	408.56	3.65	329.91	2.95	-0.7025
Woody Wetlands	689.95	6.16	683.77	6.11	-0.0553
Total Area	11197.34				

Table 11. Deer Lake development area and % change from 1990-2000 (Data Source: UMN Landsat).

Category	1990 Acres	Percent	2000 Acres	Percent	% Change 1990 to 2000
Total Impervious Area	40	0.59	54	0.78	0.19
Urban Acreage	321	2.87	325	2.9	0.03

Demographics

Deer Lake is classified as a Recreational Development lake. Recreational Development lakes usually have usually have between 60 and 225 acres of water per mile of shoreline, between 3 and 25 dwellings per mile of shoreline, and are more than 15 feet deep.



The Minnesota Department of Administration Geographic and Demographic Analysis Division extrapolated future population in 5-year increments out to 2035. Compared to Itasca County as a whole, Deer River Township has a slightly higher growth projection(Figure 18). (source: http://www.demography.state.mn.us)

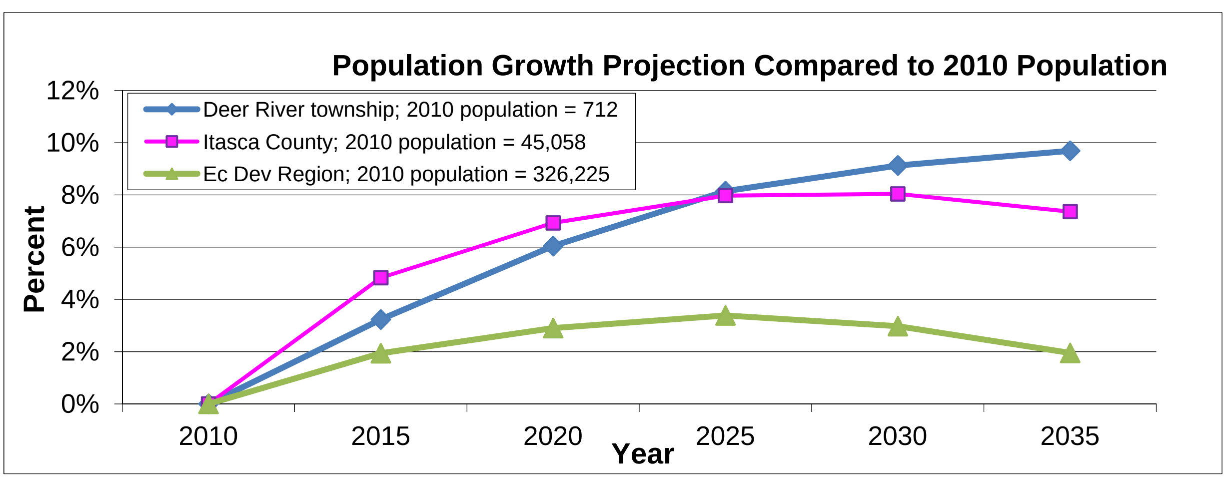


Figure 18. Population growth projection for adjacent townships and Itasca County.

Lakeshed Water Quality Protection Strategy

Each lakeshed has a different makeup of public and private lands. Looking in more detail at the makeup of these lands can give insight on where to focus protection efforts. The protected lands (easements, wetlands, public land) are the future water quality infrastructure for the lake. Developed land and agriculture have the highest phosphorus runoff coefficients, so this land should be minimized for water quality protection.

The majority of the land within Deer Lake's lakeshed is privately owned forested uplands (Table 12). This land can be the focus of development and protection efforts in the lakeshed.

Table 12. Land ownership, land use/land cover, estimated phosphorus loading, and ideas for protection and restoration in the lakeshed (Sources: County parcel data and the 2011 National Land Cover Dataset).

