PHASE I
WATERSHED ASSESSMENT
FINAL REPORT

BLUE DOG LAKE
DAY COUNTY, SOUTH DAKOTA

South Dakota Watershed Protection Program
Division of Financial and Technical Assistance
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State of South Dakota
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EXECUTIVE SUMMARY

Blue Dog Lake is a glacial lake located in Day and Robert Counties in northeast South Dakota. The total watershed for Blue Dog Lake is approximately 56,840 acres. Blue Dog Lake is classified as a warmwater permanent fishery. Other beneficial uses include immersion recreation, limited contact recreation, and stock watering and wildlife propagation.

The Day Conservation District was the local sponsor of the Blue Dog Lake/Enemy Swim Watershed Assessment project. As local sponsor the Conservation hired the local coordinator and administered project funds. Funds for the project were from Section 319 Nonpoint Source funds administered by the Environmental Protection Agency (EPA). EPA granted the money to the State of South Dakota for the water quality assessment. The 40% local match needed for the project was provided by the Blue Dog Lake Association and the Enemy Swim Lake Sanitary district.

Results from the study indicated that Blue Dog Lake had excessive nutrients and relatively low sedimentation from the tributaries (approximately 0.5 acre-foot a year). Erosion from the shoreline was also adding sediment to Blue Dog Lake in turn, reducing Secchi disk measurements. From late August of 1997, to May of 1998 approximately 17 acre-feet of Blue Dog Lake's shoreline eroded away. Although algae and chlorophyll *a* production can be quite high in Blue Dog Lake (73 mg/m^3), the particles in the water column appear to limit sunlight penetration in the water which limits algae growth.

There are 25 animal feeding areas in the Blue Dog Lake Watershed. Twelve of these feeding areas had AGNPS ratings greater than 55. These livestock concerns were responsible for 17% of the phosphorus loading and 7.5% of the nitrogen loading to Blue Dog Lake according to the AGNPS model. The water quality samples had fecal coliform bacteria in the majority of the samples collected pointing to animal feeding as a probable nutrient source.

The Agricultural Non-point Source (AGNPS) model agreed with the water quality monitoring in that it predicted very little overall sediment coming from the watershed. However according to the AGNPS model, a few cultivated areas lose higher than acceptable amounts of soil. These areas had very little residual crop cover and slopes greater than 7%. These critical cells input approximately 18% of the total load of phosphorus to Blue Dog Lake. The model reported that these areas were responsible for 8% of the nitrogen load to Blue Dog Lake.

Nutrient loads from the watershed were greatest in the spring with snowmelt and spring rains. The watershed upstream of both Site #6 and Site #5 appear to be inputting the most nutrients in the Owen's Creek drainage. Site #4 is on the other main tributary to Blue Dog Lake with a majority of its water coming from Enemy Swim Lake. However, the watershed upstream of Site #4 did appear to have its own sources of sediment and other nutrient parameters. Although the water exiting Enemy Swim Lake is relatively clean, the amount of water involved made a significant impact to the loadings at Site #4.

The average inlake concentration of phosphorus (0.080 mg/L) is more than enough to support an algal bloom in Blue Dog Lake. The major source of nutrients in the watershed is from animal feeding areas, summer-long grazing, and poor manure management. The AGNPS model rated 25 feedlots in the watershed, and of these, 12 had rankings over 50. The model showed that removal of nutrients from these 12 animal feeding areas should reduce the phosphorus to Blue Dog Lake by 17%.

The recommended target for improving the water quality of Blue Dog Lake is to reduce phosphorus inputs by 30%. Reducing phosphorus inputs by 30% will move the average phosphorus TSI from hypereutrophic to eutrophic. According to the AGNPS model, eliminating feeding areas with rankings over 50 will result in an 17% reduction in phosphorus. Applying no-till practices to 1,640 acres will reduce phosphorus inputs by another 18%. The extra 6% of predicted phosphorus removal could be considered a safety margin to ensure a 30% reduction.

Once the water in Blue Dog Lake stops rising, shoreline protection and restoration practices should be implemented. The sediment inputs from the Blue Dog Lake shoreline were adding to the suspended solids concentration in the lake. Establishment of vegetation around the shoreline should reduce suspended sediment concentrations and add valuable fish habitat to Blue Dog Lake. Long-term monitoring should continue on Blue Dog Lake to track trophic state trends to see if watershed improvements had any impact on the inlake trophic state levels.

ACKNOWLEDGEMENTS

The cooperation of the following organizations and individuals is gratefully appreciated. The assessment of Blue Dog Lake and its watershed could not have been completed without their assistance.

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Introduction

Blue Dog Lake is a 608 hectare (1,502 acre) natural lake located on the eastern central border of Day County in northeast South Dakota (Figure 1). Blue Dog Lake was most likely formed by an ice block from a receding glacier during the Pleistocene Epoch. Blue Dog Lake has a maximum depth of 2.4 meters (8 feet) when the lake elevation reaches the crest of the outlet structure. The mean depth is 1.9 meters (6.2 feet) at that elevation. Blue Dog Lake has approximately 9.5 kilometers (8.7 miles) of shoreline.

The total watershed for Blue Dog Lake is roughly 23,003 ha (56,840 acres). One half of the watershed boundary of Blue Dog Lake extends east into Roberts County. The main tributary to Blue Dog Lake is Owen's Creek. Owen's Creek begins in Roberts County on the western slope of the Waubay Moraine. The Waubay Moraine was left after the advancement of the second and third glaciers of the Pleistocene Epoch. The placation formed the Coteau de Prairies, the major physiographic formation of far eastern South Dakota. The meltwater of the glaciers cut channels and deposited glacial outwash in those channels that connects most of the major lakes in the area through ground water (Leap, 1988)

The outlet of Enemy Swim Lake/Campbell Slough is the other main tributary for Blue Dog Lake. Enemy Swim Lake is located approximately 5 miles north of Blue Dog Lake and has some of the best water quality of any natural lake in the state.

Land use in the watershed is primarily agricultural. The conservation district estimated 35.2% of the land is rangeland, 25.4% is crop, 31.2% is hay or CRP ground, 0.2% woodland, and 8% of the land is in other uses (water, municipalities, and low lake developments). Two small communities are included in the Blue Dog watershed. The city of Waubay is located on the south shore of Blue Dog Lake, although only a small corner of the town is actually in the watershed. The town of Ortley is located 4 miles west and 1 mile south of the Owen's Creek inlet to Blue Dog Lake. According to the 1998-1999 Municipal Directory, Ortley has a population of 63 people (SDML, 1998). The south and east shores of Blue Dog Lake are lined with cabins. The lake cabins were connected to a central wastewater collection system in 1992.

Land ownership in the watershed is diverse. The conservation district estimated 83% private, 7.5% tribal, 3% state, and 6.5% federal. The state and federal lands are mostly small game and waterfowl production areas. Tribal lands are intermixed with privately owned lands.

The climate for the Blue Dog watershed basin is classified as sub-humid. Temperatures can be extreme, varying from over 35°C (95°F) in the summer to –40°C (-40°F) in the winter. The Day County has an average 120 to 130 growing days per year. Precipitation in the area averages 0.5 meters (21 inches) annually with 70 to 75% falling during the growing season. Snowfall is extremely variable. While snowfall averages 0.8 meters (33 inches) it can vary from 0.25 meters (10 inches) as in 1941 to 2.5 meters (71 inches) in 1936. The humidity average ranges from 50% to 65% in the afternoon (summer and winter respectively), to 85% to 80% in the morning (summer and winter). The wind speed averages 11 to 12 miles per hour but may reach as high as 50 miles per hour any month of the year. Most of the high wind speeds occur during summer storms (Spuhler, 1971).

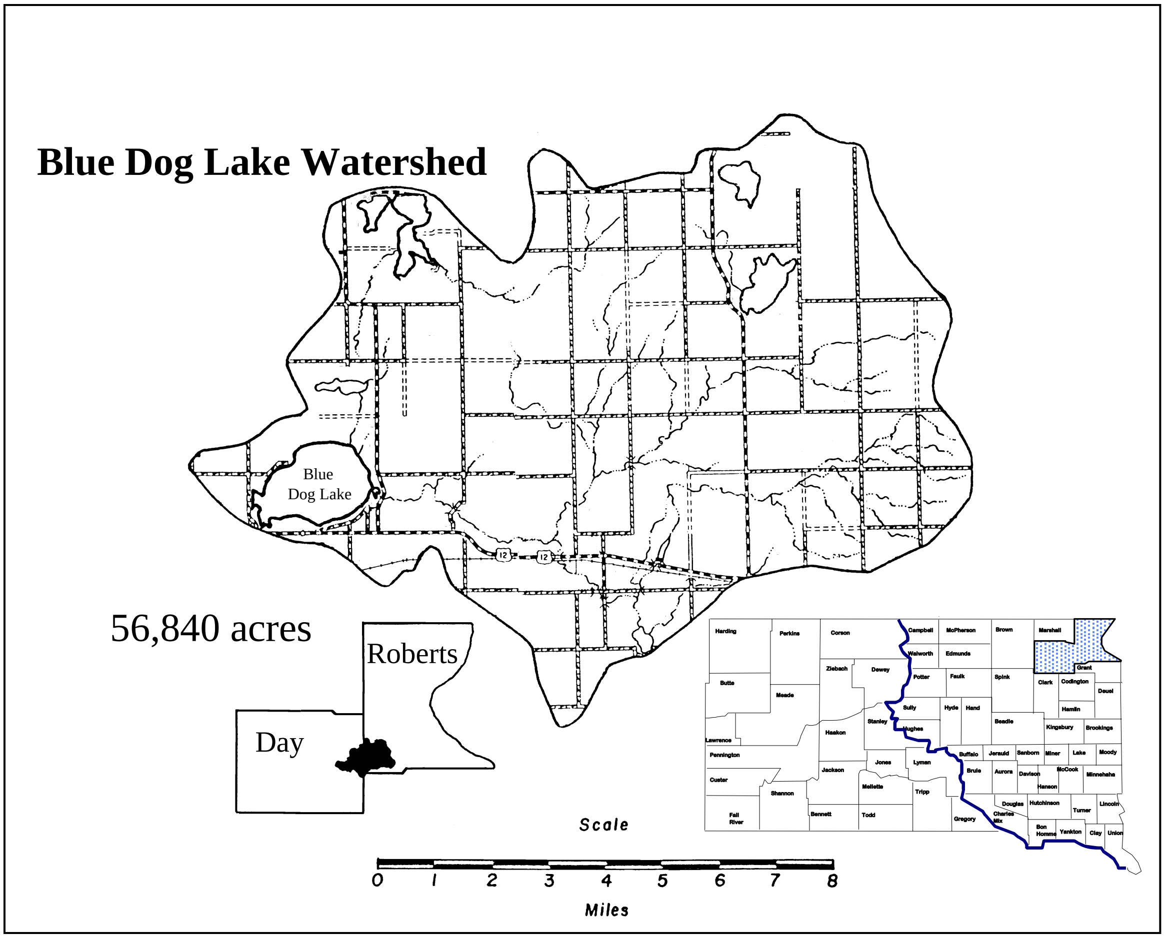


Figure 1. Location of the Blue Dog Watershed.

Blue Dog Lake is classified as a warmwater permanent fish life propagation water. There is extensive cabin development along the shores of Blue Dog Lake and the lake is home to the Blue Dog State Fish Hatchery.

The joint Blue Dog/ Enemy Swim Watershed Assessment was initiated in 1996. EPA Section 319 Nonpoint Source Funds totaling $70,000 were secured for the project. The 319 funds paid for 60% of the total project, requiring the local sponsor to secure the remaining 40% as non-federal match dollars. Day Conservation District agreed to sponsor the project with cash support for $20,000 from both the Blue Dog Lake Association and the Enemy Swim Sanitary District. In-kind services were also used as non-federal dollars. In-kind services came from the Blue Dog Lake Association, SD Dept. of Game Fish and Parks, Day Conservation District, Bud’s Resort, Coast Auto, and the project coordinator. The conservation district secured an additional $5,000 of federal 604(b) special project money to complete a septic leachate survey on Enemy Swim Lake.

This report will only include results and conclusions for Blue Dog Lake. A separate report will address results of the Enemy Swim Lake portion of the study.

Historical Information

Blue Dog Lake was named in honor of a Sioux Indian Chief named Blue Dog. In the early 1900's, Blue Dog Lake was home to a very nice resort on the south side. The resort had a large pavilion, ball grounds, a tourist park and a number of cottages. The lake was said to have very good fishing for pickerel, northern pike, perch and bullhead. During the summer months the lake was used by community clubs, for picnics and conventions (Ochsenreiter, 1926). The south and east shores of Blue Dog Lake are presently well developed with cabins. In 1992, a central wastewater collection system was completed around the lake. The system was tied into the City of Waubay's wastewater treatment plant. Sewage entering Blue Dog Lake from local homes should no longer be an issue.

The outlet of Blue Dog Lake has been operated as a variable control structure since 1944. An investigation of the ordinary high water mark on Blue Dog Lake took place in the winter of 1980. According to the investigation, the water elevation of Blue Dog Lake has varied between 1799.6 and 1800.35 above mean sea level (MSL). Evidence of erosion along the lakeshore was found between elevations of 1800.4 and 1801.4 MSL. The ordinary high water mark was set at 1800.7 above MSL on February 1981. A fixed elevation structure (concrete flat weir) was installed in 1981 at 1800.2 MSL. Since the structure was installed, it was re-surveyed and found to have an elevation of 1799.93 MSL.

The historic low elevation of Blue Dog Lake was recorded in October 1935, at 1794.3 feet above MSL. During the period of the study, lake elevation reached record heights. In May 1998, the lake level was recorded at 1802.9 feet above MSL. The variation in lake water levels throughout the history of Blue Dog Lake was responsible for severe shoreline erosion along the banks of the lake. Further discussion on lake elevations and shoreline erosion will be presented later in the report.

Fisheries Data

The latest fisheries data was collected from Blue Dog Lake in 1996. The results and discussion of the survey are presented below. The complete report is given in Appendix B. Walleye comprised 60.2% of the fish collected in gill nets in 1996. The lengths of the fish were from 13 to 54 cm (5-21 inches). Gill net results showed good fish size structure with the majority of fish from the 1994 year-class (46%) and the 1991 year-class (24%). Growth was slightly slower than in other lakes of the region. However, with recent evidence of natural reproduction and continued stocking the walleye fishery in Blue Dog Lake should be exemplary.

The 1996 northern pike surveyed in Blue Dog Lake had the highest catch per net of any lake surveyed in the area (length ranged from 30 to 72 cm (12-28 inches). The survey indicated the size distribution of the northern pike is slightly skewed toward larger individuals although there seems to be consistent growth in all populations. The higher water levels in Blue Dog Lake in the last few years had greatly increased northern pike reproduction and promise to maintain the lake as a good fishery.

Despite increasing water levels in Blue Dog Lake, the yellow perch population remains low. According to survey information there seems to be good year class reproduction, however, the populations do not seem to materialize into fishable adult numbers. The 27 fish collected were largely comprised of adult fish with lengths ranging from 9 to 30 cm or 3.5 to 12 inches. The most likely reasons for the loss of young fish were most likely heavy predation from walleye, northern pike, a growing white bass population, and lack of weed cover in the lake. Although anglers seem pleased with the size of the fish they catch, the relatively low numbers of fish prevents Blue Dog Lake from becoming a good perch fishery.

White bass populations sampled in 1996 were the highest record since the annual survey began in 1992. High water levels appear to aid in increasing the population of white bass with many fish growing to a catchable size. This population may present angling with an opportunity and young-of-year may provide important forage for walleye.

Lake herring, introduced in 1991 via the fish hatchery, reached their population peak in 1994. Warmer summers and high predator fish populations may eventually expunge this cold water fish from the lake.

Carp, though sampled in low numbers, are believed to exist in larger concentrations. White suckers were abundant and are probably an important forage species. Black bullheads, rock bass, and black crappie were not very abundant and contribute little to the fishery.

The South Dakota Game, Fish and Parks (SD GFP) recommends that Blue Dog Lake be managed for walleye and northern pike. SD GFP also recommends the removal of carp, and that the lake be resurveyed annually. (SD GFP, 1997)

Shoreline Erosion

Blue Dog Lake experienced eroding shoreline from fluctuating water levels since the first control structure was installed in 1944. With increasing lake levels, shoreline slopes were eroded and banks began to fall into the lake. During this assessment water levels in the lake reached historic highs. The snowfall of 1996-1997 was one of the heaviest on record. Lake basins throughout the region that were only marshes filled to become viable recreation water bodies. Following the 1996-1997 winter, the region received above average precipitation and lake levels in the area continue to rise. Figure 2 displays a chart of the recorded lake levels since 1933.

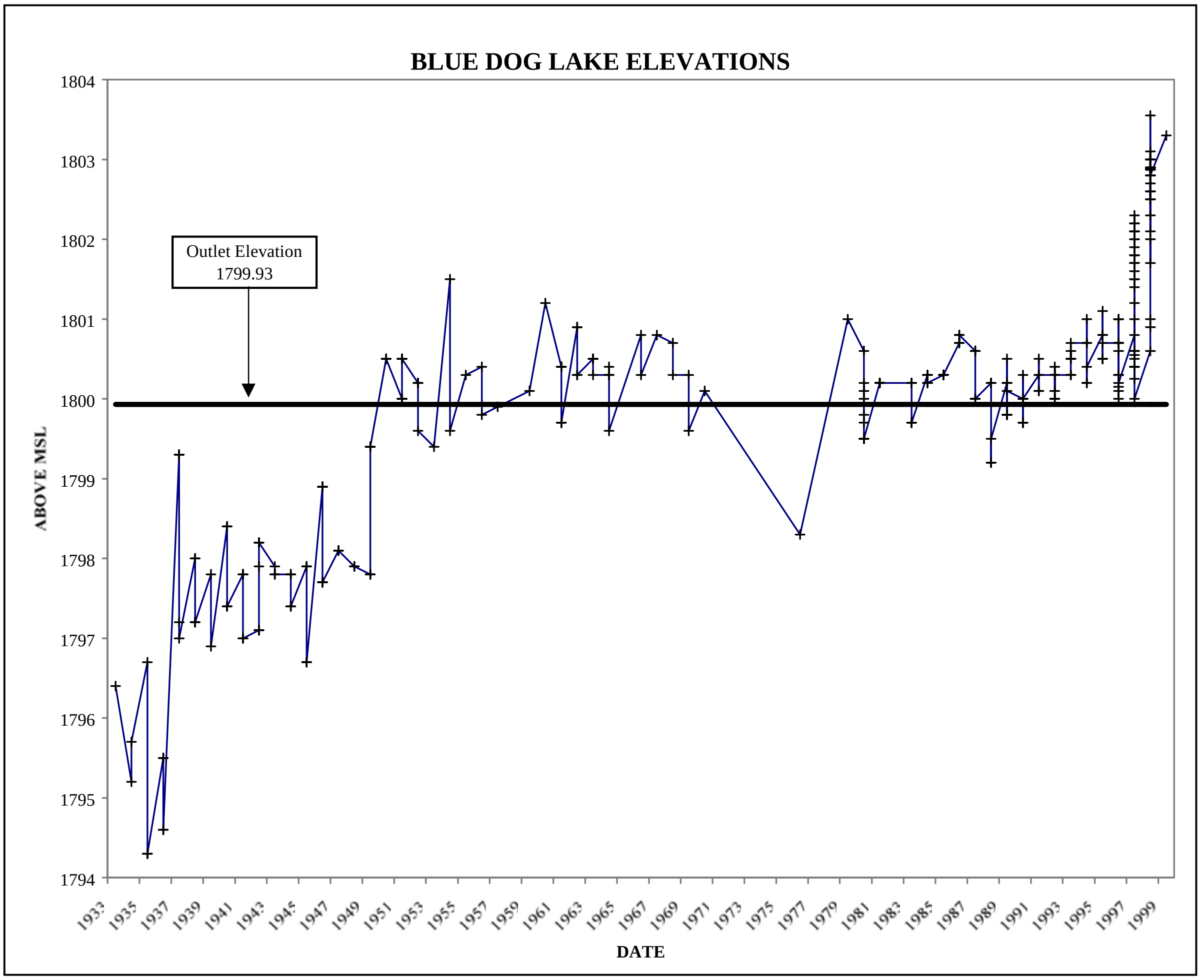


Figure 2. Historical Elevations of Blue Dog Lake

To help estimate the loss of shoreline during the sampling period, three-foot sections of rebar were placed at four sites along Blue Dog Lake's shoreline during late summer 1997 (Figure 3).

Site 1 was located along the lake's south shore, west of the city park boat ramp. Sites 2 & 3 were located in a large cut bank on the lake's north shore. This site was actively eroding during the assessment project. Site 4 was located just south of the Owen's Creek inlet on the lake's southeast shore. Site 5 was located on the lake's southwest corner. By May 1998, all of the rebar was either completely exposed or had washed into Blue Dog Lake. Severe shoreline erosion occurred as the lake rose approximately three feet during the 1998 spring snowmelt. On average, ten feet of shoreline was lost along approximately 7 miles of the lake's 8.7-mile shoreline. Eroding banks varied in height from 0.5 feet to 8 feet. It is estimated at least 20,813 m^3 (735,000 cubic feet) of earth eroded from the lake's shoreline during the summer of 1998. Cabin and lake property

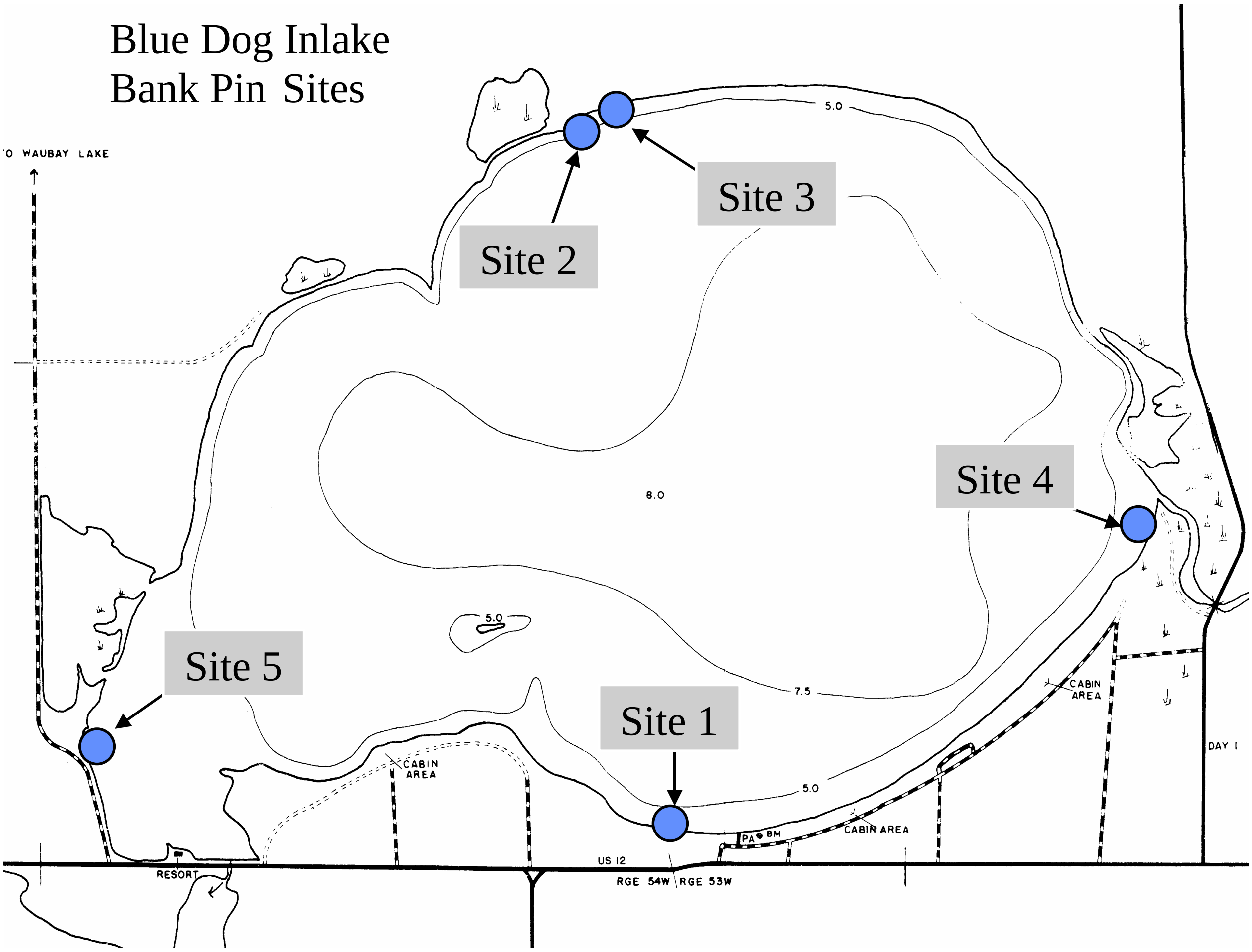


Figure 3. Bank Pin Locations

owners spent several thousand dollars on riprap in an effort to protect their property from erosion. The Day Conservation District provided information on shoreline protection, however in many cases riprap of insufficient size and type was used. Many of these sites will probably fail in the near future. Photographs in Appendix C show shoreline erosion occurring along Blue Dog Lake's shores.