	Private (50.3)					39.6	Public (10.0)		
	Developed	Agriculture	Forested Uplands	Other	Wetlands	Open Water	County	State	Federal
Land Use (%)	3.6	2.1	36.4	0.3	8.0	39.6	1.3	2.4	6.3
Runoff Coefficient Lbs of phosphorus/acre/year	0.45 – 1.5	0.26 – 0.9	0.09		0.09		0.09	0.09	0.09
Estimated Phosphorus Loading Acreage x runoff coefficient	182 –607	61	210		367		0.7	12.969	24.48
Description	Focused on Shoreland	Cropland	Focus of develop-ment and protection efforts	Open, pasture, grass-land, shrub-land	Protected				
Protection and Restoration Project Ideas	Shoreline restoration	Restore wetlands; CRP	Forest stewardship planning, 3rd party certification, SFIA, local woodland cooperatives		Protected by Wetland Conservation Act		County Tax Forfeit Lands	State Forest	National Forest

DNR Fisheries approach for lake protection and restoration

Credit: Peter Jacobson and Michael Duval, Minnesota DNR Fisheries

In an effort to prioritize protection and restoration efforts of fishery lakes, the MN DNR has developed a ranking system by separating lakes into two categories, those needing protection and those needing restoration. Modeling by the DNR Fisheries Research Unit suggests that total phosphorus concentrations increase significantly over natural concentrations in lakes that have watershed with disturbance greater than 25%. Therefore, lakes with watersheds that have less than 25% disturbance need protection and lakes with more than 25% disturbance need restoration (Table 13). Watershed disturbance was defined as having urban, agricultural and mining land uses. Watershed protection is defined as publicly owned land or conservation easement.

Table 13. Suggested approaches for watershed protection and restoration of DNR-managed fish lakes in Minnesota.

Watershed Disturbance (%)	Watershed Protected (%)	Management Type	Comments
< 25%	> 75%	Vigilance	Sufficiently protected -- Water quality supports healthy and diverse native fish communities. Keep public lands protected.
	< 75%	Protection	Excellent candidates for protection -- Water quality can be maintained in a range that supports healthy and diverse native fish communities. Disturbed lands should be limited to less than 25%.
25-60%	n/a	Full Restoration	Realistic chance for full restoration of water quality and improve quality of fish communities. Disturbed land percentage should be reduced and BMPs implemented.
> 60%	n/a	Partial Restoration	Restoration will be very expensive and probably will not achieve water quality conditions necessary to sustain healthy fish communities. Restoration opportunities must be critically evaluated to assure feasible positive outcomes.

The next step was to prioritize lakes within each of these management categories. DNR Fisheries identified high value fishery lakes, such as cisco refuge lakes. Ciscos (*Coregonus artedi)* can be an early indicator of eutrophication in a lake because they require cold hypolimnetic temperatures and high dissolved oxygen levels. These watersheds with low disturbance and high value fishery lakes are excellent candidates for priority protection measures, especially those that are related to forestry and minimizing the effects of landscape disturbance. Forest stewardship planning, harvest coordination to reduce hydrology impacts and forest conservation easements are some potential tools that can protect these high value resources for the long term.

Deer Lake's lakeshed is classified with having 57% of the watershed protected and 5% of the watershed disturbed (Figure 19). Therefore, this lakeshed should have a protection focus. Goals for the lake should be to limit any increase in disturbed land use. Deer Lake has five other lakesheds flowing into it (Figure 20).

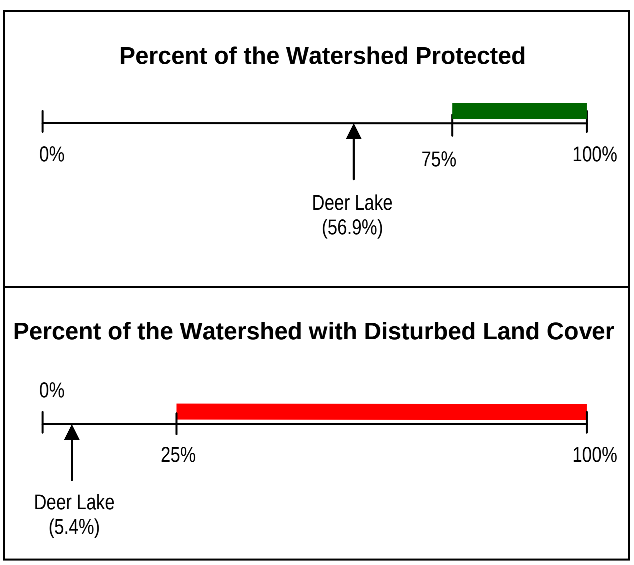


Figure 19. Deer Lake's lakeshed percentage of watershed protected and disturbed.