Several lake homes and cabins were flooded during the spring snowmelt of 1998. Four residences have been removed from the lakeshore and relocated elsewhere. Little aquatic vegetation was found along the shores of Blue Dog Lake and riparian vegetation had been altered or removed along the lake's populated south shore. Shoreline erosion can be expected to continue until the lake level recedes by natural means or flooding is relieved through downstream drainage.

It should be noted, Blue Dog Lake property owners have expressed interest in dredging Blue Dog Lake to reclaim depth lost to present and past shoreline erosion and sedimentation.

Methods and Materials

Hydrologic Data

Seven tributary locations were chosen for collecting hydrologic and nutrient information from the Blue Dog Lake watershed (Figure 4). Due to the large size of the watershed,

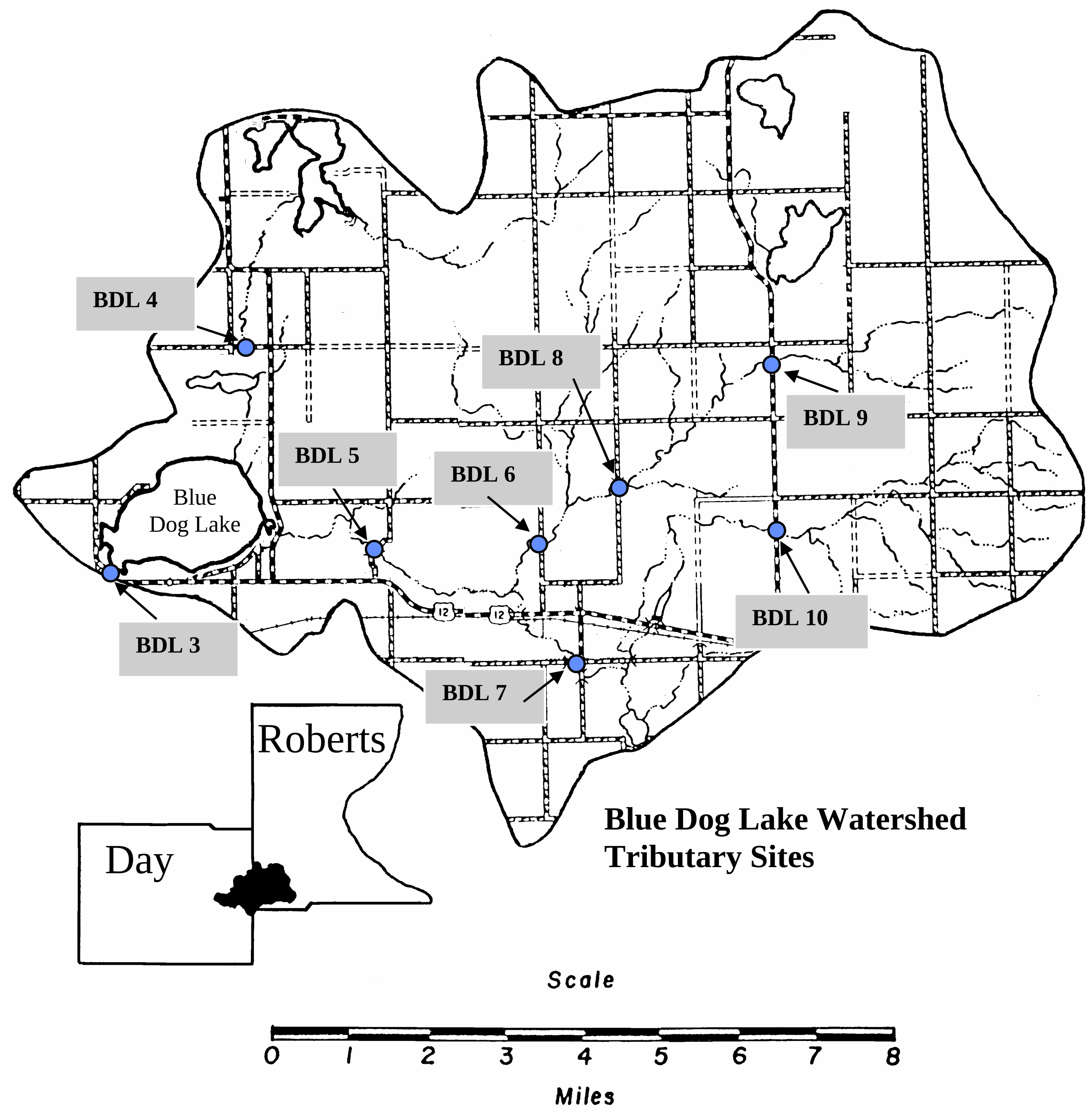


Figure 4. Tributary Site Locations.

tributary site locations were chosen that would best show watershed managers which subwatersheds were contributing the largest nutrient and sediment loads. Stevens Type F paper graph recorders were placed at six of the sites to record the water height. The recorders were checked weekly to change the graph paper and reset the chart. After the chart was changed, daily averages were calculated to the nearest 1/100th of a foot. An Omnidata data logger with a transducer was placed at the main inlet of Owen's Creek to Blue Dog Lake. Daily averages were calculated from Stevens Recorder graph paper and after the loggers were downloaded to a laptop computer. A Marsh-McBirney flow meter was used to measure water discharge at different stage heights at all tributary sites. Discharge data were collected according to South Dakota's *Standard Operating Procedures for Field Samples*. Actual discharge measurements were entered into a regression equation and a stage discharge table was produced for each site (Appendix D). The stage discharge table was used to calculate an average daily loading for each site. The daily loadings were then totaled for an annual loading.

As with every project, problems arise when trying to collect accurate discharge data. Site #8, located between Sites #6 and #9 was affected by beaver dams throughout the project. Because the site did not have consistent flow, a stage discharge table could not be calculated and thus, no daily loading were calculated. Site #4 experienced similar beaver problems at different times during the project. Spurious data was removed, and at times, daily loadings were calculated by averaging flows between discharge measurements. Stage and discharge data were collected from late summer of 1996 to late summer of 1998. The stage recorders, installed each spring, were removed in the fall before temperatures caused water to freeze in the stilling basin.

Outlet data for the Blue Dog Lake spillway was calculated by using the following standard equation:

{**Equation 1**}

$$Q = C * L * \left(H^{3/2}\right)$$

Where: Q = Flow in CFS
L = Length (150 feet)
H = Stage Height
C = Coefficient
C = 2.6

In 1997 and 1998, nearby Rush Lake reached an elevation matching Blue Dog Lake's outlet, causing a back flow situation. The instantaneous discharge measurements collected during 1997 and 1998 were averaged between measurements. The discharge rating tables for all of the sites, including the outlet can be found in Appendix E.

Water Quality Sampling

Samples collected at each site were taken according to South Dakota's EPA approved *Standard Operating Procedures for Field Samplers*. Water samples were sent to the State Health Laboratory in Pierre for analysis. Quality Assurance/Quality Control samples were collected for 10% of the samples according to South Dakota's EPA approved *Non Point Source Quality Assurance/Quality Control Plan*. These documents can be referenced by contacting the South Dakota Department of Environment and Natural Resources at (605) 773-4254.

Agricultural Non-Point Source Model (AGNPS)

In addition to water quality monitoring, information was collected to complete a comprehensive watershed land use model. The AGNPS model was developed by the United States Department of Agriculture (Young et al, 1986) to give comparative values for every forty-acre cell in a given watershed. Twenty-one parameters were collected for every 40-acre cell in the watershed.

The twenty-one main parameters included:

1) Cell Number
2) Receiving Cell
3) Aspect Ratio
4) NRCS Curve #
5) Land Slope
6) Slope Length
7) Slope Shape
8) Manning's Coeff.
9) Soil Erodibility
10) Cropping Factor
11) Practice Factor
12) Surface Constant
13) Soil Texture
14) Fertilizer Level
15) Available Fertilizer
16) Point Source
17) Gully Source
18) COD Factor
19) Impoundment
20) Channel Indicator
21) Channel Slope

The point source indicator (16) cell lets the data collector enter a value if an animal feeding area is present in the cell. If the cell does contain an animal feeding area, there are approximately eight more parameters to collect on the feeding area. These parameters are:

1) Cell Number
2) Feedlot Area
3) Curve Number
4) Roofed Area
5) Area of land contributing water through the lot
6) Buffer Data
7) Area of land between the lot and channeled flow
8) Animal Data

Parameters 5, 6, and 7, in the feedlot section may require multiple sets of sub data if the curve numbers change over the land areas. The animal data (#8) may also require multiple parameters depending on how many different types of animals are in a given feeding area.

If one cell contains two different values for the same parameter, such as soil curve number, the local coordinator takes the value that covers the majority of the cell. Each 40-acre cell was given an export value for phosphorus, nitrogen, and suspended solids. After the report is completed, the cells with high export values are field checked to make sure the model highlights the correct problem areas in the watershed. The export values of each subwatershed are compared to each other and to the water quality data on a relative basis only.

Findings from the AGNPS report can be found throughout the water quality discussion. The conclusions and recommendations will rely heavily on the AGNPS data. The entire AGNPS report can be found in Appendix A.

Seasonal Water Quality

Different seasons of the year can yield differences in water quality due to changes in precipitation and agricultural practices. To discuss seasonal differences, Blue Dog Lake samples were separated into spring (snowmelt – May 31), summer (June 1 – August 31), and fall (September 1 – October 31). The Blue Dog Lake watershed experienced heavy snows during the 1996 – 1997 winter. A wet pattern continued into 1998. During the project, 65 samples were collected in the spring samples, 53 samples in the summer months and 55 samples in the fall months. The summer and fall samples were collected after heavy rainfall that occurred in scattered areas of the watershed. Not all sites were sampled during every runoff event in the summer and fall due to the scattered rains and intermittent flow.

Concentrations

Sediment and nutrient concentrations can change dramatically with changes in water volume. Large hydrologic loads at a site may have small concentrations; however, more water usually increases nonpoint source runoff and thus higher loadings of nutrients and sediment. The average and median concentrations of different parameters changed with the seasons as shown in Table 1.

Dissolved oxygen concentrations were highest in the spring. This is most likely due to the heavy flow of the water, becoming aerated as it moves along the stream. The lower oxygen concentrations in the summer were most likely due to warm water temperatures, decomposition of organic matter and lower flows.

The alkalinity seems to be related to surface and ground water runoff. The highest concentrations were in the fall when the ground water levels were most likely the highest. Ground water typically has higher alkalinity than rainwater because of dissolved minerals in the soil.

Table 1. Seasonal Mean and Median Tributary Concentrations.

Parameter	Spring			Summer			Fall		
	Count	Mean	Median	Count	Mean	Median	Count	Mean	Median
Diss. Oxygen	65	10.10	10.40	55	8.29	8.20	53	9.52	9.60
Field pH	65	7.93	7.86	54	8.12	8.03	53	8.01	8.04
Alkalinity	65	182	188	55	237	240	53	245	254
Total Solids	65	257	260	55	336	333	53	365	360
Susp. Solids	65	15	8.5	55	25	14	53	21	14
Ammonia	65	0.04	0.01	55	0.016	0.01	53	0.05	0.01
Nitrate-Nitrite	65	0.47	0.30	55	0.67	0.30	53	0.81	0.30
Total Kjeldahl – N	65	0.74	0.69	55	0.75	0.63	53	0.88	0.78
Total Phosphorus	65	0.122	0.083	55	0.123	0.109	53	0.130	0.111
Total Diss. Phosphorus	65	0.057	0.044	55	0.052	0.040	53	0.068	0.051
Fecal Coliform	53	938	20	55	3,443	430	48	3,325	425

*Highlighted areas are the seasons that recorded the highest concentrations for a given parameter.

Like alkalinity, higher total solids concentrations in the fall are most likely due to ground water. The summer had lower concentrations most likely from rainwater, which, like alkalinity, typically has lower concentrations than ground water springs. The summer samples had the highest concentrations of suspended solids. Intense rains on agricultural lands typically cause higher erosion and thus higher suspended solids in the water. Although the concentrations of suspended solids are not extremely high, the largest concentrations during the wet years of 1997 and 1998 added to the sedimentation in Blue Dog Lake.

The average nitrogen concentrations are highest in the fall. The fall average concentration of ammonia was 0.05 mg/L. The highest ammonia concentration collected was also in the fall (0.65 mg/L). This sample, collected on September 3, 1996, was 8 times higher than the standard deviation, showing the sample was unusual for the sample set. Ninety percent of the other samples were below 0.10 mg/L and most were below the State Health Laboratory detection limit. Sources for high ammonia concentrations could be animal feeding areas, decomposition of organic matter, or runoff from applied fertilizer.

Nitrate-nitrite showed much more variability than ammonia. The fall season had the highest mean and median. The range of the nitrate-nitrite in the fall was from a minimum of 0.05 mg/L to a maximum of 6.0 mg/L. The maximum sample was collected at Site #10 on September 30, 1996. Site #10 appears to have a source of nitrate. Often this source greatly increased the value of nitrate but none of the other nutrient parameters. The maximum nitrate concentration in the spring was 5.4 mg/L and the maximum sample in the summer was 5.1 mg/L, both maximums occurred at Site #10. A very likely source of these high nitrates might be from over-fertilization and pivot irrigation systems upstream of Site #10.

Total Kjeldahl Nitrogen (TKN) is composed of mostly organic nitrogen. There was very little seasonal difference in TKN in the Blue Dog watershed sampling. TKN had the highest concentrations in the fall. The highest concentration (2.97 mg/L) of any TKN sample collected during the project period occurred on September 24, 1996. Because the sample occurred in the fall, it is difficult to say if the higher organic concentrations were from decaying organic matter in the drainage area or directly from animal waste. Since fecal coliform bacteria were found in almost every fall sample, animal waste is a likely source.

Total phosphorus and dissolved phosphorus concentrations were highest in the fall. The mean fall concentrations were 0.130 mg/L and 0.068 mg/L for total phosphorus and total dissolved phosphorus, respectively. Higher phosphorus concentrations often coincide with higher fecal coliform concentrations. As stated in the TKN discussion, high fecal coliform concentrations were found throughout the sampling period. When elevated phosphorus samples were found without high fecal coliform concentrations, high suspended solids concentrations were usually present. These samples point to suspended solids as the major carrier of phosphorus.

Fecal coliform concentrations were highest in the summer. The mean and median of the summer samples were 3,443 and 430 colonies/100ml respectively. Fall samples had a similar mean and median, 3,325 and 425 colonies/100ml. These means and median are extremely high when compared with data from other watershed assessment projects. Season-long grazing, runoff from animal feeding areas and poor manure management were the most likely sources of these high fecal coliform counts. There does not seem to be any real seasonal pattern to the high fecal concentrations. High fecal concentrations were found from February to October. Site #6 seems to have an inordinate number of high fecal concentrations. Out of the 10 highest fecal bacteria concentrations, nine were collected at Site #6.

Inlake Seasonal Comparison

Two water quality sites were established in Blue Dog Lake (BDL-1 and BDL-2). The data from the two sites were combined because the concentrations of measured parameters from those two sites were very similar and showed little if any variation. Seasonal inlake variations are shown in Table 2.

Table 2. Comparison of Inlake Seasonal Concentrations.

Parameter	**Winter**		**Spring**		**Summer**		**Fall**	
	Mean	Median	Mean	Median	Mean	Median	Mean	Median
Water Temperature (°C)	0.78	1.00	14.5	15	21.7	21.5	12.7	12.75
Dissolved Oxygen	9.83	9.00	10.1	9	8.24	8.3	9.16	9.1
pH	7.92	7.80	8.34	8.38	8.52	8.50	8.53	8.51
Secchi Disk (m)	-	-	0.80	0.82	0.33	0.30	0.27	0.27
Alkalinity	211	230	195	202	217	216	223	223
Total Solids	331	408	276	273	328	324	341	344
Susp. Solids	3.9	5.0	9.0	7.0	28.25	29.5	31.88	30.50
Ammonia	0.19	0.05	0.01	0.01	0.01	0.01	0.02	0.02
Nitrate-Nitrite	0.76	0.60	0.08	0.08	0.09	0.10	0.25	0.25
Total Kjeldahl–N	0.77	0.80	0.52	0.59	1.07	0.96	0.72	0.78
Total Phosphorus	0.077	0.086	0.048	0.050	0.085	0.089	0.106	0.106
Total Diss. Phosphorus	0.064	0.051	0.016	0.015	0.031	0.033	0.045	0.045
Fecal Coliform (colonies/100ml)	5	5	8.3	5	18.75	7.5	71.25	15
Chlorophyll *a*	[1]15.75	[1]15.75	[2]0.67	[2]0.067	[3]31.97	[3]20.44	[4]12.86	[4]13.07

*Highlighted areas are the seasons that recorded the highest concentrations for a given parameter.

[1] One winter sample collected (02/20/97).

[2] Two spring samples collected (both on 06/05/97).

[3] Seven summer samples collected.

[4] Five fall samples collected.

With a few obvious exceptions, there are very few seasonal differences between inlake mean concentrations. Obviously, the water temperature was coolest in the winter and warmest in the summer. Dissolved oxygen and pH showed little variation through all four seasons.

Secchi disk depth was greatest in the spring. Secchi depth decreased in the summer and to a lesser degree in the fall, due to increased algal production and suspended sediments caused by wind and wave action. The influx of spring runoff waters most likely lowered the alkalinity and total solids. The volume of the lake was greatest in the spring, which increased the dilution factor. Also, fresh water runoff typically has lower total solids and alkalinity concentrations. Since ground water generally has higher concentrations of alkalinity and total solids, the ground water entering the lake during fall most likely increased the mean inlake concentrations of both parameters.

Suspended solids concentrations were higher in the summer and fall. As explained above with regard to the Secchi depth, algal production and suspended sediments in the water column were responsible for the increase in total suspended solids. Because sediment carries a higher phosphorus load, the inlake suspended sediments were most likely responsible for the seasonally high total phosphorus concentrations. The total dissolved phosphorus concentration is highest in the winter when sediments are shielded from wind and waves by ice. In addition, decomposition of organic matter may cause an increase in dissolved phosphorus concentrations.

Ammonia concentrations were greatest in the winter. Decomposition of organic matter releases ammonia into the water column. Anaerobic conditions near the sediment greatly increase this process. Nitrate levels were also highest in the winter. Certain bacteria, nitrobacter and nitrosomonas, convert ammonia to nitrite and nitrate (NO_2 and NO_3) through a process called nitrification. The nitrification process most likely caused these higher nitrate levels.

The highest chlorophyll *a* levels in Blue Dog Lake coincided with the highest Total Kjeldahl Nitrogen (TKN) concentration and second highest total phosphorus concentration. TKN is ammonia plus organic forms of nitrogen. Since ammonia concentrations are typically a small percentage of TKN, TKN is often used as a measure of organic nitrogen in a water sample. As chlorophyll-producing algae are organic organisms, it is not unusual for the TKN concentrations to mirror chlorophyll *a* concentrations.

Fecal coliform bacteria concentrations were greatest in the fall. Fall samples in both 1996 and 1997 had concentrations greater than any other inlake sample collected. Fecal bacteria come from the intestine of warm-blooded animals. Since the lake has a central wastewater collection system, human waste is not as plausible a source as animal waste. Many of the tributary samples collected in the fall were high in fecal bacteria. The tributary flow may have been great enough to collect fecal coliform from one of the high runoff events. Summer samples had the second highest seasonal average. The winter samples had no detectable fecal concentrations. Zero inflow from the tributaries during winter months is more evidence that the fecal coliform colonies recorded in the summer and fall months come from the watershed.

Tributary Water Quality

South Dakota Water Quality Standards

Owen's Creek, from Blue Dog Lake to S17, T122N, R52W, is given the beneficial uses of warmwater permanent fishery, and limited contact recreation. All waters of the state are also given the beneficial uses of stock watering and irrigation. The following table lists the most stringent water quality parameters that apply. Only Sites #5 and #6 fall under the South Dakota warmwater permanent fishery beneficial use standard. The remaining sites (Figure 4) have irrigation and wildlife and stock watering as their only assigned uses.

Table 3. South Dakota Water Quality Standard Limits for Sites #5 and #6.

Parameter	Limits
Unionized ammonia	< 0.04 mg/L
Dissolved Oxygen	> 5.0 mg/L
pH	> 6.5 and < 9.0 su
Temperature	< 26.67 ^{o}C
Suspended Solids	< 90 mg/L
Total Dissolved Solids	< 2,500 mg/L
Nitrates	< 50mg/L
Alkalinity	< 750 mg/L
Fecal Coliform	[1]< 2,000 counts/100 ml (grab)

[1] The fecal coliform standard is in effect from May 1 to September 30.