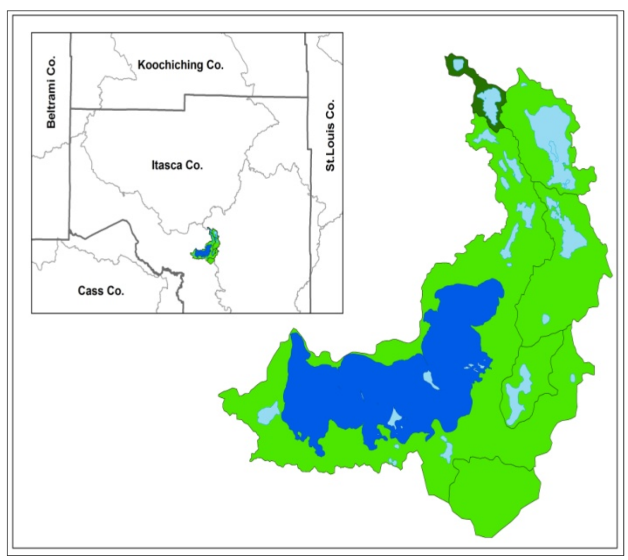


Figure 20. Lakesheds that contribute water to the Deer Lake lakeshed. Color-coded based on management focus (Table 13).

Status of the Fishery (DNR, as of 07/30/2012)

Deer Lake is a class 22 lake located northeast of Deer River, Minnesota. There is one public access on the southwest part of the lake. There were 373 homes or cabins counted during the 2005 survey, indicating moderate to high shoreline development. The 2006 lake management plan indicated muskellunge, smallmouth bass and walleye as the primary species of management with northern pike as a secondary species. The 2012 assessment also included sampling of near shore fish species in order to calculate an Index of Biotic Integrity (IBI) score.

Muskellunge are difficult to sample with our standard sampling methods. In the 2012 assessment, only one muskellunge was sampled in the gill nets. The most recent spring muskellunge assessment was conducted in 2003. Spring netting conditions were ideal for sampling muskellunge since the weather was relatively stable and water temperatures progressively increased. Of the 339 muskellunge captured (1.7/net) in the 199 trap nets, 72 were recaptures. The population was estimated at 600 fish or 0.15 fish/acre. The fish ranged from 26 to 50 inches with 79% being 42 inches or less.

Walleye gill-net catch rates have fluctuated considerably since the first assessment in 1948. The lowest catch rate was 2.3 fish/net in 1975 and the highest catch of 13.3 fish/net occurred in 1984. In 2012, the gill-net catch was 12.9 fish/net, which exceeded the 3rd quartile value of 9.6 fish/net. The catch exceeded the aggressive management goal of 11 walleye/gill net. The walleye population appeared to be in good condition based on the size and age structures sampled. Walleye from 7.8 to 27.6 inches were sampled and they had a mean length of 14.1 inches. Ten year-classes were identified by scale, opercle, and otolith analysis. Age-1 through 4 walleye dominated the sample, representing close to 90% of the total. Walleye growth was good with age-4 fish averaging 18.8 inches. Mean back-calculated length-at-ages were similar to statewide averages for all ages.

Largemouth bass were sampled with spring night electrofishing four times from 1995 to 2012. Catch rates had increased substantially from 2.2 fish/hr in 1995 to 45.0 fish/hr in 2005 but declined to 15.5 fish/hr (on-time) in 2012. The sampled fish ranged from 6.7 to 16.1 inches and had a mean length of 11.2 inches. Nine year-classes were sampled from two to 10 years old. No one age-class dominated the sample. Growth was poor compared to the statewide averages. Mean back-calculated lengths were below 15% of the statewide average.

Smallmouth bass were also sampled with spring night electrofishing four times from 1995 to 2012. Catch rates followed a similar trend as for largemouth bass. From 1995 to 2005, the smallmouth bass electrofishing catch increased from 17.3 fish/hr to 55.9 fish/hr but declined to 28.5 fish/hr (on-time) in 2012. Gill nets can often sample smallmouth bass quite effectively depending on the lake. In 2012, 85 fish were sampled for a catch of 5.7/gill net. The gill-net sampled fish ranged from 5.1 to 19.1 inches and had mean length of 14.0 inches. The spring electrofishing sample ranged from 4.6 to 19.5 inches and had a mean length of 12.0 inches. Age and growth information was only collected during the spring electrofishing sample. Ten year-classes were sampled from two to 11 years old with age-2 fish representing nearly 28% of the sample. Growth was slower than statewide averages for all ages.

Northern pike gill-net catch rates have always been below the lake class 1st quartile of 3.0 fish/net. The highest catch rate of 1.1 fish/net occurred in 1948 and 1984. In 2012, the gill-net CPUE was 0.3 fish/net. Low northern pike numbers frequently results in good size structure. Northern pike ranged from 15.4 to 27.2 inches and had a mean length of 20.0 inches. Age and growth information was not collected in this assessment.

The black crappie population has always been low and will likely remain low due to the lack of suitable habitat. Black crappie were only sampled by trap nets once from 1948 to 1990 and were first sampled by gill nets in the 2000 assessment. Black crappie gill-net and trap-net catch rates were both 0.7 fish/net in 2005. In 2012, the gill-net and trap-net catches were 0.7 and 0.1 fish/net. Black crappie ranged from 6.3 to 11.2 inches for the combined gears. Age and growth information was not collected in this assessment.

Bluegills were seldom sampled prior to the 1990 population assessment (0.2 to 2.7 fish/trap net). Bluegill catch rates have increased substantially beginning in 1990 with a catch of 21.0/net. In the four assessments since 1990, the trap-net catch has fluctuated from 10.5 to 32.0/net. The catch was 16.8 fish/net in 2012. Bluegill catch rates have been near or above the lake class median of 15.3 fish/net in the last five assessments. Bluegill lengths ranged from 3.6 to 8.0 inches, with a mean of 6.0 inches. Age and growth information was not collected in this assessment.

Tullibees, due to their pelagic nature, are difficult to sample with our standardized, summer assessments. As a result, tullibee catch rates are generally low but they can be highly variable. In 1948, the gill-net catch rate was 11.2 fish/net but in the next assessment in 1975 none were captured. In 1980, 8.6 tullibee/net were sampled but in the next five assessments the highest catch was 0.3 fish/net. None were sampled in gill nets in 2005 and only four were sampled in 2012. Anecdotal information indicates there is an abundance of tullibee in the lake and the sampling methodology has not accurately reflected the population.

The yellow perch population has been relatively stable remaining between the 1st and 3rd quartile values for all assessments. In 1948, the catch was 11.8 fish/gill net (lowest on record), and catches have gradually increased to 32.2 fish/gill net (highest on record) in 2005. In 2012, the catch declined to 10.7 fish/gill net. Yellow perch lengths ranged from 5.8 to 11.5 inches and had a mean length of 8.1 inches. Age and growth information was not collected in this assessment. Yellow perch are probably more important within the fish community as a prey source than as a species desired by anglers.

Other species observed during the population assessment included bowfin, hybrid sunfish, lake whitefish, pumpkinseed sunfish, rock bass, white sucker. Additional species observed during IBI sampling included banded killifish, blackchin shiner, blacknose dace, bluntnose minnow, brook stickleback, central mudminnow, common shiner, Iowa dater, Johnny darter, least darter, logperch, longnose dace, mottled sculpin, and spottail shiner.

In order to maintain or improve fish and wildlife populations, water quality and habitat must be protected. People often associate water quality problems with large-scale agricultural, forestry, urban development or industrial practices in the watershed. In reality, the impact of land use decisions on one lake lot may be relatively small, yet the cumulative impact of those decisions on many lake lots can result in a significant decline in water quality and habitat. For example, removing shoreline and aquatic vegetation, fertilizing lawns, mowing to the water's edge, installing beach sand blankets, failing septic systems and uncontrolled run-off, all contribute excess nutrients and sediment which degrade water quality and habitat. Understanding these cumulative impacts and taking steps to avoid or minimize them will help to insure our quality fisheries can be enjoyed by future generations.

See the link below for specific information on gillnet surveys, stocking information, and fish consumption guidelines. http://www.dnr.state.mn.us/lakefind/showreport.html?downum=31071900

Deer – Pokegama Diagnostic Study, 2013

A Clean Water Partnership project was conducted on Deer and Pokegama lakes in 2011-2013. The goals were to study two lakes in very good condition to give insight to water quality in the region and focus on protection. The following text and Figure 21 are from the final report.