Table 4. South Dakota Water Quality Standard Limits for All Other Sites.

Parameter	Limits
Nitrates	< 50mg/L
Alkalinity	< 750 mg/L
pH	> 6.5 and < 9.0 su
Total Dissolved Solids	< 2,500 mg/L

Unionized ammonia is the fraction of ammonia that is toxic to aquatic life. The concentration of unionized ammonia is calculated and dependent on temperature and pH. As temperature and pH increase so does the percent of ammonia which is toxic. In 173 samples collected at all sites in the watershed, there was no exceedence of the un-ionized ammonia standard. There were also no exceedences of the nitrate and alkalinity limits. The maximum values for nitrates and alkalinity were 6.0 mg/L and 305 mg/L respectively.

There were exceedences of the dissolved oxygen standard for Sites #5 and #6. Dissolved oxygen concentrations below 5.0 mg/L were recorded on three occasions at Site #7. Site #7 is less than two miles from the section of Owen's Creek designated as a warmwater permanent fishery. Biological demand on oxygen due to animal waste is the most likely cause of the low dissolved oxygen concentrations.

Site #5 had one exceedence of pH (9.31 su) on September 16, 1997. The exceedence was 0.31 su above the recommended standard. Conditions in a ponded area of water just upstream of the site may have been optimal for an algae bloom causing the pH to rise. There was no temperature exceedence of the State Water Quality Standards at Sites #5 and #6. Site #7 and the series of sites 4a, 4b, and 4c experienced temperatures over 26.67°C. There is no water quality standard for these tributary segments.

Four exceedences of the suspended solids standard were found at Site #6 during the project period. Table 5 shows the date and concentration of suspended solids that resulted in the standards exceedence.

Table 5. Site #6 Suspended Solids Exceedences

Date	Event	Suspended Solids Value
8/14/97	Storm	90 mg/L
8/29/97	Storm	178 mg/L
10/8/97	Storm	162 mg/L
10/5/98	Storm	118 mg/L

The dates of the exceedences were during storm events. Volatile solids analysis showed approximately 75% of the solids was sediment and 25% were organic. The higher suspended solids were from eroding croplands, poor grazing management, or animal feeding areas. High fecal coliform concentrations were found on two of the same dates listed in Table 5. There were no samples with exceedences for dissolved solids during the project. The mean and maximum concentrations of dissolved solids were 315 mg/L and 889 mg/L, respectively.

Table 6. Fecal Coliform Exceedences

Site	Date	Event	Concentration Colonies/100 ml
BDL-5	10/30/96	Storm	10,000
BDL-5	8/14/97	Storm	2,800
BDL-5	5/12/98	Storm	2,900
BDL-5	10/5/98	Storm	7,200
BDL-6	9/4/96	Base Flow	5,600
BDL-6	10/30/96	Storm	42,000
BDL-6	7/16/97	Base Flow	20,000
BDL-6	8/14/97	Storm	11,000
BDL-6	8/27/97	Base Flow	24,600
BDL-6	9/15/97	Storm	4,200
BDL-6	5/12/98	Storm	38,000
BDL-6	8/3/98	Storm	59,000
BDL-6	8/22/98	Storm	37,000
BDL-6	10/5/98	Storm	46,000

Fecal coliform bacteria standards were exceeded 14 times during the project. Most of the exceedences took place in the summer and fall. Dilution most likely keeps the concentrations down in the spring. Table 6 shows when, where, and during what event (base flow or storm event) that a sample was collected. Site #6 was a major influence on the fecal coliform concentrations at Site #5. Site #5 is downstream of Site #6 and experienced exceedences on the same dates Site #6 had exceedences. Site #6 had exceedences on both base flow and storm event days; however, the exceedences were only passed on to Site #5 during storm events. Runoff from animal feeding areas, cattle pastured in the riparian area, poor manure management, or waste from beavers and other wildlife may be responsible for the high fecal concentrations. Cattle were most likely the source because the fecal concentrations were highest during storm events. If beaver or other wildlife were the source, fecal concentrations would be diluted because the runoff would not cause an increase in fecal coliform concentrations.

Discussion of Water Quality by Tributary Site

Site #10

Site #10 is a tributary site on the southeast part of the watershed. Site #10 drains approximately 2,950 hectares or 7,280 acres (Figure 5). Site #10 drainage comprises approximately 13% of the total Blue Dog Lake watershed area. Approximately 1.2% of the total discharge to Blue Dog Lake passes through Site #10. The comparisons of the total load from the watershed as a percent loading of solids and nutrients in 1997, were as follows; Total Solids (1.4%), Total Suspended Solids (0.3%), Ammonia (0.9%) Nitrate-Nitrite (15.4%), TKN (0.6%), Total Phosphorus (0.5%) and Total Dissolved Phosphorus (0.6%). The average concentration of fecal coliform bacteria for the entire project period at Site #10 was 13 colonies/100 ml, the median for the site was 60 colonies/100 ml.

As can be seen from the percent loadings, Site # 10 plays a very small role in the loadings to Blue Dog Lake. The only parameter that had an inordinate amount of loading in the drainage was nitrate. With only 1.2% of the watershed hydrologic load, Site #10, had a nitrate loading of 15% of the total nitrate loading to the lake. The average concentration of nitrate at Site #10 was 2.44 mg/L. The closest mean at any other site was 0.69 mg/L (Site #6). Upon investigation, it was found that two pivot irrigation systems are located in the drainage. Ground water samples collected at a well close to Site #10 had nitrate levels of 3.5 mg/L in August 1997, 12.9 mg/L in May 1993, and 9.14 mg/L in August of 1993 (Gilbertson, 1996). Nitrate leaching into the ground water is the most likely cause of the elevated level. If surface water were influencing the nitrate levels, samples collected during runoff

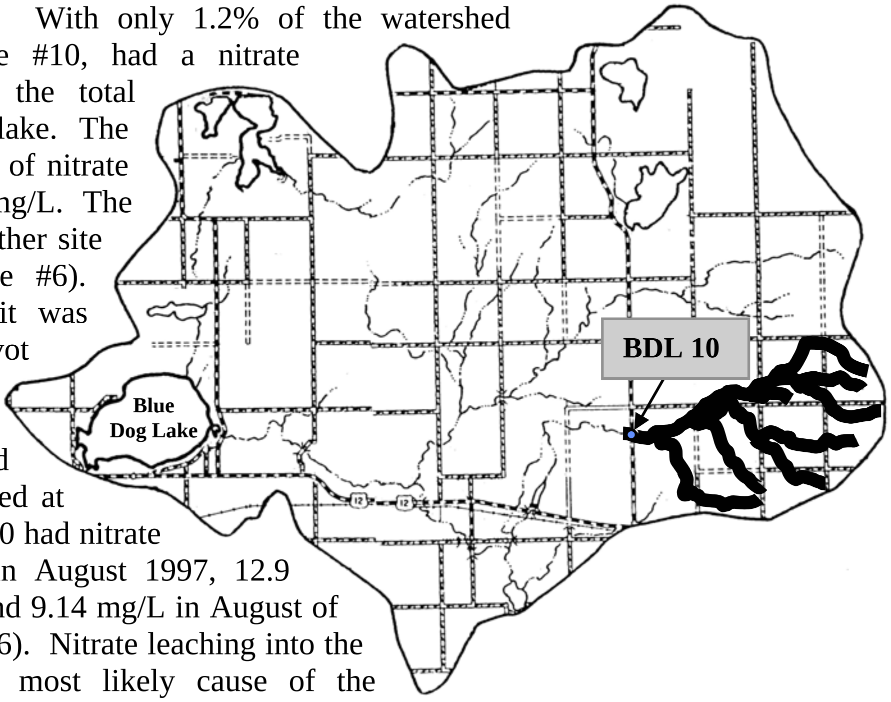


Figure 5. Location of Site #10.

events would be higher than samples collected during base flow. The average base flow concentration was 3.23 mg/L and the average storm runoff sample was 1.41 mg/L. This is evidence of higher concentrations in ground water effecting the water samples collected at Site #10.

Fecal coliform bacteria concentrations were lowest at Site #10 when compared to other tributary sites during the project. The fecal bacteria that were found in samples were most likely from cattle grazing in watershed. The suspended solids total for 1997 at Site #10 is 2,423 kg (2.67 tons). Using 135 lbs/ft^3 of sediment (Kuck, 1998), and estimating approximately 5,342 pounds of sediment passing through Site #10, the 1997 export of sediment toward Blue Dog Lake is approximately 1.12 cubic meters (m^3) or 39.6 ft^3. As with other parameters coming from Site #10 the loadings to Blue Dog Lake are extremely small.

Seasonally in 1997, the largest amount of water passed through the site in the spring 224,934 m^3. The summer had a seasonal volume of 182,519 m^3 and the fall had the least seasonal volume of water with 48,959 m^3. Seasonal loadings for solids parameters were greatest in the spring. However, nutrient parameters including nitrate, TKN, total phosphorus, and total dissolved phosphorus had the largest loadings in the summer. Fecal coliform bacteria concentrations also had the highest average in the summer at Site #10.

According to the AGNPS model, there were two animal feeding areas in the Site #10 watershed. One animal feeding area in the watershed rated 66. During the project, any feeding area rated over 50 was considered an area of concern. Waste from this feeding area was not noticeably detected during the water quality monitoring.

Site #7

Site #7 is downstream of Site #10, located just south of Ortely South Dakota in Roberts County. The watershed of Site #7 including Site #10 encompasses approximately 4,745 hectares (11,720 acres) or 20.6% of the watershed (Figure 6). The watershed between Sites #7 and Site #10 is approximately 1,795 hectares (4,440 acres).

Approximately 16% of the total discharge to Blue Dog Lake passes through Site #7. Site #7 has more runoff per-acre than any other site in the Owen's Creek watershed (1,253 m^3/hectare or 0.4 acre-feet/acre. The percent of the total load from Site #7 as solids and nutrients in 1997, were as follows; Total Solids (14%), Total Suspended Solids (8%), Ammonia (8%), Nitrate-Nitrite (14%), TKN (10%), Total Phosphorus (16%) and Total Dissolved Phosphorus (21%). The average concentration of fecal coliform bacteria for 1997 was 856 colonies/100 ml; the median for the site was 230 colonies/100 ml.

There is less pasture and more cropland and farmsteads in Site #7's drainage compared to the Site #10 drainage. The increases in fecal coliform bacteria were most likely from animal feeding areas and animals grazing in riparian areas.

The hydrologic loadings at Site #7 were highest in the spring. The volume of water in the spring was 72% of the total load at the site in 1997. Summer loadings were next largest with 22% of the hydrologic load. The fall comprised only a small percent of the load for all parameters in 1997.

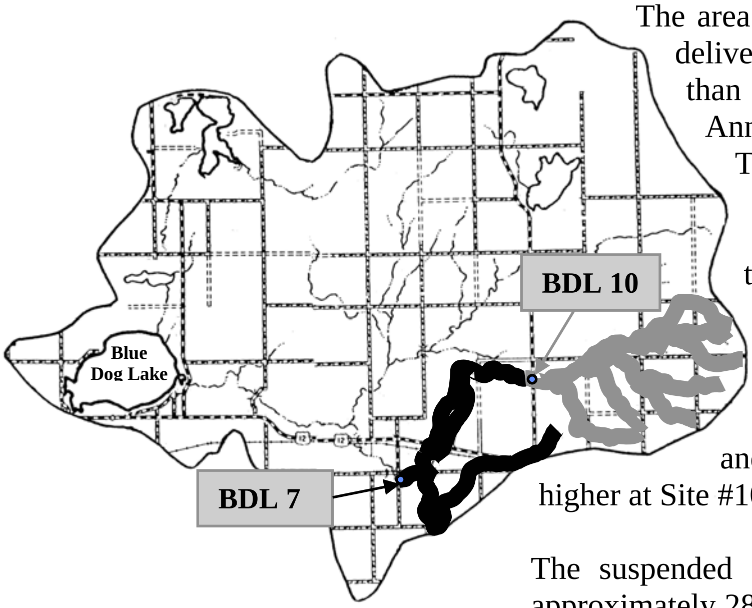


Figure 6. Site #7 Location

The area between Site #7 and Site #10 delivers more nutrients and sediment than the area upstream of Site #10. Annual per-acre loadings for TKN, total phosphorus and total dissolved phosphorus were much higher at Site #7 than they were at Site #10. Compared to Site #10, in the spring of 1997, the per-acre loading of nitrate was higher at Site #7. However, summer and fall loadings per-acre were higher at Site #10.

The suspended solids loads at Site #7 were approximately 28 times greater at site #7 than at Site #10. The increase in suspended solids is most likely due to less grass in this part of the watershed and more cropland. The load of suspended solids for 1997 at Site #7 is 68,309 kg (75 tons). Using 135 lbs/ft^3 of sediment, as was done for Site #10, approximately 31.5 m^3 (1,116 ft^3) passed through Site #7.

Except for nitrate, all nutrient loadings were higher at Site #7 than at Site #10. In many cases, the loadings were as much as 20 times greater at Site #7 than at Site #10. Ammonia loadings were four times higher (65.2 kg/year), TKN was 17.7 times higher (2,730.1 kg/year), and the total phosphorus and total dissolved phosphorus concentration were 34 and 33 times higher at Site #7 than at Site #10 (513.5 and 291.4 kg/year respectively).

The high nitrate loads and concentrations at Site #10 were not seen at Site #7. Actually, the yearly loadings at Site #7 were slightly below the loadings at Site #10 although the hydrologic loading is 13 times greater at Site #7. The nitrates may have been used by plants along the riparian corridor, converted to other forms of nitrogen, diluted by additional water, or lost to ground water. Seasonally, there was actually more nitrate in the spring samples at Site #7 than at Site #10 but the summer and fall loadings at Site #10 far outweighed the loadings at Site #7.

The fraction of phosphorus that was dissolved (readily available for uptake by plants) at Site #7 was approximately 57% over the entire year. As the suspended solids load increased, the percent of dissolved phosphorus decreased, which suggested that the dissolved fraction was attaching to the solids coming downstream. Overall, the per-acre phosphorus loads at Site #7 were low according to the water quality data (0.11 kg/hectare).

The total loadings per-acre at Site #7 were average or a bit low compared to loadings at the other sites. The nitrate loadings were somewhat high, most likely due to the loadings from Site #10. Phosphorus concentrations per-acre at Site #7 were quite a bit higher than at Site #10. There was also more fecal coliform bacteria found between Site #7 and Site #10, which points to agricultural livestock as the source for the increased phosphorus concentrations.

There is only one animal feeding area in the drainage between Site #10 and Site #7. The ranking of this feeding area was 65. According to the feedlot model, this animal feeding area and some of the surrounding cropland were responsible for increased suspended solids and nutrient loads at Site #7.

Site #9

Site #9 is located in the northeast part of the watershed (Figure 7). The drainage to Site #9 is approximately 3,756 hectares (9,280 acres). Site #9 comprises approximately 16.3% of the entire Blue Dog Lake watershed. Hurricane Lake is small lake located within the drainage of Site #9 (Figure 7).

The land use in the Site #9 drainage is mostly grass, not unlike the Site #10 watershed. The steep slopes of the Coteau make cropland farming very difficult. The grassed pasture areas increase the infiltration of rainwater reducing runoff. The hydrologic load at Site #9 was only 9% of the total load to Blue Dog Lake. Much of the hydrologic load came from the water of Hurricane Lake. In 1997, 97% of the flow through Site #9 occurred during spring snowmelt and rain showers. During the summer and fall, there was very little or no flow through the site.

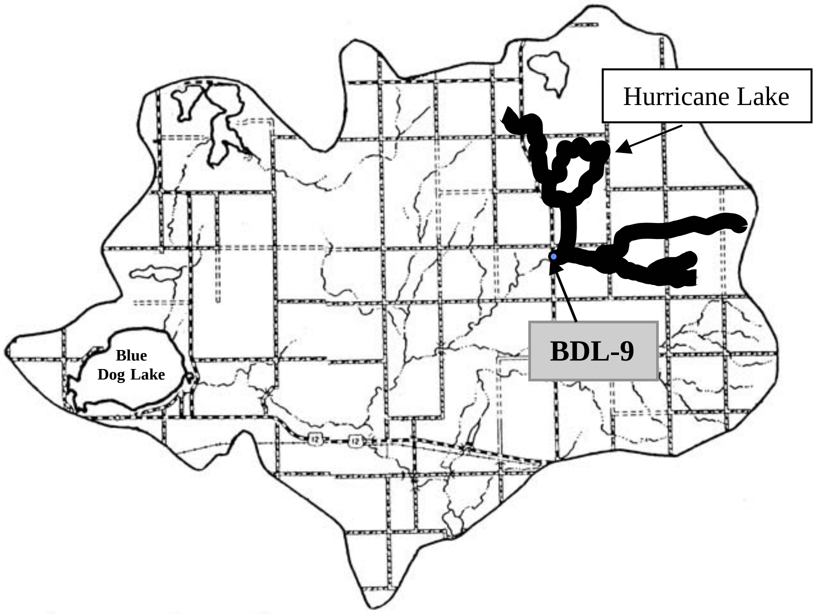


Figure 7. Location of Site #9.

The total loadings to Blue Dog Lake in 1997 from the Site #9 drainage were as follows; 1) Total Solids (6%), Total Suspended Solids (2.6%), Ammonia (2%), Nitrate-Nitrite (7.8%), TKN (6.2%), Total Phosphorus (7.8%) and Total Dissolved Phosphorus (10%).

The average concentration of fecal coliform bacteria for 1997 was 856 colonies/100 ml, the median for the site was 693 colonies/100 ml. The minimum fecal sample collected in 1997 was a non-detect sample; the maximum was 4,400 colonies/100ml. With a standard deviation of 1,612 colonies/100ml, there is a large variability in the fecal samples.

Although the ammonia concentrations were only 2% of the total load to Blue Dog Lake they were 45% of the load to Site #6, the next downstream site. Like ammonia, the total load of TKN to Blue Dog Lake was 6.2%, but was 46% of the load to Site #6. There appeared to be an organic source of nutrients in the watershed above Site #9. Hurricane Lake and the wetland at the outlet of the lake may have been responsible for the increase in organic nitrogen (TKN). To a small extent, ammonia increases might have been coming from the wetland, however high ammonia concentrations were more often found in association with waste. Fecal coliform bacteria were found in most of the summer and fall samples collected at Site #9 throughout the project. The AGNPS model rated three animal feeding areas in the subwatershed, however, only one was ranked significant (>50). Since summer fecal bacteria concentrations were higher, cattle in summer pastures may have been responsible for the increased nutrient loads along with animal feeding areas.

The spring flows were quite large at Site #9 compared to Site #10, (2,622 acre-feet and 182 acre-feet, respectively). The volume of water passing through Site #9 during the spring was actually greater than the entire runoff at Site #10 during 1997, and thus the 1997 annual loadings were much higher at Site #9. Summer loadings were higher at Site #10. Where as Site #10 maintained almost continuous flow throughout 1997, Site #9 was dry during most of the summer and fall. In the fall however, although the flows at Site #10 were much higher, the loadings of three nutrient parameters (TKN, total phosphorus, and total dissolved phosphorus) were greater at Site #9. Site #9 does not seem to be as effected by ground water as Site #10.

The per-acre loss of suspended solids at Site #9 was the second lowest in the entire Blue Dog watershed in 1997. Only Site #10 had a lower per-acre loss of suspended solids. Approximately 5.88 kg/hectare (5.25 lbs./acre) of suspended solids was being delivered to Site #9. Site #9 had the lowest average concentration of suspended solids (4 mg/L) of any site in the Blue Dog drainage. Hurricane Lake was most likely acting as settling basin, retaining many of the suspended particles. More grazing than cropping in the watershed was another reason the suspended solids concentrations were lower at Site #9.

All of Site #9’s total loadings (except nitrate) were higher than the similar sized watershed of Site #10, however, there was more than 7 times the water coming through Site #9 than Site #10. There was less than 0.5 kg/hectare (0.44 lbs./acre) of any nutrient parameter being delivered to Blue Dog Lake. The overall water quality at Site #9 is good, with a few exceptions of higher fecal coliform bacteria found in the summer and fall. These higher fecal coliform samples are most likely responsible for the relatively higher TKN and phosphorus concentrations at Site #9.

Site #8

There will be no discussion of loadings at Site #8, shown in Figure 8, because the site was adversely affected by beaver dams, so no stage discharge table could be calculated.

Site #6

Site #6 drains the largest area of Owen's Creek's north and south forks (8,353 hectares or 20,640 acres). Site #6's watershed is approximately 36.3% of the total watershed to Blue Dog Lake (Figure 8). The subwatershed between site #6 and Site #9 is approximately 4,706 hectares (11,630 acres).

The hydrologic load to Blue Dog Lake from Site #6 was 20% of the total load in 1997. Site #6 averaged 885 m^3/hectare (0.29 acre-feet/acre) of discharge in 1997. The per-acre loadings of nutrients and sediment (except TKN) were much higher at Site #6 than they were at Site #9. The area between the sites was a larger contributor of nutrients and sediments than the watershed above Site #9.

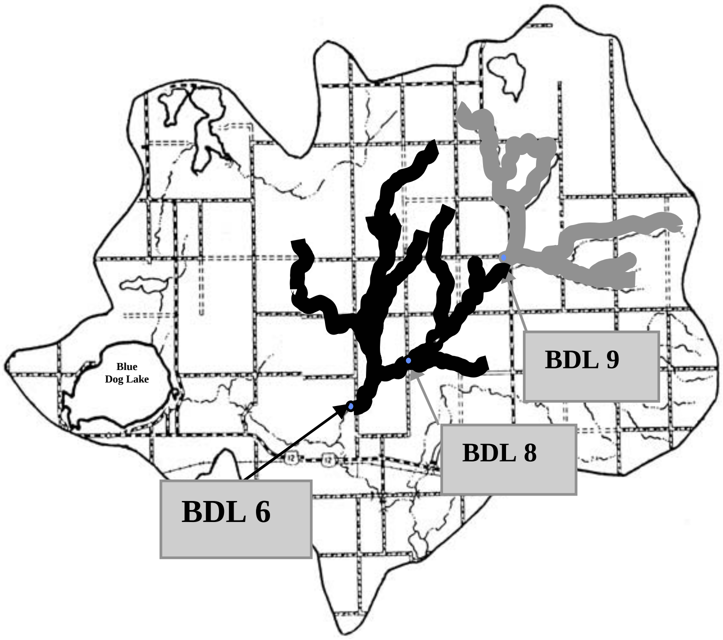


Figure 8. Location of Site #6.

There was more cropland in the Site #6 drainage area than in the drainages monitored by Site #9 and Site #10. The per-acre loss of suspended sediment at Site #6 was higher than any other subwatershed in the Owen's Creek drainage (30.6 kg/hectare). The loading at Site #6 during 1997 was approximately 254,980 kg/year (281 tons). Converting the estimated weight to an area measurement, the area load at Site #6 was approximately 118 m^3 (4,167 $feet^3$). Site #6 had approximately 4 times the load of sediment as Site #7. The most likely source of the suspended solids was eroding cropland, animal feeding areas, and cattle in the riparian areas.

The nutrients at Site #6 were also high compared to the other areas in the Owen's Creek watershed. There were 4 permanent irrigation pivots in the drainage between Site #9 and Site #6. These pivots, as at Site #10, were most likely responsible for the high nitrate values found at Site #6 (3,164 kg/year or 3.5 tons). Site #6 contributed approximately 40% of the nitrate load to Blue Dog Lake. Although no loading information was available for Site #8, the mean and median nitrate concentrations at that site were 0.69 mg/L and 0.80 mg/L, respectively. These concentrations were slightly higher than those found at Site #6 (0.51 mg/L and 0.50 mg/L for the mean and median). The irrigation pivots were located upstream of Site #8 so higher nitrate concentrations could be expected.

Other nitrogen parameters had lower percentages of the total load to Blue Dog Lake than nitrates. TKN made up only 13.4% (3,619 kg/year) of the total load to Blue Dog. The ammonia load was 4.4% of the total load to Blue Dog Lake, slightly higher than the load from Site #7. Both the total phosphorus and total dissolved phosphorus loads to Blue Dog Lake from Site #6 were approximately 32% for the 1997 sampling season.

Site #6 also had the highest average total phosphorus concentration. The highest total phosphorus concentrations coincided with either high fecal bacteria counts or high suspended solids concentration, and in many cases, both. Less than one-half of the total phosphorus was in dissolved form. This demonstrates that most of the phosphorus at this site was attached to some organic or inorganic particle. There was very little difference in the fraction of dissolved phosphorus between base-flow and runoff samples, 46% and 54% respectively.

The fecal coliform bacteria concentrations at Site #6 were consistently higher than at any other site. The average concentration for the whole project period (August 1996-July 1998) was 11,057 colonies/100ml with a median of 1,400 colonies/100ml. Seven of the highest fecal concentrations during the project were found at Site #6. The range of these samples were from 20,000 to 59,000 colonies/100 ml. Runoff samples averaged 17,156 colonies/100ml while base flow samples averaged less at 4,489 colonies/100ml. According to AGNPS data collected, there were six feeding areas in the subwatershed downstream of Site #9. Of these six, one was rated above 50 and two were rated above 60. Feeding areas rated above 50 are those which should be considered for an animal waste management system. Cattle are also grazed in many areas around the main channel of Owen's Creek. These two factors along with poor nutrient management are most likely the cause of the elevated fecal and nutrient parameters.

Site #5

The drainage area for Site #5 encompasses nearly the entire Owen's Creek watershed. The site was located as close as possible to Blue Dog Lake without being effected by back-flow from rising lake levels (Figure 9). The estimated drainage area for Site #5 is 15,362 hectares (37,960 acres) comprising 66.8% of the entire Blue Dog Lake watershed. Site #6 and Site #7 together make up 85% of the watershed monitored at Site #5.

Forty-eight percent of the 1997 annual flow to Blue Dog Lake passed through this site. The annual discharge through Site #5 in 1997 was 17.7 billion m^3 (14,359 acre-feet). Seventy-three percent of the hydrologic load through Site #5 can be accounted for at Sites # 6 and #7. The average discharge per-unit area at Site #5 was 1,153 m^3/hectare (0.37 acre-feet/acre). The per-area discharge of water was second only to Site #7 in the Owen's Creek watershed.

The 1997 suspended solids load through Site #5 was 326,976 kg/year (21.3 kg/hectare). The suspended solids load was only 39% of the total load to Blue Dog Lake in 1997. There is a large ponded area upstream of the site. This ponded area may be settling out many of the solids from upstream sites. The suspended solid loadings from Sites #6 and #7 were approximately 99% of the load to Site #5. However in the summer of 1997, the combined loads from Sites #6 and #7 were 109% of Site #5's seasonal loading. The fall loadings at Sites #6 and #7 comprise even a higher percentage of the total load to Site #5 (164%). Because of the lower flows in the summer and fall, the suspended solids at Sites #6 and #7 are most likely deposited in the channel and then flushed downstream during the intense spring snow melts and rain storms.

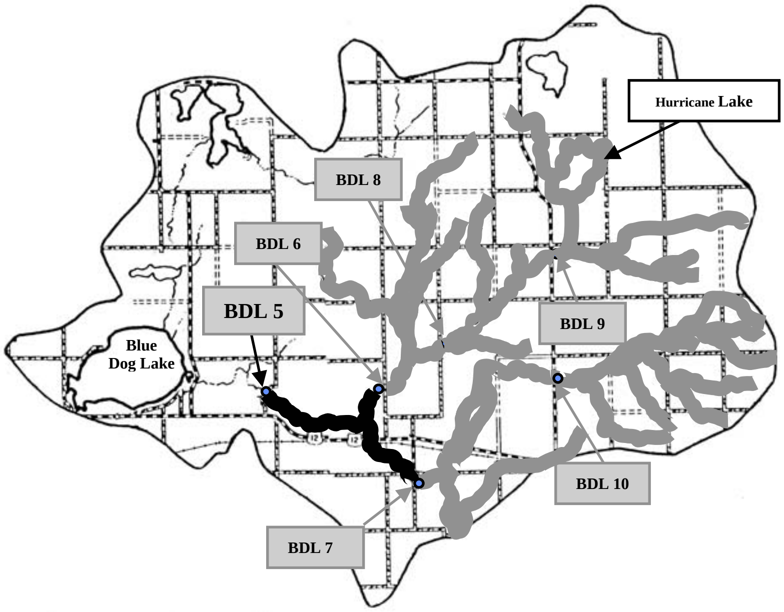


Figure 9. Location of Site #5.

The ammonia loads at Site #5 were relatively low (13.7%) compared to the total load entering Blue Dog Lake. However, the loading from the drainage downstream of Sites #6 and #7 (approximately 2,265 hectares or 5,600 acres) was 60% of load at Site #5. The small area (15% of the drainage) between the upstream sites and Site #5 appears to input a significant loading of ammonia. The average ammonia concentration at Site #5 was actually lower than Sites #6 and #7 but had a larger loss per-area (0.015 kg/hectare). The increased loadings were most likely due to the greater hydrologic load and the animal feeding areas in the drainage.

The TKN loadings at Site #5 were 35% of the total load to Blue Dog Lake in 1997. The combined loading from Sites #6 and #7 was 65% of the load to Site #5. As with ammonia, the per-acre loss of TKN in the Site #5 drainage was slightly larger than either Site #6 or Site #7 (Site #5 — 0.63 kg/hectare, and Site #6 and Site #7 – 0.43 kg/hectare and 0.58 kg/hectare, respectively) however, the average concentration was less at Site #5. Again, the increased hydrologic load most likely diluted the TKN concentration as it increased the overall load.

The high nitrate concentrations that were found upstream at Site #6, and to a lesser extent Site #7, were most likely being carried downstream to Site #5. The percent loading of nitrate to Blue Dog Lake in 1997 was 66%. The per-area average of nitrate at Site #5 in

1997 was 0.34 kg/hectare. Site #6 had per-hectare loadings of 0.38 kg/year. The loadings from the two subwatersheds that run into Site #5 made up 82% of its total load. The average nitrate concentration of samples collected throughout the project at Site #5 and Site #6 were 0.34 mg/L and 0.56 mg/L, respectively. Concentrations were most likely diluted as the hydrologic load increased.

Total phosphorus loadings from Site #5 during 1997 made up 54% of the total load to Blue Dog Lake (1,717 kg/year or 1.9 tons/year). The phosphorus loss per-unit area in the Site #5 watershed was not inordinate compared to the other major subwatersheds in the Owen's Creek drainage. The average phosphorus concentration at Site #5 for the entire project was 0.119 mg/L. The higher phosphorus concentrations correlate with the detection of elevated fecal coliform concentrations and on some occasions, higher suspended solids. Due to the frequent occurrence of fecal coliform bacteria, animal waste was the most likely cause of the higher phosphorus concentrations. When the loadings at Site #6 and Site #7 were combined, it was found that the total was 88% of the total load at Site #5. It appears that much of the phosphorus passing through the upstream sites may be reaching Site #5.

The average fraction of phosphorus that was dissolved at Site #5 was approximately 50%. When suspended solids were low in concentration, the dissolved fraction was usually higher (36% and 58% respectively). Base-flows samples at Site #5 actually had higher suspended solids and lower fractions of dissolved solids than runoff events. One possible explanation was that during storm events, the large pond of water located upstream of the sample site may have experienced algal blooms that were flushed out before the samples could be collected. The suspended solids (algae) that were collected during base flows may have been missed. Another explanation is that during base flows, it was easier to sample the entire water column, while during runoff events a surface sample may have been all that could be collected.

The average fecal coliform sample at Site # 5 was 1,165 colonies/100ml. Runoff events had a much higher average than base flow events (1,895 colonies/100ml and 379 colonies/100ml respectively). Animal waste from concentrated feeding areas were most likely the cause for the high fecal concentrations during runoff. These colonies may be passing to Site #5 from the upstream sites, especially Site #6. There are 5 animal feeding areas in the subwatershed between the upstream site and Site #5. All of these feedlots have a rating of 50 or greater and two have a rating greater than 60.

The nutrient and sediment loadings to Site #5 were greatly influenced by the upstream sites. Some of the fecal and phosphorus loads from the upstream sites were making their way to Site #5, however there were 5 highly-rated animal feeding areas in the subwatershed also adding to the nutrient load to Blue Dog Lake. Ammonia and TKN loadings seemed to increase significantly between the upstream sites and Site #5. This was also evidence that there were nutrient sources between the upstream sites and Site #5.

Site #4

Site #4 is located near the north side of the lake (Figure 10). During the study, Site #4 was renamed Site #4b. The drainage for Site #4b is relatively small. However, because it was the recipient of water from Enemy Swim Lake and Campbell's Slough, the volume of water that passed through the site was comparable to that of Owen's Creek. The drainage to Site #4b is approximately 3,383 hectares (8,360 acres), comprising 14.7% of the total watershed. Site #4's drainage area when combined with Enemy Swim Lake's drainage was 12,415 hectares (30,680 acres). Including the acreage from Enemy Swim Lake, the drainage to Site#4b would be approximately 39% of total drainage to Blue Dog Lake. For this report, the discussion will be based on the smaller acreage starting at the outlet of Campbell's Slough.

Additional sites were added to the drainage from the outlet of Campbell's Slough. Site #4a was added for two reasons; 1) high water made it impossible to collect a sample at Site #4b, and 2) to find if nutrient and sediment sources were located between Sites #4a and #4b. Site #4c, located closest to Blue Dog Lake was added to see what effect the wetlands between Site #4b and Site #4c had on water quality (Figure 10).

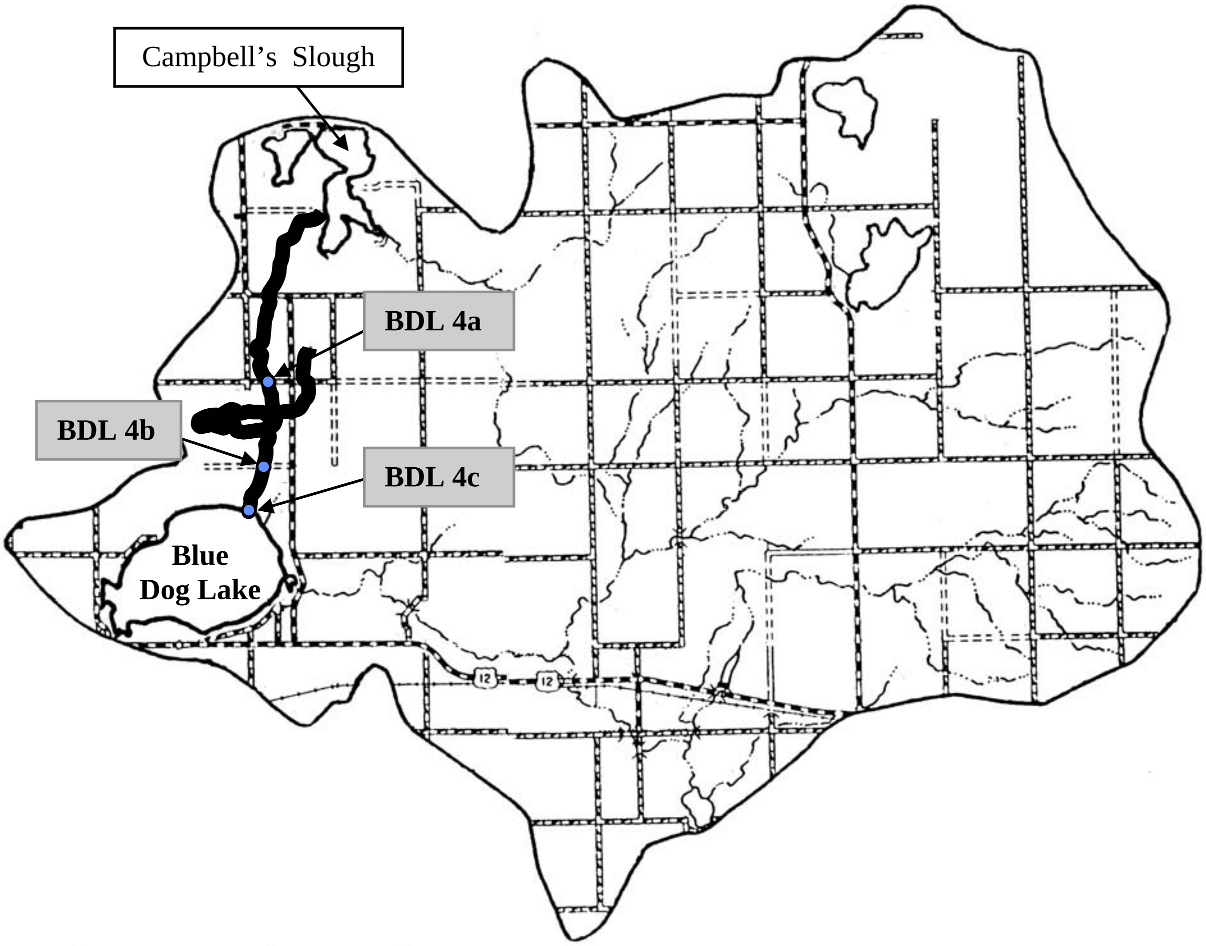


Figure 10. Location of Sites #4a, 4b, and 4c.

The majority of the drainage upstream of Site #4a is grassland and pasture. The majority of the area downstream of Site #4a is cropland. The majority of the land between Site #4b and #4c is wetland. Only concentrations will be considered when comparing the three sites in the drainage from Campbell's Slough. Five samples were collected at each site on different days during the summer of 1997. A comparison of the parameters' average concentration is shown in Table 7.

Table 7. Average Concentration of Parameters at the Three Sites in the Campbell's Slough Drainage.

Parameter		Site		
Name	**Units**	**4a**	**4b**	**4c**
Water Temperature	^{o}C	20.7	21.36	20.2
Dissolved Oxygen	mg/L	9.76	10.00	5.88
Alkalinity	mg/L	223	237	245
Total Solids	mg/L	337	337	348
Susp. Solids	mg/L	40	18	8.8
Ammonia	mg/L	0.03	0.05	0.04
Nitrate-Nitrite	mg/L	0.14	0.13	0.14
Total Kjeldahl – N	mg/L	0.98	1.09	1.03
Total Phosphorus	mg/L	0.148	0.111	0.120
Total Diss. Phosphorus	mg/L	0.045	0.056	0.065
Fecal Coliform	Colonies/100ml	1,888	210	360

🟨 These areas have the highest concentration at any of the three sites.

There was very little change in the water temperature from site to site, however there was a slight increase in the temperature from Site #4a to Site #4b. This was most likely due to the radiant heat having a longer time to affect the water. The temperature, however, did not continue to increase at Site #4c. Shading from wetland plants or influence of the cooler lake water may have kept the temperature from rising. The dissolved oxygen concentrations at Sites #4a and #4b were high; however, there was a sharp drop from Site #4b to Site #4c. The wetlands between these two sites may have been using the oxygen for aerobic decomposition of organic matter. There was no significant difference in total alkalinity or total solids. Suspended solids concentration show a dynamic change from site to site. At Site #4a, the average concentration was 40 mg/l. At Site #4b the concentration was reduced by one half (17 mg/L) and a 50% reduction was again found at Site #4c (8mg/L). Between one-quarter to one-third of the suspended solids in the sample are volatile suspended solids, meaning a large portion of the suspended solids concentration was inorganic solids (sediment) from bank or field erosion. Dilution may play a slight role in the changes from site to site; however, it appeared that there was some erosion taking place upstream of Site #4a. The suspended solids appear to drop out of the water column throughout the drainage.

Ammonia concentrations were highest at Site #4b, however there is only a 0.01 mg/L to 0.02 mg/L difference between the samples collected at Site #4b and at Sites #4a and #4c. There was virtually no difference in nitrate or TKN concentrations between any of the samples. Total phosphorus was highest at Site #4a, most likely it was from a combination of the higher suspended solids concentrations and the higher fecal coliform counts upstream of the site. Livestock and poor agricultural practices are probably the phosphorus source.

Dissolved phosphorus concentrations were higher at Site #4c. The slower flow of the wetland settling out solids and the breakdown of organic compounds in the wetland most likely released more dissolved phosphorus than the other sites in the drainage. As found in Table 7, Site #4a had the highest average of fecal coliform colonies (1,888 counts/100ml). There appeared to be a dilution of the fecal bacteria between Site #4a and Site #4b. After Site #4b, Site #4c experienced an increase in fecal concentrations. There were muskrat houses and small beaver dams/lodges in the wetland area. These two factors were most likely responsible for the slight increase of fecal coliform at Site #4c.

The loadings to Blue Dog Lake through Site 4b were determined using a combination of samples collected at Site #4a and 4b. When conditions did not allow access to Site 4b, samples and flows were collected at Site #4a and used in the loading calculations at Site #4b. Because of their relative closeness, the hydrologic load was assumed the same at both sites.

The nutrient and sediment parameters at Site #4b were a large percentage of the total loadings to Blue Dog Lake. The large loadings were most likely due to the large volume of water passing through Site #4b during the 1997 sampling season. The percent of the nutrient and sediment loadings to Blue Dog Lake from Site #4b during 1997 were as follows; 1) total solids 50.7%, 2) suspended solids 61%, 3) ammonia 86.3%, 4) nitrate 34.5%, 5) TKN 64.6, 6) total phosphorus 46.1%, and 7) total dissolved phosphorus 37.9%.

Seventy-eight percent of the flow through Site #4b in 1997 came from snowmelt until May 31, 1997. The summer hydrologic load in 1997 was 20% of the annual load, and the fall sample was only 1% of the total hydrologic loading through the site.

Compared to Site #5 and the total loading to Blue Dog Lake, the spring hydrologic load from Site #4b was 56% of the total load to Blue Dog Lake, the summer load was 52%, and the fall load at Site #4b was 12% of the 1997 load to Blue Dog Lake. The 1997 yearly loading to Blue Dog Lake from Site #4b was 19.25 billion m^3 (15,605 acre-feet) or 52% of the load to the lake.

The percentage load of alkalinity and total solids at Site #4b followed the percent of the hydrologic load almost exactly (50% and 51% respectively). As expected, the majority of the suspended solids load at Site #4b came during the spring season. Site #4b carried 72% of the total suspended solids spring load to Blue Dog Lake in 1997. The summer load at Site #4b was only 35% and the fall sample was 15% of the total load to the lake. The total load to Blue Dog Lake in 1997 was 512,216 kg/year (565 tons). The sediment load to Blue Dog Lake converts to 237 m^3 or 8,368 ft^3 (Kuck, 1998).

The ammonia loadings from Site #4b were extremely high, 87% of the total load to Blue Dog Lake. Since many of the other tributary sites had non-detectable concentrations in the samples collected, a small concentration of ammonia, especially in the spring, may have caused the relatively large loading from Site #4b. Two samples collected in the spring at Site #4a had ammonia levels of 0.12 and 0.15 mg/L. The mean of spring tributary samples was 0.05 mg/L. Of the 30 samples collected at different tributary sites in the spring of 1997, only 8 had detectable levels of ammonia. The volume of water passing through the site during the spring increased the loadings at Site #4b. Site #4b had only two samples collected during the spring, so these levels were averaged. With only two samples, the average may be artificially high. The calculated load for ammonia in 1997 was 1,453 kg/year.

The percent of the nitrate load passing through Site #4b (35%) was less than the percentages of the other nutrient parameters. Because the amounts of nitrate found in the tributary samples collected from Owen's Creek were so large, the percentage from Site #4b was relatively low. The 1997 nitrate load at Site #4b was 2,738 kg/year. The TKN loading at Site #4b was 17,598 kg/year. Organic matter being flushed from Campbell's Slough was most likely the source of the TKN loading. The loading of TKN to Blue Dog Lake was 65% of the load from all of the tributaries. Site #4b had 3 of the 4 highest TKN concentrations sampled over the entire project. The maximum sample collected was a base flow sampled on September 4, 1996, that contained 2.97 mg/L TKN. Fall samples are typically higher in TKN than at any other time of year because of decaying organic matter from waste or plants that die in the fall.

Total phosphorus loadings were not overly high considering the large amount of water passing through the site. The total load of phosphorus was 46% of the load to Blue Dog Lake. The average concentration for the entire project at Site #4b was 0.110 mg/L. Maximum concentration at the site was 0.184 mg/L on September 4, 1996. This was the same date the maximum concentrations for ammonia and TKN were sampled. The average percent of dissolved phosphorus for Site #4b was 35%. Most of the phosphorus that passed through the site particle-attached. The percent of dissolved phosphorus upstream at Site #4a was even less at 26%. Downstream of the wetlands at Site #4c, the dissolved fraction increased to 54%.

Fecal coliform concentrations at Site #4b were not as high as those found at Sites #5 and #6. The maximum concentration (7,300 colonies/100ml) found at the sites in the north drainage was sampled at Site #4a during a storm event on October 7, 1997. The next highest fecal bacteria sample (1,400 colonies/100ml) was collected during base flow at Site #4b on September 4, 1996. On both of these sample dates, nutrient parameters were at their highest concentrations for their specific locations. The source of the fecal coliform and high nutrients at Site #4a was most likely runoff from an animal feeding operation. At Site #4b, the source may have been either from an animal feeding area or from beavers, muskrats, or waterfowl.

The per-acre losses of nitrate and ammonia at Site #4 were higher than at any other tributary sites. The differences ranged from 2 times higher than the average loss per-acre of nitrate to 28 time higher per-acre loss for ammonia. The large volume of water coming from Enemy Swim Lake added to the loadings and artificially skewed the per-acre losses at Site #4b.