It was found that Deer Lake is quite sensitive to additional phosphorus loading. Precipitation and atmospheric loading is an unexpectedly large source of nutrients for Deer Lake. In spite of the dominance of precipitation as a source of nutrients to Deer Lake, substantial nutrient input also derives from surface streams (19.6% of inputs) and groundwater transport (7% of inputs) (Figure 21).

Modeling found the water residence time of Deer Lake to be 17.5 years. This is relatively long, and means that phosphorus inputs to the lake are not cycled out quickly. They can sit and build up in the sediments. Dissolved oxygen profiles show that the hypolimnion does go anoxic at the end of the summer.

The nutrient budget of Deer Lake is based on long water retention and very low nutrient supplies. Much of the nutrients are supplied by rainfall. In spite of the lake having a tiny watershed relative to the lake, there are several hotspots of phosphorus in both groundwater and surface water supplies. These seem more enriched than normal for lakes of this trophic status.

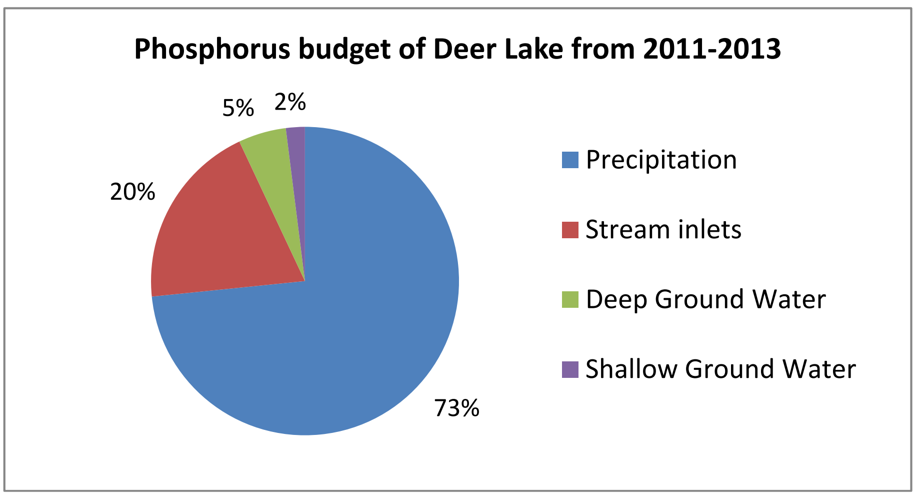


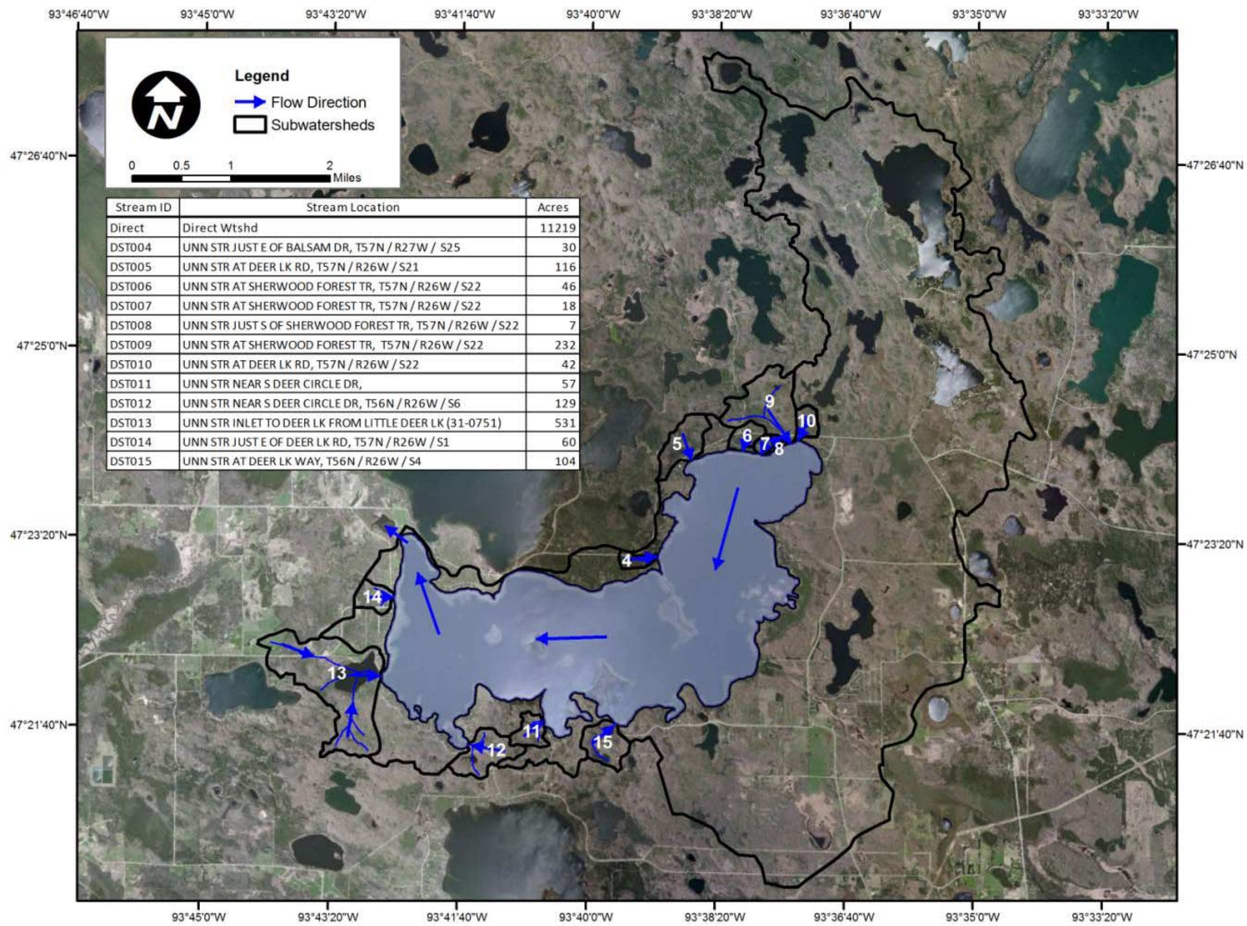
Figure 21. Phosphorus budget of Deer Lake from 2011-2013, from the Deer – Pokegama Diagnostic Study, 2013.

Key Findings / Recommendations

Monitoring Recommendations