As stated throughout the Site #4b discussion, the volume of water, and thus the load, passing through the site was greatly increased from water leaving Enemy Swim Lake. Actual flows, water quality data, and the AGNPS model were used to make an estimation of the input from Enemy Swim Lake. The AGNPS model found Site #4b to have the highest per-acre hydrologic load than any other subwatershed. For a comparison, the actual runoff at Site #7, a similar subwatershed, was 0.41 acre-feet. Since AGNPS estimated slightly more water leaving the Site #4 watershed, a factor of 0.43 acre-feet of water coming through Site #4b was used to estimate the load at Site #4b without the Enemy Swim input. Using the calculated numbers and factors it was estimated that 77% of the water passing through Site #4b was from Enemy Swim Lake.

Using surface water quality data collected at Enemy Swim Lake, seasonal estimates of loads leaving Enemy Swim Lake's outlet were calculated. These seasonal loads were combined for the total yearly loading. As could be expected, the suspended solids load leaving Enemy Swim Lake was very low. Enemy Swim contributed only 11% of the suspended solids load to Site #4. However, Enemy Swim's suspended solids probably settled out into Campbell's Slough. It can be assumed that most of the suspended solids found at Site #4 were from the immediate watershed.

The loadings of TKN and nitrate leaving Enemy Swim Lake were actually greater than the loads found at Site #4 (142% and 123%, respectively). The nitrate and TKN may have been volatilized, used by plants or converted into other forms of nitrogen. These processes could have taken place in Campbell's Slough, or the small wetland just north of Site #4c. In any case, a large portion of the nitrate and TKN load to Blue Dog Lake may have come from Enemy Swim Lake.

The percent totals of loads for ammonia and total phosphorus from Enemy Swim Lake were less than the other nutrient parameters (54% for ammonia and 59% for phosphorus). Phosphorus concentrations in Enemy Swim Lake were very low. Ammonia concentrations typically increase with decay. There typically isn't much decay near the outlet of Enemy Swim Lake. Some of the phosphorus and maybe a little of the ammonia load may be passed through Campbell's Slough before reaching Site #4b. It can be assumed anywhere from 25% to 40% of the ammonia and total phosphorus load at Site #4b was from Enemy Swim Lake.

The fraction of phosphorus that was dissolved in Enemy Swim Lake was very high during the spring of the year (85%). In the summer and fall, as phosphorus leaves the lake as part of algae, the total dissolved fraction was much lower (22% and 29% respectively). The large spring load of dissolved phosphorus (171% of the spring load to Site #4) may have been attached to suspended silt and clay particles or may have been taken up by plants upstream of Site #4. Summer and fall loads from Enemy Swim were much lower than the summer and fall loads at Site #4 (13% and 10%, respectively).

Overall, the water quality coming from Enemy Swim Lake is good. However, the hydrologic loading from the lake to Site #4 is so large, Enemy Swim does impact some parameters at Site #4. Suspended solids loads from Enemy Swim did not seem to have an impact on Site #4, however, in some cases Enemy Swim may be inputting up to 50% of the nutrients to Site #4.

Summary of Tributary Sites

In summary, Site #10 had the highest inputs per-acre of nitrate due to irrigation pivots located in the subwatershed. Although nutrient loads at Site #9 were relatively low, there was a nutrient source from an animal feeding area and/or pasturing cattle. None of the loadings at Site #7 were extremely high nor were they very low. The nitrate loads at Site #10 may have influenced the higher nitrate levels at Site #7 however there was very little nitrate input from the small drainage between Site #10 and Site #7. Site #6 had the highest per-acre loadings of suspended solids and phosphorus and the second highest loading of nitrate. Fecal coliform concentrations at Site #6 were consistently higher than any other site. Sources of nutrients and sediment in the Site #6 drainage area were animal feeding areas, poor nutrient management, overgrazing, erosion from fields, and nitrates from pivot irrigation systems. Site #5 is on the main tributary of Owen's Creek. The resulting loads at Site #5 come largely from Site #6 and Site #7 (approximately 80%). The area between Sites #6-#7 and Site #5 did significantly increase the TKN and ammonia concentrations. Five animal feeding areas in the small drainage were the most likely source. Site #4 received a large supply of water, and thus a sizable load, from the outlet of Enemy Swim Lake. Although the area of the drainage monitored by Site #4 was quite small, the sediment and nutrient loadings equaled or exceeded many of the parameter loads at Site #5. Large loads of inorganic sediment from erosion or particulate matter were the most likely source of the phosphorus loadings in the drainage. Organic nitrogen and ammonia loads were very high at Site #4. The loadings from Enemy Swim Lake, animal feeding areas, and decay from large wetlands in the drainage were the most likely sources.

Overall, the suspended solids loading to Blue Dog Lake was quite low, but nutrient loading to the lake was high. From the AGNPS data collected it was found that there were approximately 12 feeding areas with high rankings (>50). One half of these were located in the watersheds for Sites #5 and #6. AGNPS also highlighted approximately 1,640 acres of cropland with either excessive phosphorus or sediment coming off the land. There were a number of pastures in the area that may need better management, however, the land-use model used does very little to estimate loadings from these areas.

Ungauged Tributaries

Because of the lack of roads, lack of access, and back-flow problems in the Blue Dog Lake watershed, it was difficult to gauge every tributary running into the lake. It was estimated from the AGNPS model that 16% of the watershed was not gauged. To estimate the loading from this drainage, the total area of the ungauged sites was multiplied by the same per-acre loss as Site #5. After the total from the ungauged sites was added to the loadings total, it was found that the ungauged sites added an additional 17% of the hydrologic load to the lake. AGNPS data was used to estimate the additional percent of phosphorus, sediment and nitrogen loadings to the lake. Using relative numbers from the AGNPS model, the ungauged tributaries contributed 11% of the phosphorus, 5% of the sediment and 12.5% of the total nitrogen. There were two animal feeding areas with rankings over 50 in the ungauged tributaries drainage. The feeding areas, along with improper manure management, and overgrazed pastures were the most likely sources of nutrients and sediment to Blue Dog Lake.

Nutrient and Sediment Budget

Hydrologic Budget

The hydrologic budget explains how much water entered the lake and how much water left the lake. The hydrologic, sediment and nutrient budgets will be based on the 1997 sampling season (April to October). Due to the amount of precipitation in the Blue Dog area, ground water recharge kept Owen’s Creek flowing all year long. Sampling and gauging began when ice left the stream and continuous discharges could be collected.

The hydrologic inputs to Blue Dog Lake included precipitation, tributary runoff gauged and ungauged, and ground water. Hydrologic outputs from Blue Dog Lake included the water leaving over the spillway from the beginning of April to the end of October during 1997, evaporation, and ground water. Both precipitation and evaporation data was acquired from the state climatologist. Monthly precipitation data was taken from the Waubay field station. Tributary sites were gauged when possible, and, as stated in the previous section, ungauged discharge was estimated using the gauged data and the AGNPS model. In many projects, the volume of water below the level of the spillway at the beginning or end of the project is calculated as an input or output. During 1997, the water never went below the level of the spillway and thus all water was gauged at Site#3.

After all of the hydrologic outputs were subtracted from the inputs, only 1.2 million m^3 (984 acre-feet) of was unaccounted for. The only source not yet accounted for was ground water. Ground water inputs or outputs are typically very difficult to estimate. If surficial aquifers are near streams and reservoirs they can add or take away large quantities of water. In Blue Dog Lake, ground water contribution was nearly negligible as input volumes were very close to the output volume.

The largest source of water input was Site #4. However Site #4 received approximately 77% of its water from the outlet of Enemy Swim Lake. Discounting Enemy Swim Lake inputs, Owen’s Creek is the single largest source of water for Blue Dog Lake. In drier years, Enemy Swim would not be such a large factor. The loss to ground water was approximately 19 cm (7.5 inches) of water over the entire surface area of the lake.

Table 8. Input and Output Sources of Blue Dog Lake.

INFLOW		OUTFLOW	
Source	**Acre-feet**	**Source**	**Acre-Feet**
Site #4	15,605	Spillway (Site #3)	31,071
Site #5	14,359	Evaporation	3,427
Ungauged Tributaries	3,418	Ground water	984
Precipitation	2,099		
TOTAL	**35,482**	**TOTAL**	**35,482**

One factor that was never measured in Blue Dog Lake was the total volume of ground water that passed through the lake. Table 8 shows that more water left the lake than entered from surface water, however, it does not show how much ground water entered or left the lake. The water that comes from ground water is usually of very good quality and has little effect on the overall water quality of the lake. However, if the high nitrate concentrations found in some of the upstream sites and ground water samples made their way to Blue Dog Lake, ground water nitrate loads may have greatly impacted Blue Dog Lake.

Suspended Solids Budget

As described in the tributary section of the report, overall suspended solids from the watershed did not appear to be significant during the sampling period. According to the data collected and estimated from all of the tributaries, Blue Dog Lake received approximately 397 m^3 (0.3 acre-foot) of sediment in 1997. The volume of sediment was calculated by dividing the annual kilograms of sediment by 2,162.5. One cubic meter of sediment weighs approximately 2,162.5 kilograms (135 lbs/ft^3) (NRCS). Because the water quality data might have underestimated the total sediment due to the missing flow data, the sediment from the AGNPS model was considered. According to the AGNPS model, only 615 m^3 (0.5 acre-foot) of sediment was estimated in the annual loading. AGNPS had no way to consider the loading from Enemy Swim, as it was not part of the watershed included in the data collection. Relative comparisons with the AGNPS data and the water quality data determined that 92% of the suspended solids at Site #4 were from Enemy Swim Lake. However, even doubling the total load to Blue Dog Lake would only add a 1,230 m^3 (1 acre-feet)

As mentioned earlier in the shoreline survey, bank pins placed along the lakeshore in the summer of 1997 were all exposed or missing by May of 1998. If even 10% of the loss from the shoreline occurred in the late summer and fall of 1997 the load to Blue Dog lake would have more than doubled. Ten percent of the estimated shoreline loss from late summer of 1997 to the spring of 1998 would be 2,0813 m^3 (1.7 acre/feet). This small amount of loading is most likely the result of the large amount of pasture in the watershed. In addition, many basins in the watershed that may be settling out the suspended solids load. The areas in the watershed that appear to be contributing large amounts of suspended solids, according to the AGNPS model, are cropping areas close to the lake planted on high slopes. Typically, these high erosion areas are on land with slopes greater than 7%. It is not known how much of the suspended solids are inorganic sediment or organic matter (decaying vegetation). Although the amount of sediment to Blue Dog Lake is low, AGNPS estimated that 18% of the total phosphorus load could be reduced by treating the most highly erodible land.

Figure 11 shows the estimated percentage of load from the watershed areas derived from water quality sampling, including 10% from the total shoreline lost to erosion. As can be seen from the chart, the shoreline erosion at 84% is a lot more than the measured loadings at all the other sites. Site #4 had the largest input of tributary sites; however, the AGNPS model predicted that without the input from Enemy Swim Lake, the input from Site #4 would be reduced by 82%. AGNPS highlighted a few critical areas directly upstream of the sampling site. In the direct watershed of Blue Dog Lake, the subwatershed between Site #7 and Site #5 had the largest percent of critical areas. Critical areas were typically grain fields planted on slopes greater than 7%. There were also some areas in the watershed with overgrazed pastures contributing sediment to Blue Dog Lake.

The calculation of the suspended solids at the outlet (Site #3) found approximately 620 m^3 (0.5 acre-foot) of sediment leaving Blue Dog Lake. The amount of sediment left in Blue Dog Lake was approximately 1,860 m^3 (1.5 acre-feet). The suspended solids leaving Blue Dog Lake may have been organic (algae) or inorganic (suspended bottom sediments). Due to the shallow depths of Blue Dog Lake, (2.4 meters) wind and wave actions suspend bottom sediments into the water column.

The outlet of Blue Dog Lake ran throughout the year. Algal blooms that rose to the surface of the water could have been blown to the outlet during the summer and collected in samples taken at the spillway, adding to the suspended sediment load at the outlet. Many algae, however, do not leave the lake and are broken down to release nutrients. This process is a form of internal loading.

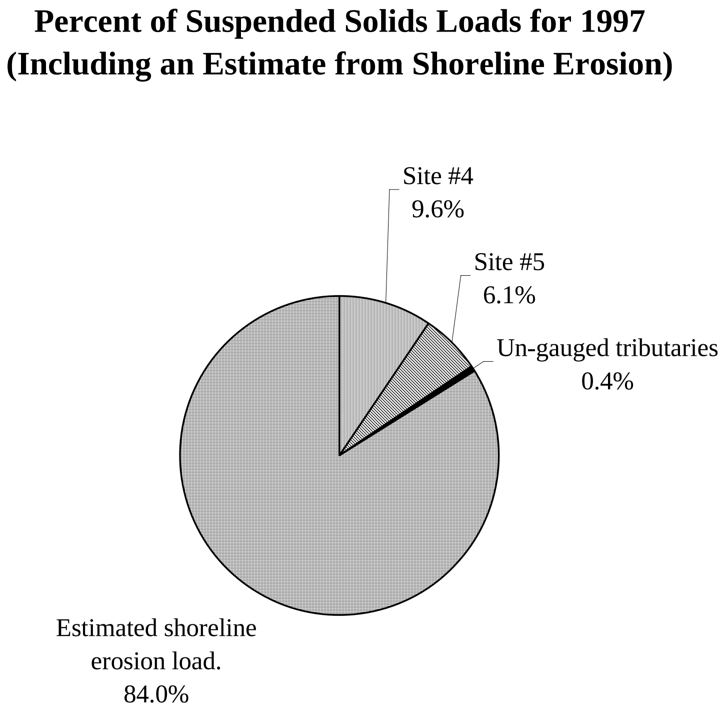


Figure 11. Suspended Solids Load

Nitrogen Budget

Inputs for the nitrogen budget for Blue Dog Lake were the tributaries and ground water. Tributary loadings were taken from the water quality data collected. Data for ground water nitrate concentrations were taken from water quality data collected from wells placed by the South Dakota Department of Environment and Natural Resources and the United States Geological Survey (SD DENR, Water Rights, 1991 and Gilbertson, 1996). Water quality data for nitrates in ground water was somewhat scattered, however samples collected from both of the sources had nitrate concentrations approximately 9.5 mg/L. Ground water loading was not considered in the overall input budget because there was no way to measure the input or fate of nitrate from the time it enters the lake until it leaves. There was also no way to measure the concentration of nitrate in the ground water as it left the lake. Input from precipitation according to Hutchinson, 1957, varies greatly across the earth and in many cases is minimal. Atmospheric nitrogen can enter a waterbody in many forms: as nitrogen, nitric acid, ammonia, nitrite, and as organic compounds either dissolved or particulate (Wetzel, 1983). It is impossible to know what ratio of inorganic to organic nitrogen entered the lake from the atmosphere. Because no water quality data from precipitation data was collected, the inputs will be estimated as minimal and not considered in this report. The estimated ungauged tributary inputs of the nitrogen parameters were derived from a relative comparison between AGNPS and the water

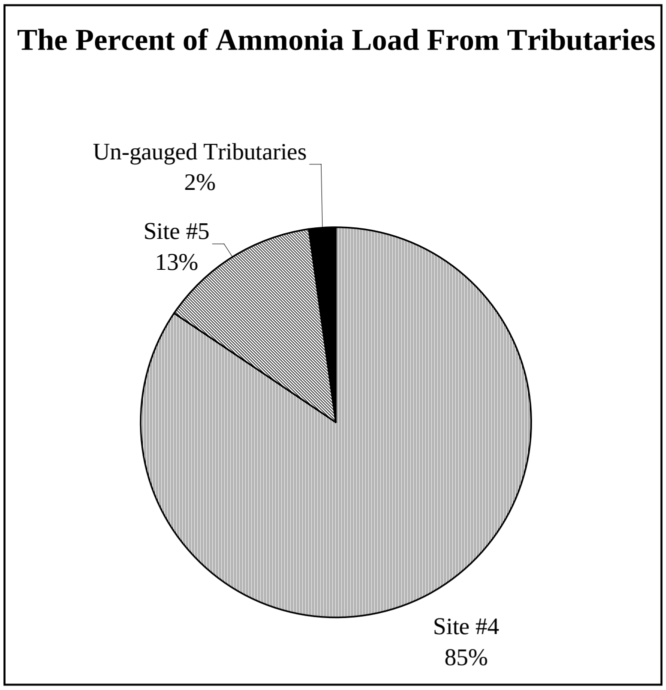


Figure 12. Percent Load of Ammonia

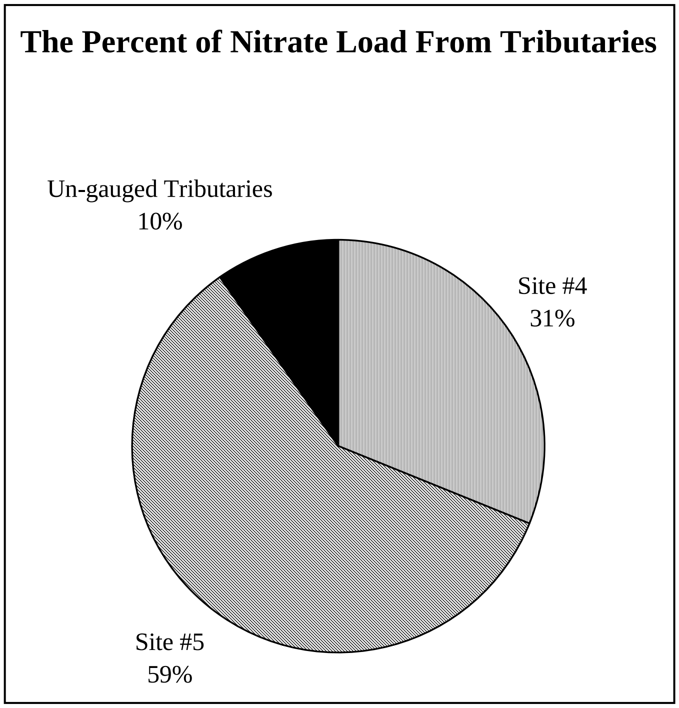


Figure 13. Percent Load of Nitrate

quality monitoring data. The following charts show the percent of nitrogen loadings from different sources (Figure 12, Figure 13, Figure 14, and Figure 15).

The ammonia budget for Blue Dog Lake showed an increase in inlake ammonia of 1,267 kg (1.4 tons) for the 1997 sampling season. As can be seen from Figure 12, the largest input was from Site #4. The load of ammonia at Site #4 is so large because of the large hydrologic input from Enemy Swim Lake. Seventy-four percent of the ammonia load to Blue Dog Lake was lost to algae or converted to other forms of nitrogen. Ammonia is inorganic and used readily by algae for uptake and growth.

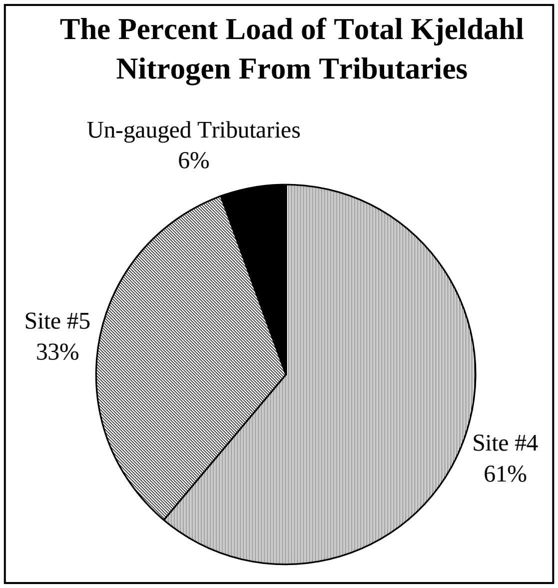


Figure 14. Percent Load of TKN

Another inorganic parameter sampled was nitrate-nitrite. The nitrate-nitrite budget showed Blue Dog Lake retaining a small amount of nitrate. The estimated amount of nitrate-nitrite added to Blue Dog Lake was 13.2% of the input or 1,160 kg (1.3 tons). Site #5 is the tributary with the largest input of nitrate. This is most likely due to the large irrigation pivots located in the watershed. Plants can take up nitrate-nitrite nitrogen if available and then convert it to ammonia for use through a nitrate reduction process.

Total Kjeldahl Nitrogen (TKN) is a combination of organic nitrogen and ammonia. Due to the small fraction of TKN that is ammonia, TKN can be looked at as mainly organic nitrogen. Figure 14 shows the Site #4 tributary with the largest input. Without a wet year in 1997, the input from Enemy Swim Lake would have been much less and thus Owen's Creek (Site #5) would most likely have been the largest single source of TKN. Approximately 22% or 6,465 kg (7 tons) of the TKN load to Blue Dog Lake was retained in the lake. The majority of TKN is organic and can come in the form of animal waste, vegetation from the watershed or algae. If the TKN (organic nitrogen) is not dissolved it can drop out of the water column once it reached the lake. In the bottom sediments, TKN can be broken down to usable forms of nitrogen.

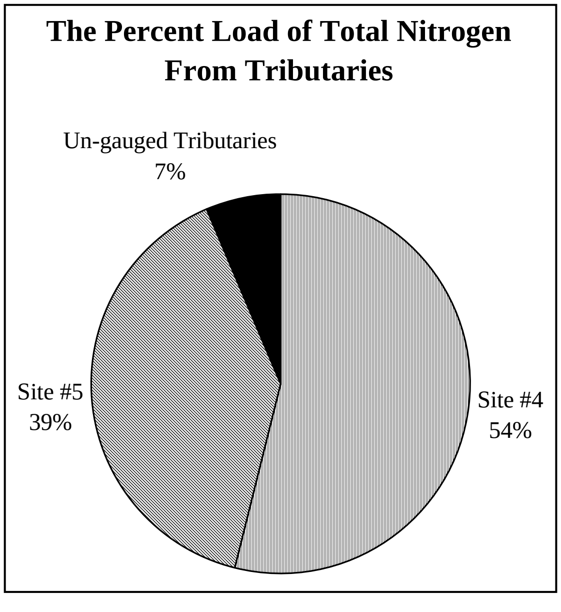


Figure 15. Percent Load of Total Nitrogen

Algae can then use the converted nitrogen for growth and then leave the lake through the outlet (Site #3).

According to the samples collected, the inlake quantity of total nitrogen in Blue Dog Lake increased by 7,625 kg (8.4 tons) during the 1997 sample period. As all forms of nitrogen can at some time be broken down and reused for algal growth, reducing the influx of nitrogen to Blue Dog Lake will be beneficial for reducing Blue Dog Lake's eutrophic state.