Transparency monitoring at site 209, 210 and 211 should be continued annually. It is important to continue transparency monitoring weekly or at least bimonthly every year to enable year-to-year comparisons and trend analyses. Total Phosphorus and chlorophyll *a* monitoring should continue at site 213 track trends in water quality.

The Deer-Pokegama Study found that stream chemistry is quite concentrated in a few of the tributaries to Deer Lake, especially 4, 6, 7, 9, 10, and 14 (Figure 22). These tributaries could continue to be monitored to test the effectiveness of implementation projects such as vegetative buffers and stormwater mitigation.



Stream ID	Stream Location	Acres
Direct	Direct Wtshd	11219
DST004	UNN STR JUST E OF BALSAM DR, T57N / R27W / S25	30
DST005	UNN STR AT DEER LK RD, T57N / R26W / S21	116
DST006	UNN STR AT SHERWOOD FOREST TR, T57N / R26W / S22	46
DST007	UNN STR AT SHERWOOD FOREST TR, T57N / R26W / S22	18
DST008	UNN STR JUST S OF SHERWOOD FOREST TR, T57N / R26W / S22	7
DST009	UNN STR AT SHERWOOD FOREST TR, T57N / R26W / S22	232
DST010	UNN STR AT DEER LK RD, T57N / R26W / S22	42
DST011	UNN STR NEAR S DEER CIRCLE DR,	57
DST012	UNN STR NEAR S DEER CIRCLE DR, T56N / R26W / S6	129
DST013	UNN STR INLET TO DEER LK FROM LITTLE DEER LK (31-0751)	531
DST014	UNN STR JUST E OF DEER LK RD, T57N / R26W / S1	60
DST015	UNN STR AT DEER LK WAY, T56N / R26W / S4	104

Figure 22. Tributary map of Deer Lake from the Deer – Pokegama Diagnostic Study, 2013.

Overall Summary

Deer Lake is an oligotrophic lake (TSI = 37) with evidence of an improving trend in transparency in the past decade. The data show that the transparency in the lake was lower in the mid 1990s and has improved since then. The transparency still hasn't recovered to the maximums seen in the early 1990s (Figure 11). The total phosphorus, chlorophyll *a* and transparency ranges are better than the ecoregion ranges.

Only five percent (5%) of the Deer Lake lakeshed is disturbed by development and agriculture (Figure 19). The threshold of disturbance where water quality tends to decline is 25%. Deer Lake is well under this threshold. More than half (57%) of the lakeshed is protected by wetlands, open water and public land (Table 12).

Deer Lake has the advantage of a very small watershed. The lake does not have any major inlets passing through it. This means that land practices around the lake are the largest potential impact that can be controlled. The Deer – Pokegama Study found that a large portion of the phosphorus loading was from precipitation, but that source cannot be controlled.

Priority Impacts to the Lake

The priority impact to Deer Lake that can be improved, would be the expansion of residential housing development in the lakeshed and second tier development along the lakeshore. The conversion of small lake cabins to year-round family homes increases the impervious surface and runoff from the lake lots. Much of the private land around the lake has been developed in the first tier. Some of the second tier remains in large parcels and has not been subdivided for development.

Overall, the development pressure for Deer Lake appears high because of the excellent water quality, and its proximity to Grand Rapids. The housing market has slowed in the past decade, but when it picks up again the pressure to develop around Deer Lake could be high.

Best Management Practices Recommendations

The management focus for Deer Lake should be to protect the current water quality and lakeshed. Efforts should be focused on managing and/or decreasing the impact caused by additional development, including second tier development, and impervious surface area on existing lots (conversion of seasonal cabins to year-round homes).

The current lakeshore homeowners can lessen their negative impact on water quality by installing or maintaining the existing trees on their properties. Forested uplands contribute significantly less phosphorus (lbs/acre/year) than developed land cover (Table 12). Forested uplands can be managed with Forest Stewardship Planning.

In addition, filter strips or native vegetative buffers could be installed to decrease or slow the runoff reaching the water's edge. Septic systems should be pumped and inspected regularly.

The lakeshed still has large undeveloped shoreline parcels (Figure 16). Because a lot of undeveloped private land still exists, there is a great potential for protecting this land with conservation easements and aquatic management areas (AMAs). Conservation easements can be set up easily and with little cost with help from organizations such as the Board of Soil and Water Resources and the Minnesota Land Trust. AMAs can be set up through the local DNR fisheries office.

Project Implementation

The Deer – Pokegama Study identified an implementation plan. It can be found on the Itasca SWCD's website here: http://itascaswcd.org/Programs/DPCWP_Final_7-25-13.pdf.

The best management practices above can be implemented by a variety of entities. Some possibilities are listed below.

Individual property owners

- Shoreline restoration
- Rain gardens
- Aquatic plant bed protection (only remove a small area for swimming)
- Conservation easements

Lake Associations

- Lake condition monitoring
- Ground truthing – visual inspection upstream on stream inlets
- Watershed runoff mapping by a consultant
- Shoreline inventory study by a consultant
- Conservation easements

Soil and Water Conservation District (SWCD) and Natural Resources Conservation Service (NRCS)

- Shoreline restoration
- Stream buffers
- Wetland restoration
- Forest stewardship planning

Organizational contacts and reference sites

Deer Lake Association	http://deerlakeassociation.org/
Itasca County Environmental Services Department	124 NE 4th St., Grand Rapids, MN 55744 (218) 327-2857 https://www.co.itasca.mn.us
Itasca Soil and Water Conservation District	1889 East Highway 2, Grand Rapids, MN 55744 (218) 828-6197 http://www.itascaswcd.org
DNR Fisheries Office	1201 East Highway 2, Grand Rapids, MN 55744 (218) 327-4430 http://www.dnr.state.mn.us/areas/fisheries/grandrapids/index.html
Regional Minnesota Pollution Control Agency Office	525 Lake Avenue South, Duluth, MN 55802 (218) 723-4660 http://www.pca.state.mn.us
Regional Board of Soil and Water Resources Office	1601 Minnesota Drive, Brainerd, MN 56401 (218) 828-2383 http://www.bwsr.state.mn.us