Phosphorus Budget

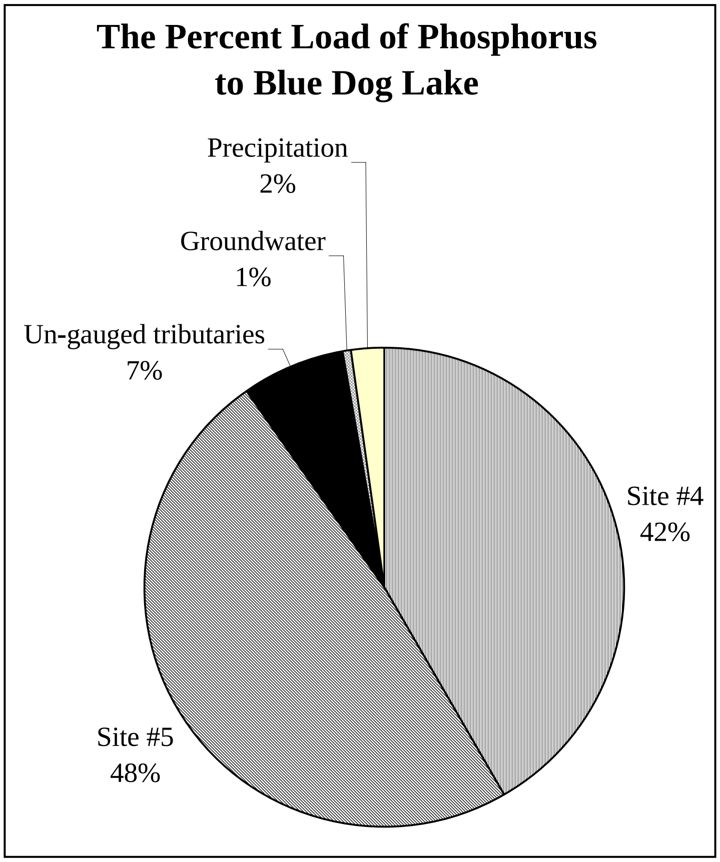


Figure 16. Total Phosphorus Load

Total phosphorus inputs to Blue Dog Lake in the 1997 sampling season totaled approximately 3,504 kg (3.9 tons). Inputs to Blue Dog Lake included gauged tributaries, an estimate for ungauged tributaries, ground water, and precipitation (Figure 16). The ground water load of phosphorus in most lakes is insignificant compared to tributary inputs. In addition, as with nitrogen, there is no way to know how much ground water entered the lake and how much left the lake. All that can be calculated is the difference. Assuming the same concentration is leaving through ground water as entering, (0.02 mg/L given in Wetzel, 1983) the load to Blue Dog Lake would only be 24 kg or 0.7% of the total load to the lake. The precipitation hydrologic load was multiplied by 0.03 mg/L, an average often found in unpopulated areas (Wetzel, 1983). The ungauged tributary load was estimated by using the relative differences found in AGNPS and applying the percent differences to actual water quality data collected.

The total load out of Blue Dog Lake was approximately 3,306 kg (3.6 tons). In the 1997 sampling season, there was an estimated 222 kg (490 lbs.) more phosphorus entering the lake than leaving the lake. Suspended solids entering the lake most likely settled out and did not release the attached phosphorus. Due to the shallow depth of the lake, there was most likely no release of phosphorus from the bottom sediments due to low oxygen. Also, because of the short hydrologic retention time, there was less utilization and growth of algae. Algae going over the spillway can be a main source of phosphorus leaving a waterbody.

The inputs of total dissolved phosphorus (Figure 17) in Blue Dog Lake were estimated at 1,505 kg (1.66 tons). Blue Dog Lake retained approximately 29% of the dissolved phosphorus load. A larger percentage of phosphorus entered the lake as dissolved phosphorus than left the lake (43% entering – 32% leaving). Due to the shallow nature of the lake, dissolved phosphorus would sorb on to particles suspended in the water column by wind and wave action.

Of all of the measured inputs, Blue Dog retained 6% of the total phosphorus load. This does not include the phosphorus attached to the sediment that fell in from the shoreline. Because sediment is an excellent source of phosphorus, the shoreline loss may have been a large unmeasured source of phosphorus to the lake. The phosphorus from shoreline erosion would most likely be found as total phosphorus instead of dissolved phosphorus.

Although there was evidence of a flushing of phosphorus from Blue Dog Lake, the difference was less than 0.6 tons for total phosphorus and 1.77 tons for dissolved phosphorus. These small amounts could be errors in sampling or in the estimated phosphorus loads from the ungauged tributaries. Even if the estimates were accurate, the tons of phosphorus entering the lake are more than sufficient to keep Blue Dog Lake hyper-eutrophic.

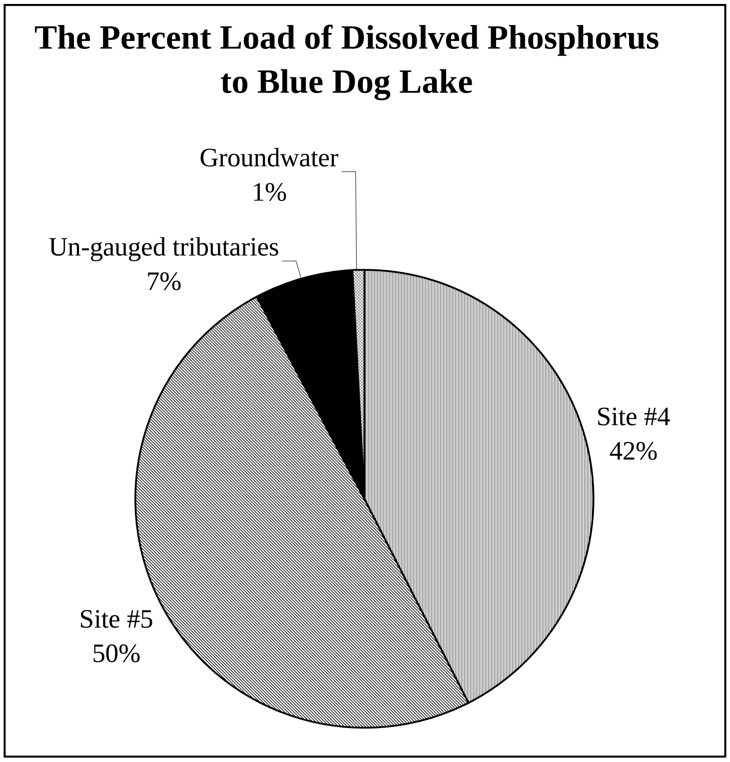


Figure 17. Total Dissolved Phosphorus Load

INLAKE DATA

Methods and Materials

Two inlake sample locations were chosen for collecting nutrient and sediment information from Blue Dog Lake during the study. The locations of the inlake sampling sites are shown in Figure 18. A sample set consisted of a surface sample collected from each site each month. After the summer of 1997, Site #2 was no longer sampled. There was no significant difference between sites. Additional inlake data were collected in 1989, 1991, and 1992 for the state-sponsored annual lake assessment. These samples were used to analyze water quality trends over time. Samples collected for the Statewide Lake Assessment were collected by compositing three widely separated sub-sample sites in each lake (Stueven, 1999). Individual surface and bottom samples were collected for the assessment. The samples were collected and analyzed according to the *South Dakota Standard Operating Procedures for Field Samplers*.

The water quality sample set analyzed by the State Health Laboratory consisted of the following parameters:

Total Alkalinity   Total Solids   Total Suspended Solids
Ammonia   Nitrate-Nitrite   Total Kjeldahl Nitrogen
Fecal Coliform   Total Phosphorus   Total Dissolved Phosphorus

Water quality parameters that were calculated from the parameters analyzed above were:

Unionized Ammonia   Organic Nitrogen   Total Nitrogen

In addition to the chemical water quality data above, inlake field parameters and biological data were also collected. The following are a list of field parameters collected:

Water Temperature   Air Temperature   Dissolved Oxygen Profiles
Field pH   Secchi Depth   Chlorophyll *a*
Algae counts and identification

The chlorophyll *a* samples were used with the phosphorus and Secchi disk data to evaluate the eutrophic status and trends in Blue Dog Lake. The hydrologic and nutrient budgets were used to find the lake response if phosphorus inputs were reduced. The model was taken from Vollenweider and Kerekes, 1980.

All samples collected at the inlake sites were taken according to South Dakota's EPA-approved *Standard Operating Procedures for Field Samplers*. Water samples were sent to the State Health Laboratory in Pierre, SD for analysis. Quality Assurance/Quality Control samples were collected in accordance with South Dakota's EPA-approved *Nonpoint Source Quality Assurance/Quality Control Plan*. These documents can be obtained by contacting the Department of Environment and Natural Resources at (605) 773-4254.

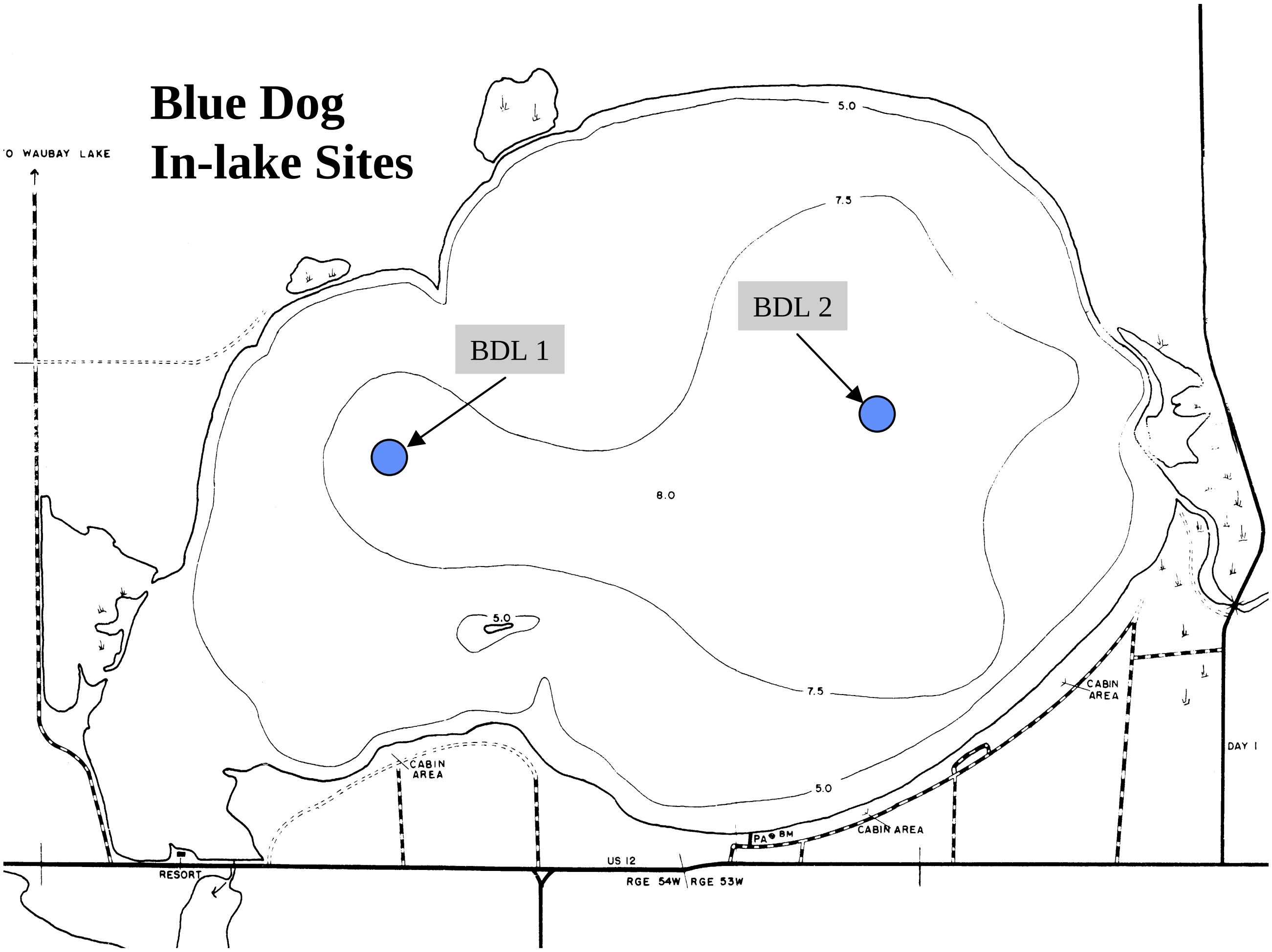


Figure 18. Location of Inlake Sites on Blue Dog Lake.

South Dakota Inlake Water Quality Standards

Blue Dog Lake has been assigned the beneficial uses of:

- Warmwater permanent fish life propagation
- Immersion recreation
- Limited contact recreation
- Wildlife Propagation and Livestock watering

When the above uses have two or more standard limits for the same parameter, the most stringent standard is applied. Table 9 shows the most stringent standards for the parameters sampled in Blue Dog Lake during the study.

Table 9. State Water Quality Standards for Blue Dog Lake.

Parameter	Limits
Unionized ammonia	< 0.04 mg/L
Dissolved Oxygen	> 5.0 mg/L
pH	> 6.5 and < 9.0 su
Suspended Solids	< 90 mg/L
Temperature	< 26.67 ^{o}C
Fecal Coliform	< 400 counts/100 ml (grab)
Alkalinity	<750 mg/L
Nitrates	< 10 mg/L

There were no exceedences of any standards in samples collected during the project period.

The following discussion will be based on individual parameters. The discussion will include the importance of the parameter and its effect on the water quality of Blue Dog Lake. As mentioned earlier, there were no significant differences in the two sampling sites. For the following discussion, the parameter concentrations for the two sites will be averaged if both sites were sampled on the same date.

Inlake Water Quality

Water Temperature

Water temperature is important to the biology of a lake, as it affects many chemical and biological processes in the lake. Higher temperatures increase the potential for raising the unionized fraction of ammonia (toxic to fish). Algae have optimal temperature ranges for growth. Blue-green algae are more prevalent in warm waters. Green algae and diatoms are often found more dominant in cooler waters. Fish life and propagation are also dependent on water temperature. The overall mean in Blue Dog Lake over the sampling season was 13.24 ^{o}C. Figure 19 shows all the average temperatures throughout the project period. The maximum temperature sampled during the sampling season was 25 ^{o}C taken from a surface sample in late June 1998. There was very little evidence of any thermal difference in the water column in Blue Dog Lake. The wind and wave action most likely keep Blue Dog Lake's water mixed throughout the water column. Complete temperature profiles for all of the sites can be found in Appendix E.

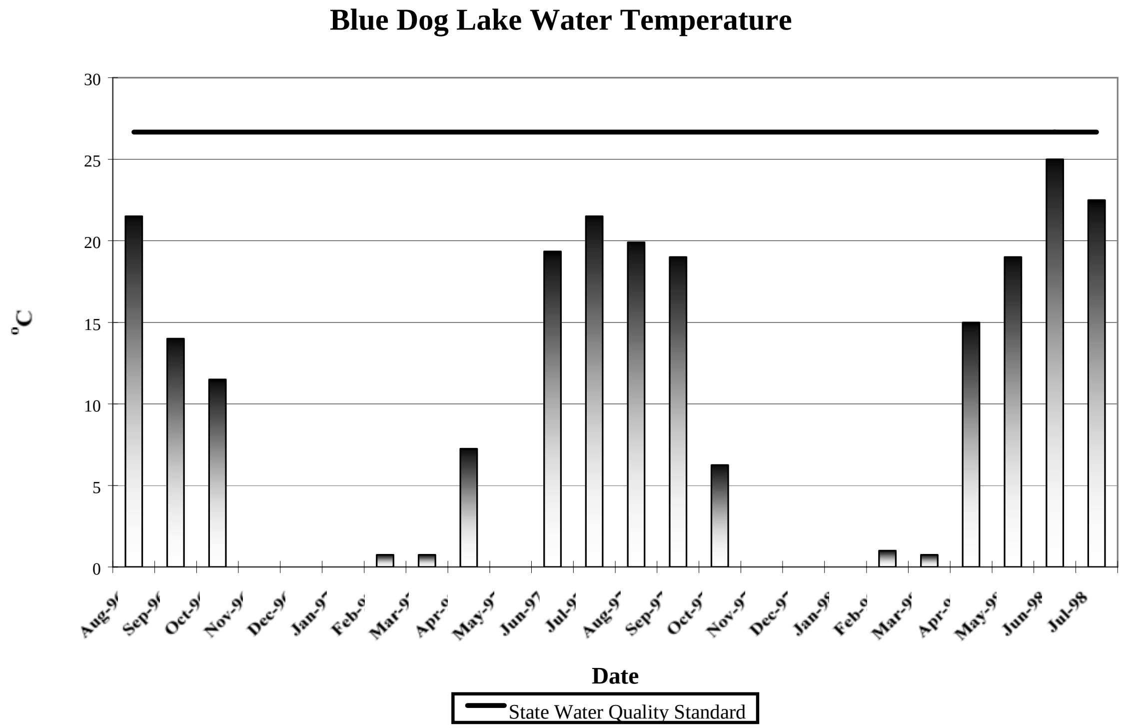


Figure 19. Blue Dog Lake Water Temperature

Dissolved Oxygen

The dissolved oxygen concentrations change with the growth and decomposition of living organisms in a lake system. As algae and plants grow and photosynthesize, they release oxygen into the water. When living organisms decompose, bacteria use oxygen from the system and replace it with carbon dioxide (CO_2). This process usually takes place near the sediment. Dissolved oxygen concentrations also change at the surface air-water interface. Wave action and other turbulence can increase the oxygen level of a lake. Dissolved oxygen averaged 9.20 mg/L (median 9.00 mg/L) over the entire duration of the study. There was less than 0.1-mg/L difference between the average of Site #1 and Site #2 dissolved oxygen concentrations. Figure 20 shows the average dissolved oxygen concentration for the entire project.

The maximum oxygen concentration in Blue Dog Lake was 13.4 mg/L. That sample was collected at Site #2 on April 29, 1997. At Site #2, the dissolved oxygen level was most likely a product of the algal photosynthesis (chlorophyll *a* 12 mg/m^3). Algae counts at Site #1 were similar to those at Site #2, however, the chlorophyll *a* analysis only showed 1.68 mg/m^3. There was most likely an error in collection or analysis of the chlorophyll *a* sample. The algal counts at both sites suggest that algae production were most likely responsible for the higher dissolved oxygen concentrations. Strong winds were recorded on the sample day. Wind and wave action can also increase oxygen concentrations in a water body. The minimum dissolved oxygen concentration was 7.0 mg/L at Site #1 on August 13, 1997. As the sample was collected in the morning, the lake may have been recovering from low, nighttime oxygen levels because of respiration. Nighttime dissolved oxygen samples were not collected during this project. Typically, as much oxygen as is produced by photosynthesis in the day, is used in respiration, or uptake of oxygen, at night. The maximum oxygen concentration usually occurs in the afternoon on clear days, and the minimum immediately after dawn (Reid, 1961).

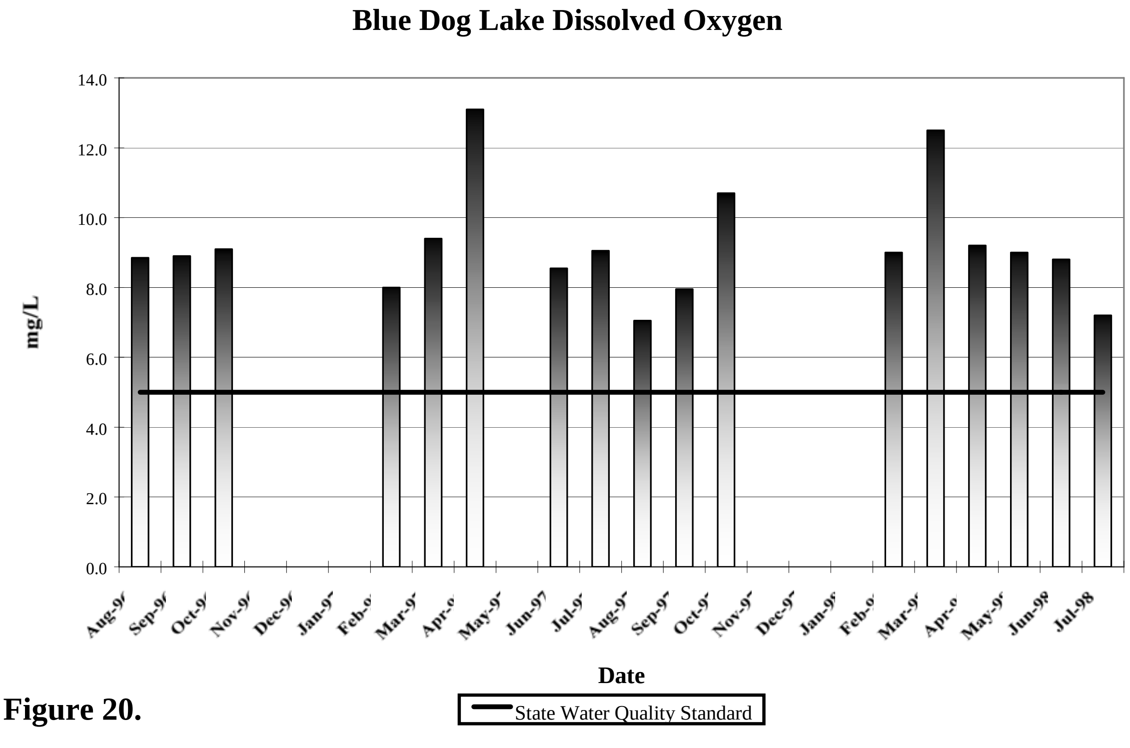


Figure 20.

There was virtually no stratification of oxygen in the water column during the project. Some common causes of oxygen depletion in the water column are; aerobic decomposition of organic matter, lack of photosynthesis from aquatic plants, drastic temperature changes in a water column, and no wind or wave action. Oxygen concentrations are uniform in Blue Dog Lake due to shallow depth and wind and wave action. Waves in Blue Dog Lake are enough to mix the entire water column and suspend bottom sediments. Under ice and with heavy snow conditions, Blue Dog Lake may experience short periods of low oxygen due to decomposition of organic matter. Appendix E has all the dissolved oxygen profiles collected in Blue Dog Lake. Although low oxygen levels may be present at deeper depths, fish will migrate to areas of the lake with the optimum temperature and oxygen levels so they will not be stressed. At all times during the study there was sufficient oxygen at some depth in the lake suitable for fish life.

pH

pH is the measure of the hydrogen ion. More free hydrogen ions lower the pH in water. During decomposition, carbon dioxide is released from the sediments. The carbon dioxide (CO_2) reacts with water to create carbonic acid. The carbonic acid creates a hydrogen ion. Bicarbonate can be converted to carbonate and another hydrogen ion. These extra hydrogen ions created from decomposition will tend to lower the pH in the hypolimnion (bottom of the lake). Increases in the different species of carbon come at the expense of oxygen. Decomposers will use oxygen to break down the material into different carbon species. In addition, the lack of light in the hypolimnion prevents plant growth, so no oxygen can be created through photosynthesis. Typically, the higher the decomposition and respiration rates the lower the oxygen concentrations and the lower the pH in the hypolimnion.

The inverse occurs when photosynthesizing plants increase pH. Plants use carbon dioxide for photosynthesis and release oxygen to the system. This process can reverse the process explained above, increasing pH.

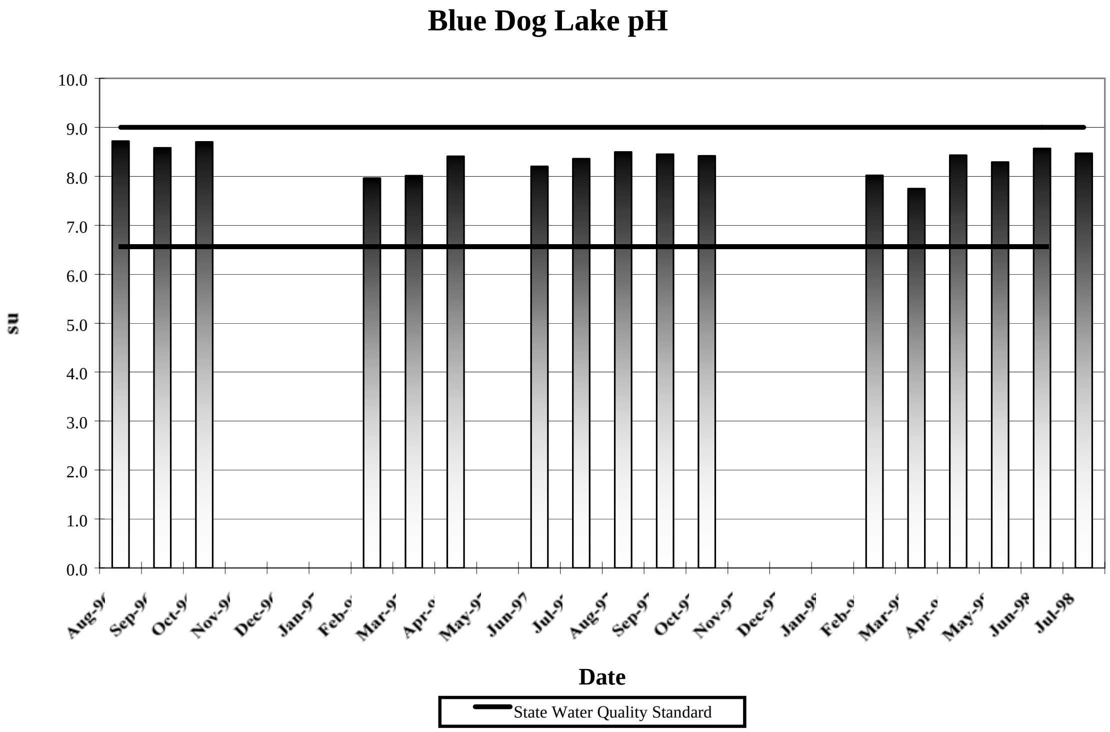


Figure 21.

As shown in Figure 21, Blue Dog Lake experienced the typical pH scenario explained above to a small degree. The pH during the winter in Blue Dog Lake was slightly lower than the pH concentrations found in the summer samples. The higher algae production in the spring and summer months most likely increased the pH concentration. The pH concentrations in Blue Dog Lake were not extreme in any samples. The relatively high alkalinity concentrations in Blue Dog Lake work to buffer dramatic pH changes. Since increases in decomposition decreases pH, increases in pH can be an indication of increased organic matter in a lake over time.

Secchi Depth

Secchi depth is a measure of lake clarity or turbidity. The Secchi disk is 20 cm in diameter and usually painted with opposing black and white quarters (Lind, 1985) (Figure 22). The Secchi disk is used worldwide for comparison of the clarity of water. Secchi disk readings can also be used in Carlson's Trophic State Index (TSI). Carlson's TSI is a measure of trophic condition, or the overall health of a lake. One limitation of the Secchi disk is that it cannot differentiate if organic or inorganic matter is limiting the depths at which the disk can be seen. A low Secchi depth reading may indicate hyper-eutrophy because of high-suspended sediments, or high algal (chlorophyll *a*) production.

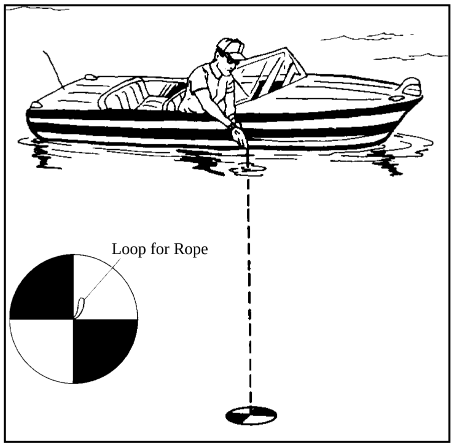


Figure 22. Secchi Disk

Figure 23 shows lower Secchi depth readings in the summer when Blue Dog Lake has higher algal production. No Secchi disk readings were collected in the winter, however, readings collected through the ice are typically clear. The highest Secchi disk reading (1.04 meters or 3.4 feet) was collected on June 5, 1997. Suspended solids concentrations on this data were only 3.5 mg/L and chlorophyll *a* was only 1.01 mg/m^3. As chlorophyll *a* values increase, the Secchi depths decrease. Besides winter samples no other sample had such low readings.

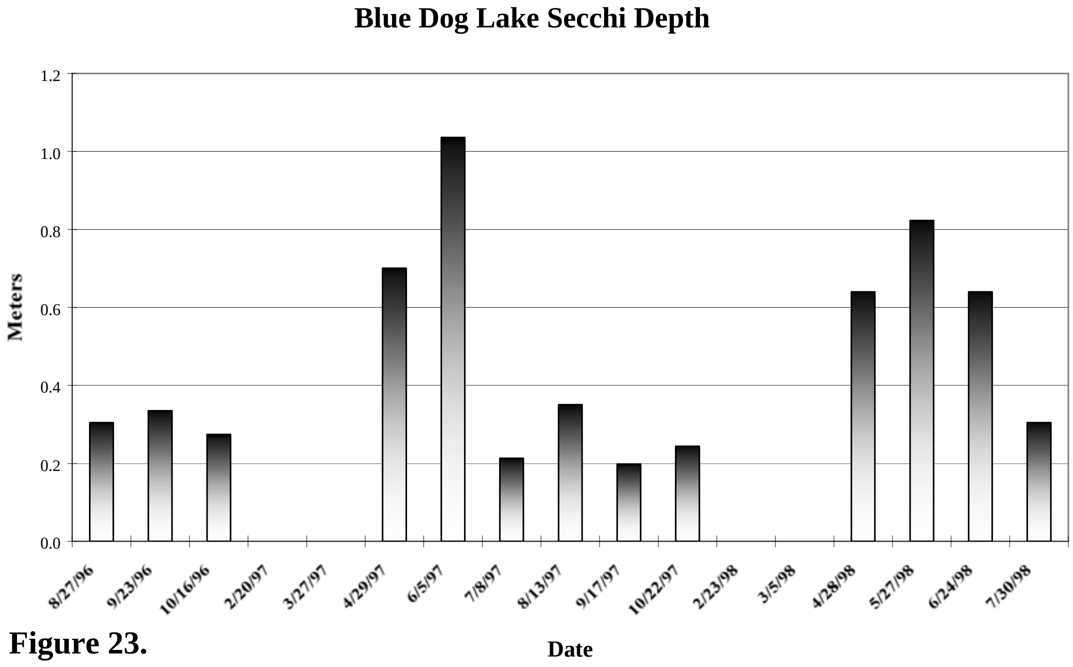


Figure 23.

Turbidity in Blue Dog Lake appears to be caused by both suspended solids (organic and sediment) and algae. Because total suspended solids include algae, suspended solids seemed to have a greater effect on the Secchi depth. When looking at the Secchi depth readings, one must remember that the low readings do not necessarily mean high chlorophyll *a* concentrations in Blue Dog Lake.

Alkalinity

Alkalinity refers to the quantity of different compounds that shift the pH to the alkaline side of neutral (>7). Alkalinity is usually dependent on geology. Alkalinity in natural environments usually ranges from 20 to 200 mg/L (Lind, 1985). The average alkalinity in Blue Dog Lake was 213 mg/L with a median of 217 mg/L (Figure 24). The minimum alkalinity concentration (<31 mg/L) was collected at Site #1 in March of 1998. Site #2 had an alkalinity concentration of 141 mg/L on the same day. The alkalinity may have dropped due to lake turnover under the ice. No other parameter concentrations were extremely high or low on the March 1998 sampling date, however, the lowest pH was also sampled that date.

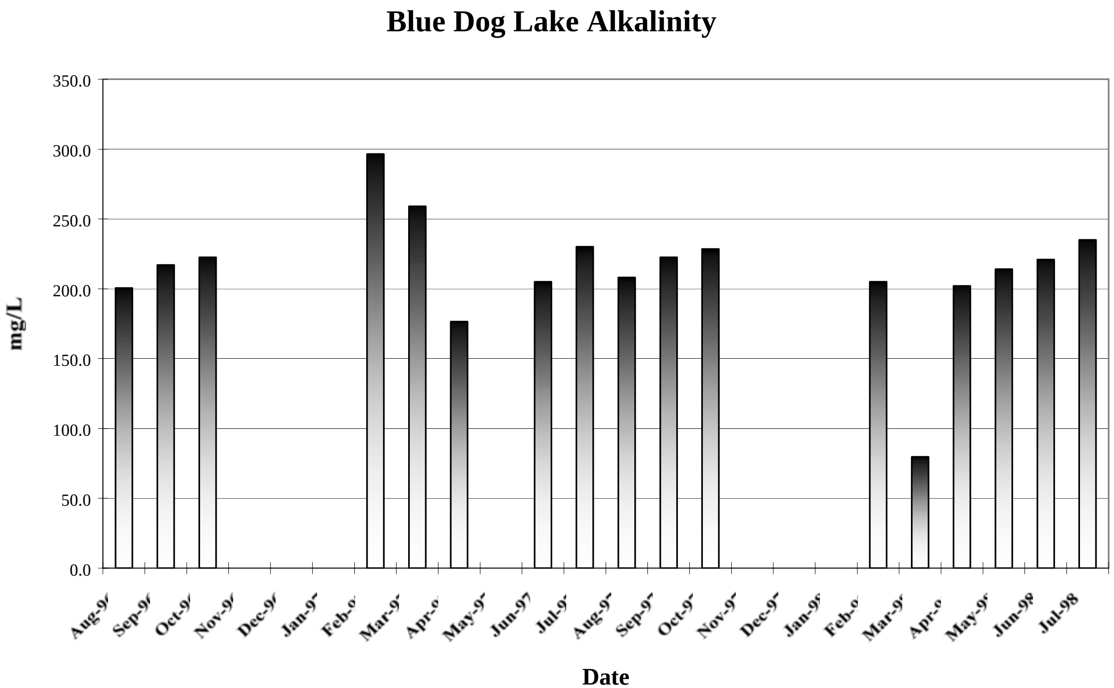


Figure 24.

The maximum alkalinity sample was on February 20, 1997. Both inlake sites had similar concentrations for an average of 296.5 mg/L. The large fluctuations in alkalinity were most likely resulted from the large input of surface water and ground water throughout different times of the year. As water freezes salts are excluded from the ice, which results in increases in dissolved solids and hardness. This process would also increase Blue Dog Lake alkalinity concentrations during winter. Seasonally, there is an increase in concentration from spring to summer and into the fall and winter (Figure 24). The gradual increase in alkalinity is most likely due to dissolved solids concentrating because of evaporation.

Solids

Total solids are the materials, suspended or dissolved, present in water. Dissolved solids include materials that pass through a water filter. Suspended solids are the materials that do not pass through a filter, e.g. sediment and algae. Subtracting the suspended solids from the total solids derives total dissolved solid concentrations. The total solids concentrations in Blue Dog Lake averaged 321 mg/L. The lowest concentrations were found in the spring. The lower solids concentrations were from snow melt and spring runoff diluting the concentrations in the lake. Snowmelt and rain generally have lower concentrations of dissolved solids. Dissolved solids are typically made up of salts and compounds that keep the alkalinity high. As the total dissolved solids concentration dropped, so did the alkalinity. The similarity between alkalinity and total solids can be seen by comparing Figure 24, with Figure 25.

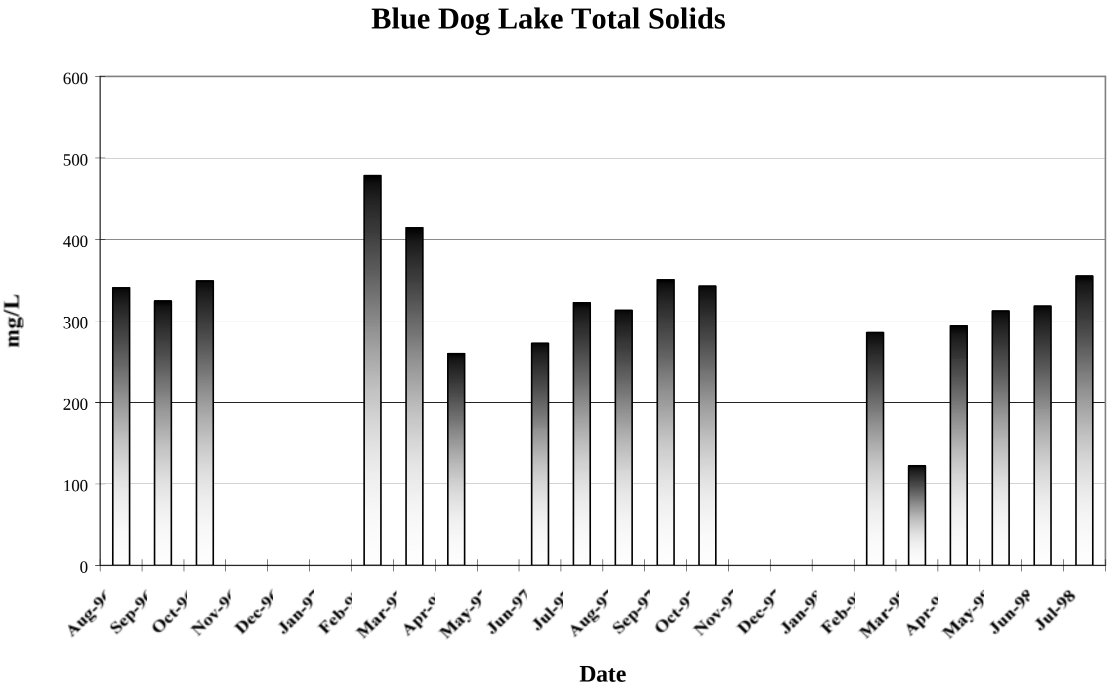

Blue Dog Lake Total Solids

Figure 25.

Daily average total suspended solids are graphed in Figure 26. Total suspended solids in Blue Dog Lake averaged 19 mg/L. The largest surface concentrations of suspended solids were collected on September 17, 1997. Suspended volatile solids (organic matter that burns in a 500^{o}C furnace) were also analyzed on that date. The State Health Lab reported that only 20% of the suspended solids were organic. Inorganic sediments from wind and wave action were the most likely cause of the high-suspended solids concentration. The Secchi disk reading on that date was also the lowest. The local coordinator noted that the winds were moderate to strong. These strong winds caused the re-suspension of bottom sediments throughout the water column. Due to the shallow depth, suspended sediments caused by wind and wave action limit clarity in Blue Dog Lake.

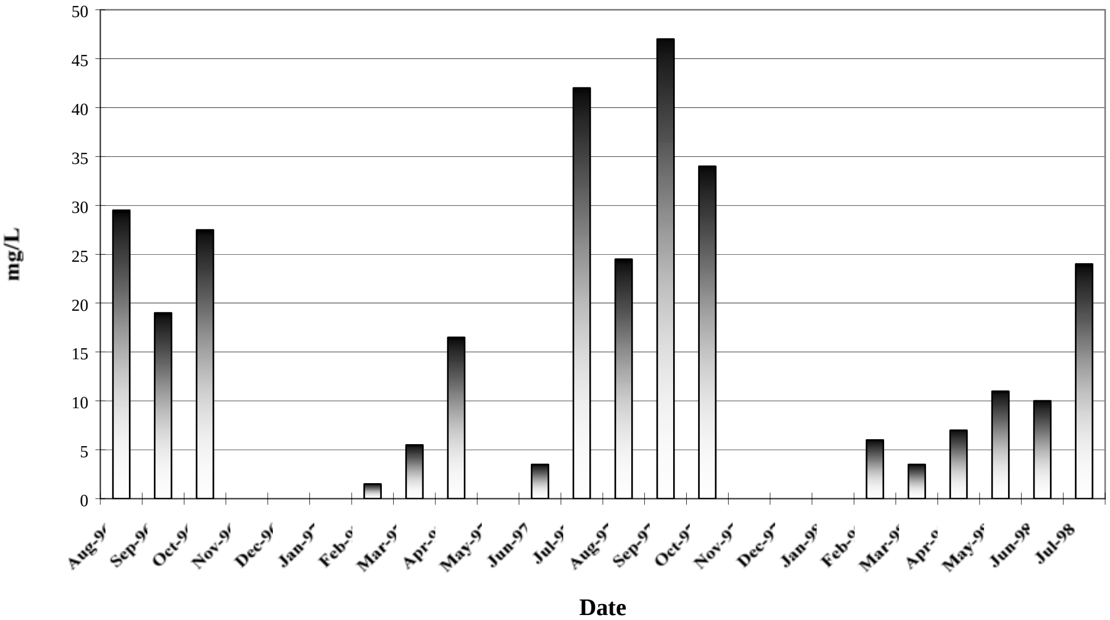

Blue Dog Lake Total Suspended Solids

Figure 26.

Ammonia

Ammonia is the nitrogen product of bacterial decomposition of organic matter and is the form of nitrogen most readily available to plants for uptake and growth. Sources of ammonia in the watershed may come from animal feeding areas, decaying organic matter, or bacterial conversion of other nitrogen compounds.

The mean concentration in Blue Dog Lake was 0.05 mg/L with a median of 0.01 mg/L. The standard deviation was 0.13 mg/L which shows a large variation in the samples. The large standard deviation and the difference between the median and the mean show a large variance in the samples collected. On March 5, 1998, the ammonia concentration average was 0.36 mg/L, seven times higher than the average for the entire sampling season (Figure 27). The other spike of high ammonia concentration was in March of 1997. These concentrations may have increased as a result of higher ammonia concentrations near the bottom raised to the surface of the lake by spring turnover (Wetzel, 1983). However, since all of the other parameters increased in concentrations at the same time, a more likely source was nutrient inflow from the tributaries. The ammonia concentrations dropped drastically after the March samples. The ammonia may have been used by algae in the system or converted to other nitrogen forms. The majority of the other ammonia samples collected in the lake were below detection limits.

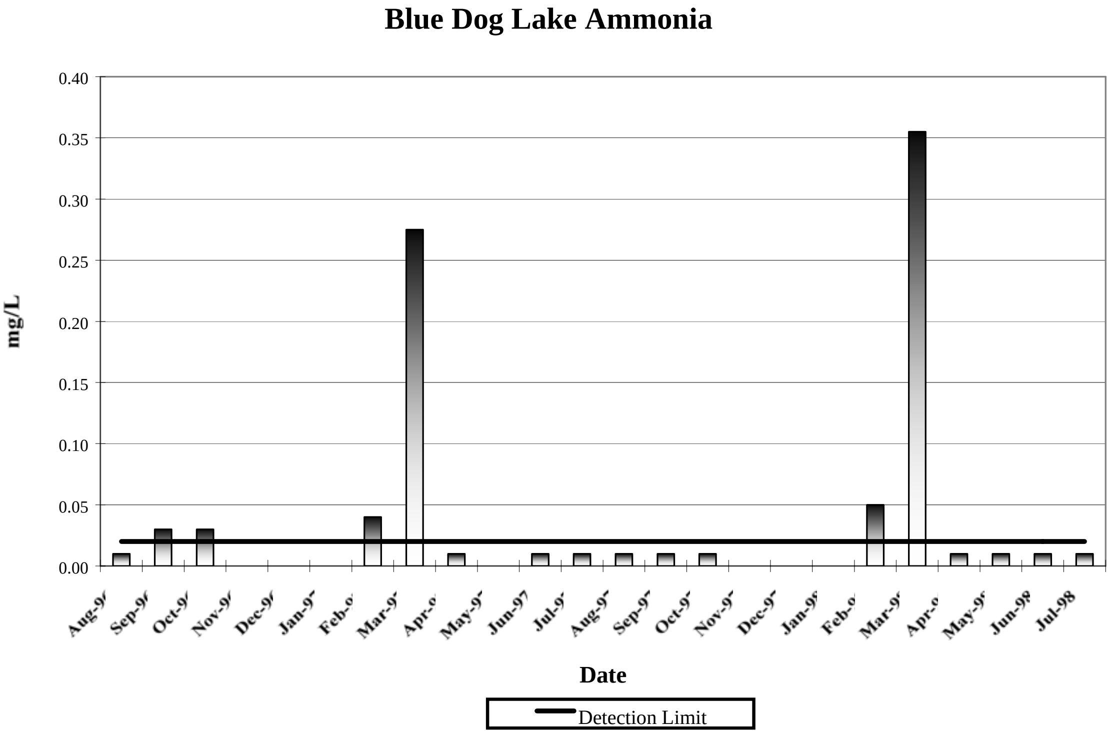


Figure 27.

Nitrate-Nitrite

Nitrate and nitrite are inorganic forms of nitrogen easily assimilated by algae and other macrophytes. Sources of nitrate and nitrite can be from agricultural practices and direct input from septic tanks, precipitation, ground water, and from decaying organic matter. Nitrate-nitrite can also be converted from ammonia through denitrification by bacteria. The process increases with increasing temperature and decreasing pH.

Decomposing bacteria in the sediments and blue-green algae in the water column can convert free nitrogen (N_2) to ammonia. Blue-green algae can then use the ammonia for growth. Although algae use both nitrate-nitrite and ammonia, highest growth rates are found when ammonia is available (Wetzel, 1983). Since nitrogen is water soluble, and blue-green algae can convert many forms of nitrogen for their own use, it is more difficult to remove nitrogen than phosphorus from a lake system.

The average nitrate-nitrite concentration for Blue Dog Lake was 0.23 mg/L (median 0.10 mg/L) for the entire project. As with ammonia, the standard deviation for nitrate was almost twice the mean (0.40 mg/L). One relatively high concentration again raised the mean for the inlake concentrations. On March 26, 1997, at Site #1 the nitrate concentration was 2.20 mg/L. This concentration was 22 times higher than the median sample. There was a smaller spike in the spring of 1998 however the concentration was not nearly as high as the March 1997 sample (Figure 28).

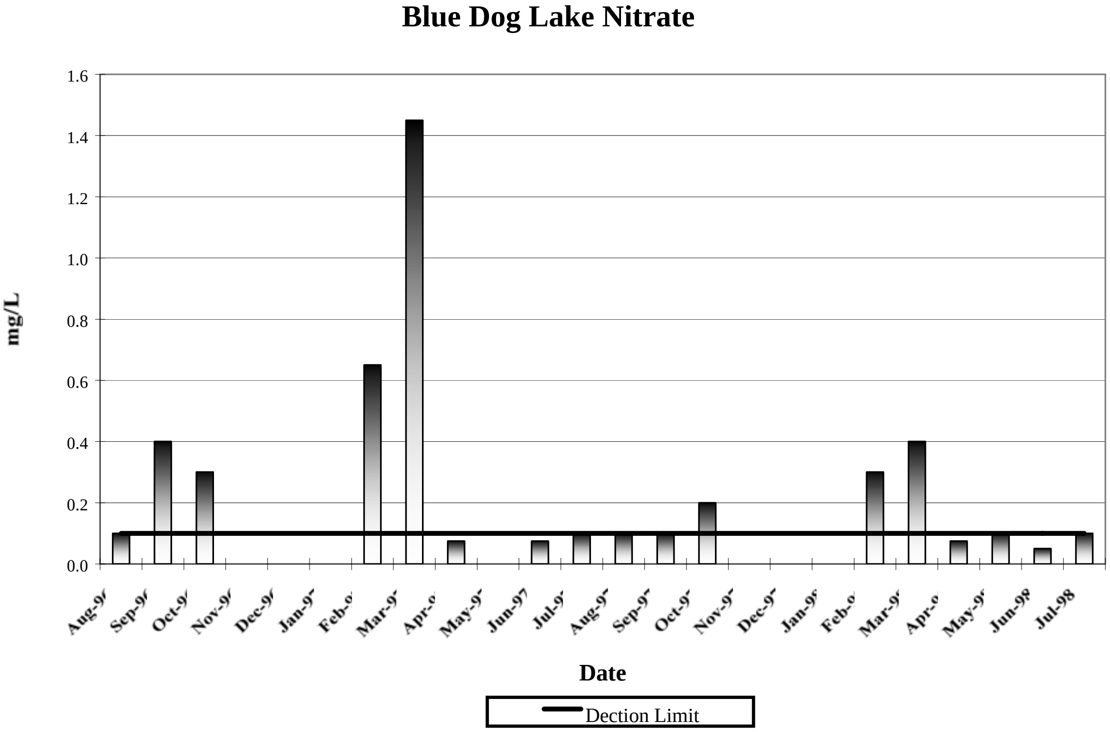


Figure 28.

The higher nitrate concentrations were most likely a result of tributary inputs. The fall of 1996 had high concentrations of nitrates, as did the loadings in the spring of 1997 and the spring of 1998. Nitrogen and phosphorus concentrations n eutrophic lakes are frequently higher after ice out due to accumulation over the winter through decay, low algal numbers and ground water input. It is difficult to tell what effect the high nitrate concentrations found in the ground water in the area are having on inlake concentrations. There is a large ground water exchange between Blue Dog Lake and the surrounding sand and gravel aquifers which most likely is increasing inlake nitrate concentrations.

Total Kjeldahl Nitrogen / Organic Nitrogen

Total Kjeldahl Nitrogen (TKN) is used to calculate organic and total nitrogen. TKN minus ammonia equals organic nitrogen. TKN plus nitrate-nitrite equals total nitrogen. Total nitrogen is used to determine if the lake is nitrogen or phosphorus limited. The limiting factor in Blue Dog Lake will be discussed later. Sources of organic nitrogen can include release from dead or decaying organic matter, lake septic systems, or agricultural waste. Organic nitrogen is broken down to more usable ammonia and other forms of inorganic nitrogen.

The mean and median organic nitrogen concentrations were 0.73 mg/L and 0.72 mg/L respectively. There was a slight increase in the concentration in the summer months (Figure 29). The increase was most likely due to the increase in algae concentrations.

The maximum organic nitrogen concentration (2.22 mg/L) was sampled at Site #2 in August of 1997. The highest chlorophyll concentration was found on the same day. Snow runoff samples, March and April, also appeared to slightly increase the organic nitrogen concentration in Blue Dog Lake.

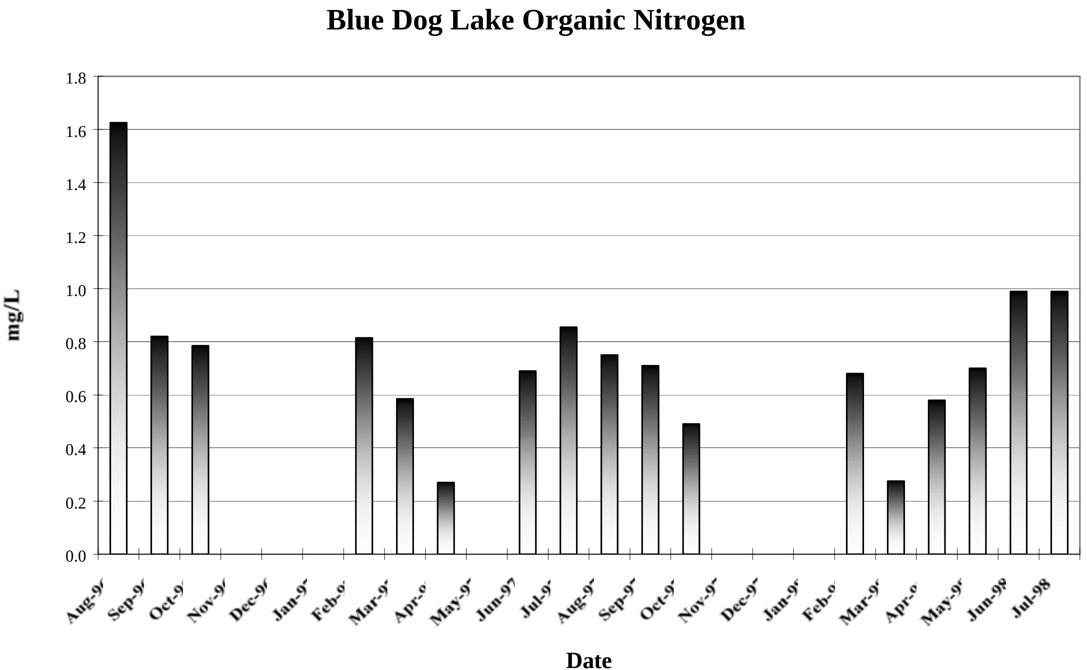


Figure 29.

Of the total nitrogen concentration, the percent that was organic ranged from 20% to 90%. The average percentage of organic was 72%. The lowest organic percentages were found during the winter months.

<u>Total Nitrogen</u>

Total nitrogen is the sum of nitrate-nitrite and TKN concentrations. Total nitrogen is used mostly in determining the limiting nutrient discussed later in the report. The maximum total nitrogen concentration found in Blue Dog Lake was 3.42 mg/L at Site #1 on March 26, 1997. The mean concentration for the entire sampling season was 1.07 mg/L. The standard deviation for total nitrogen varied only 0.59 mg/L throughout the sampling season. The large spike in the spring of 1997 was most likely due to the influx of nitrogen from the watershed.

Seasonally, the total nitrogen concentration increases as snow melt and spring runoff loadings enter Blue Dog Lake. There is a slight drop in April and May, as conditions are not ideal for green and blue-green algal production during those months. As green and blue-green algae production increases so does the concentration of total nitrogen. As algae die off, the concentrations decrease as can be seen by the fall concentrations in Figure 30.

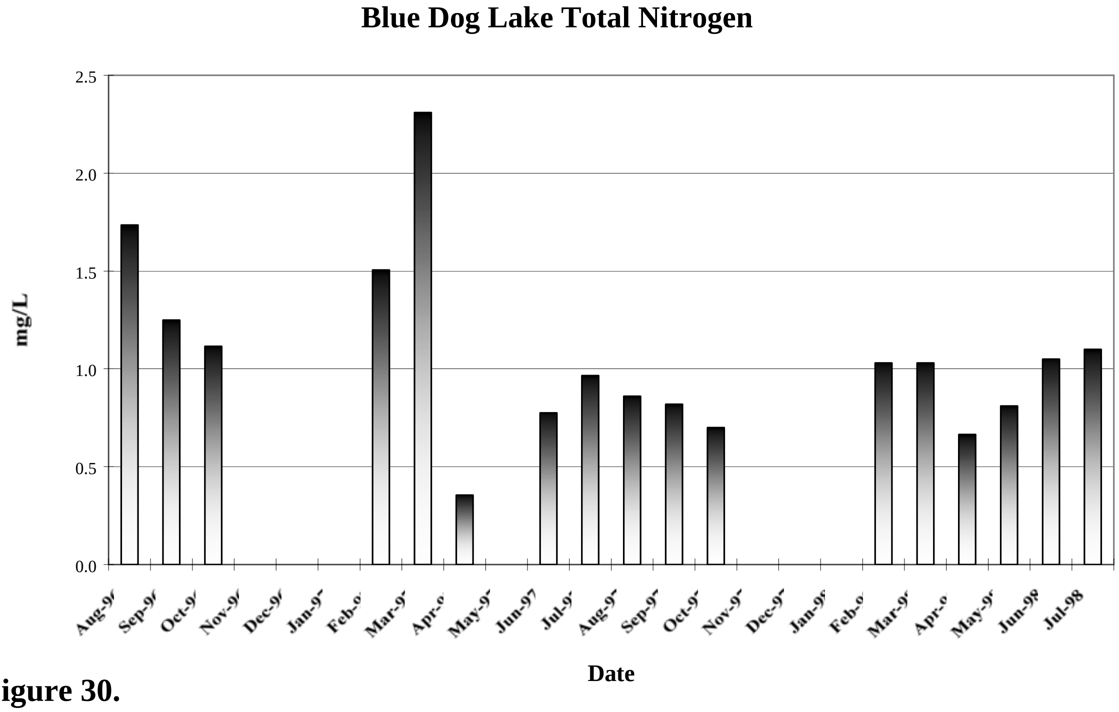


Figure 30.

Total Phosphorus

Typically, phosphorus is the single best chemical indicator of the condition of a nutrient rich lake. Algae need as little as 0.02 mg/L of phosphorus for blooms to occur. Phosphorus differs from nitrogen in that it is not as water-soluble and will sorb on to sediments and other substrates. Once phosphorus sorbs on to any substrate, it is not readily available for uptake by algae. Phosphorus sources can be natural from the geology and soil, from decaying organic matter, and waste from septic tanks or agricultural runoff. Once phosphorus enters a lake it may be used by the biota in the system or stored in the lake sediments. Phosphorus will remain in the sediments unless released by wind and wave action suspending phosphorus into the water column, or by the loss of oxygen and the reduction of the redox potential in the microzone. The microzone is located at the sediment-water interface. As the dissolved oxygen levels are reduced, the ability of the microzone to hold phosphorus in the sediments is also reduced. The re-suspension of phosphorus into a lake from the sediments is called internal loading and can be a large contributor of the phosphorus available to algae (Zicker, 1956).

The average concentration of total phosphorus throughout the study period was 0.080 mg/L (median 0.088 mg/L). There was approximately a 39% deviation from the mean with a standard deviation of 0.039 mg/L. As with most of the maximum nutrient concentrations, the maximum sample concentration was collected at Site #1 on March 26, 1997 (0.131 mg/L). The concentration sampled at Site #2 the next day was 0.060mg/L. Even when averaging Sites #1 and #2 there was still a large variance between samples collected in Blue Dog Lake (Figure 31).

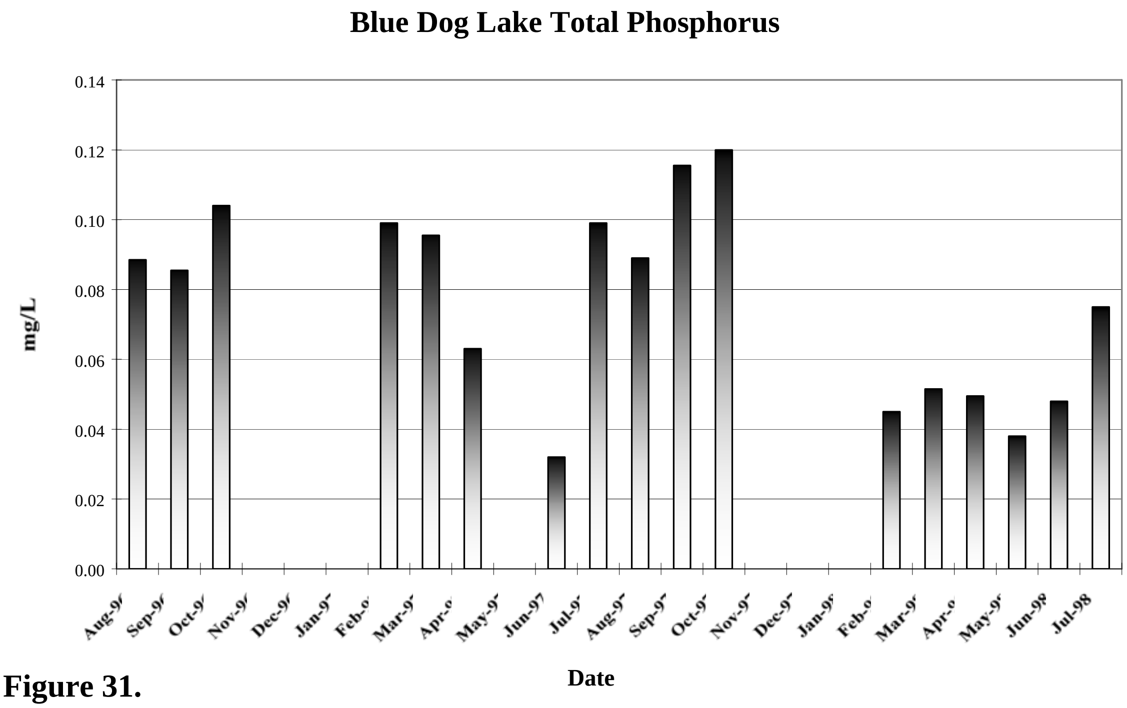


Figure 31.

As can be seen Figure 31, there are not only seasonal differences in phosphorus concentrations, but also yearly differences. The beginning of 1996 was a dry until the fall when, with increasing precipitation, loadings to the lake increased dramatically. Also the lake levels were not as high and dilution was not a major factor. The winter of 1997 showed an increase in phosphorus that may have been from internal loadings. According to dissolved oxygen profiles, Appendix E, dissolved oxygen levels may have reached near zero, weakening the microzone and releasing phosphorus from the sediments. The winter of 1996-1997 also had the deepest snowfall on record for the area. Extremely large spring loadings most likely diluted the water or flushed the high phosphorus concentrations out of the lake. Summer increases were most likely from re-suspension of bottom sediments and uptake of phosphorus by algae. Since the spring loads of 1998 were not as large as the previous winter, the spring concentrations of 1998 were slightly less than the previous years samples.

As can be seen from the graph in Figure 31, there were seasonal increases in phosphorus from May to August in both 1997 and 1998. The higher concentrations may have been due to a continual release of phosphorus from the sediments due to wind and waves or the increase of tributary inputs to the lake. Whatever the case, the increase in phosphorus concentrations in Blue Dog Lake will mean an increase in the productivity of the lake. Since phosphorus is usually the cause of algal blooms, by removing the phosphorus sources coming into the lake, in time, Blue Dog Lake should see a decline in algal blooms and better water quality.

Total Dissolved Phosphorus

Total dissolved phosphorus is the fraction of total phosphorus that is readily available for use by algae. Dissolved phosphorus will sorb on to suspended materials if they are present in the water column, and if the are not already saturated with phosphorus. Figure 32 shows a relatively clear relationship (*****$R^2 = 0.476$) between an increase in total suspended solids decreasing the percent of dissolved phosphorus in the water column in 1997. Due to yearly seasonal differences and changes in lake volume, relationships are better when data is compared one year at a time. Figure 33 shows the relationship between chlorophyll *a* and the percent of dissolved phosphorus. As the percent of dissolved phosphorus decreases, the chlorophyll a concentration increases. The graph depicts the algal uptake of dissolved phosphorus for photosynthesis.

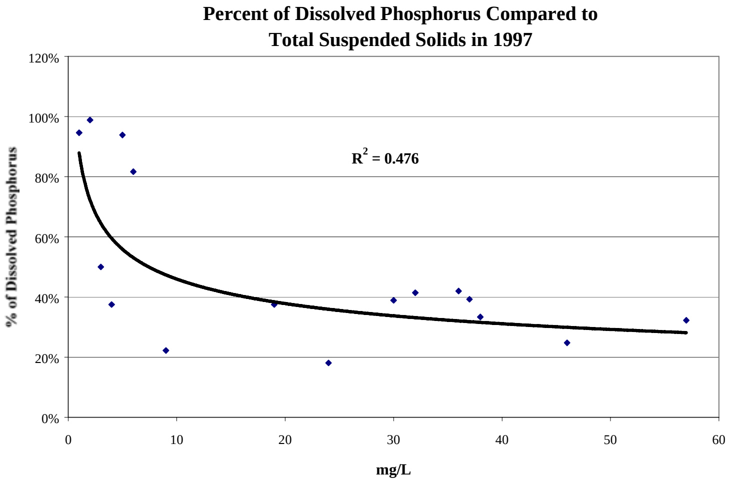


Figure 33.

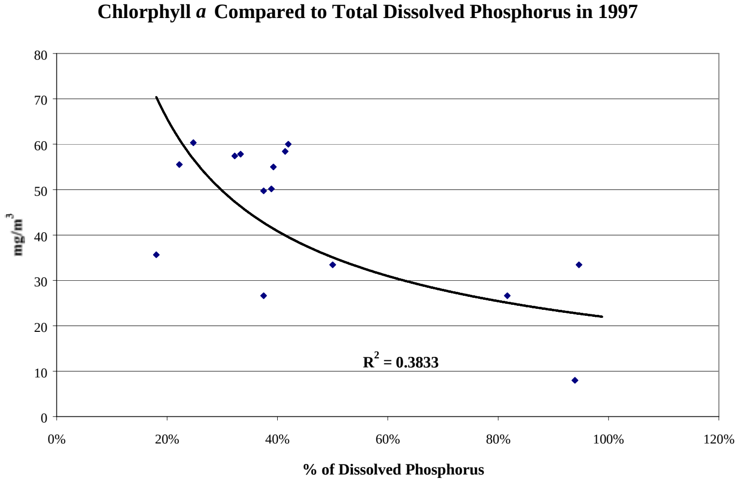


Figure 32.

As can be seen in Figure 32, there were varying amounts of suspended solids that effected the dissolved phosphorus concentration. The average percent of phosphorus that was dissolved during the project was 48%. The percent dissolved phosphorus ranged from 15% during the summer to 99% during the winter. The average dissolved phosphorus concentration in Blue Dog Lake was 0.039 mg/L (median 0.035 mg/L). Since algae only need 0.02 mg/L of phosphorus to produce an algal bloom (Wetzel, 1983), Blue Dog Lake averages twice the available phosphorus for an algal bloom.

** R^2 = is a value given for a group of points with a statistically calculated line running through them. The higher the R^2 value the better the relationship, with a perfect relationship reached when $R^2 = 1.0$.*

Average inlake dissolved phosphorus concentrations can be found in Figure 34. The cyclic phosphorus concentrations were most likely the result of algae using the dissolved phosphorus in spring and summer (lower concentrations). They then released the phosphorus back into the system as the algae died in the late summer and fall (higher concentrations). The higher winter concentrations were most likely due to the low algal production and the lack of suspended sediment in the water column. The percent dissolved phosphorus during the 1997 February and March samples (Sites #1 and #2 averaged) was 96.5% and 90% respectively.

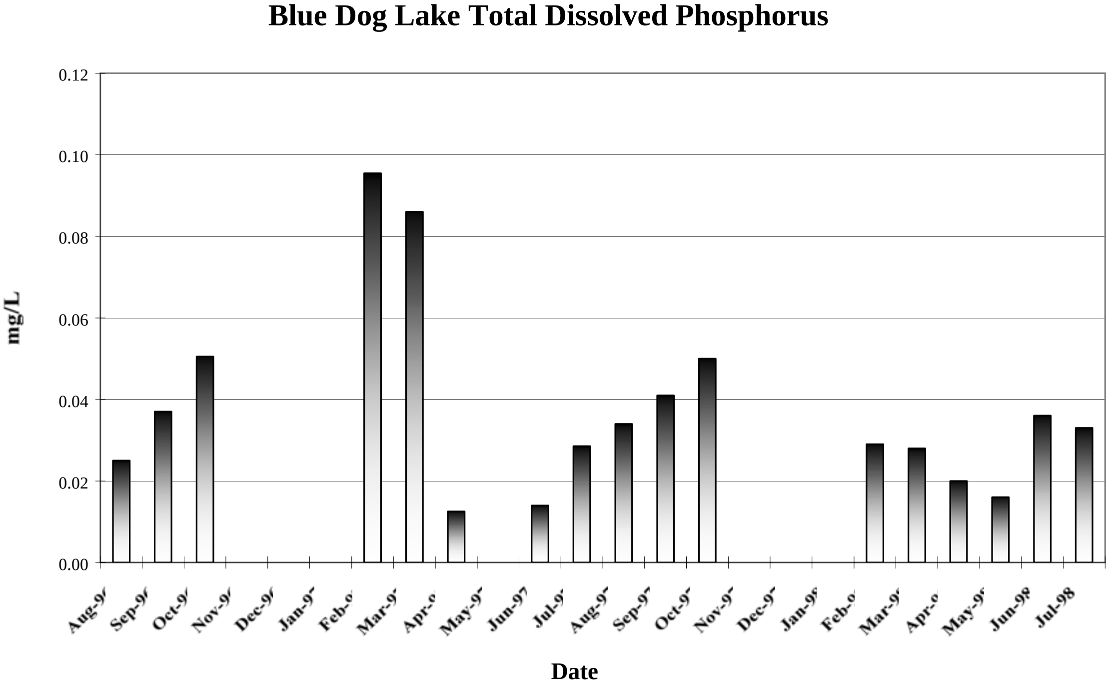


Figure 34.

In conclusion, the dissolved phosphorus concentrations in Blue Dog Lake were directly affected by algae production and suspended bottom sediments. Because of the higher suspended solids concentrations in the summer, dissolved phosphorus sorbs on to the particles in the water column. What dissolved phosphorus is left available is quickly used up by algae, lowering the summer dissolved phosphorus concentrations. The ice formed on the lake eliminated the re-suspension of sediment from wave action and allowed for higher dissolved phosphorus concentrations. In the winter months of 1997, Blue Dog Lake had twice the available phosphorus that was found in the summer, however, light availability and cool temperatures most likely limited algal production in winter.

Fecal Coliform Bacteria

Fecal coliform bacteria are found in the intestinal tract of warm-blooded animals. Fecal coliform bacteria are used as indicators of waste and presence of pathogens in a waterbody. Many outside factors can influence the concentration of fecal coliform. Sunlight and time seem to lessen fecal concentrations even though the nutrient concentrations remain high. As a rule, just because fecal bacteria concentrations are low or non-detectable, does not mean animal waste is not present in a waterbody.

Inlake concentrations are typically low because of exposure to sunlight and dilution of the bacteria in a larger body of water. Of the 30 individual samples collected, 60% of the fecal coliform concentrations were below detection limits. The maximum concentration (360 colonies/100 ml) was collected in a sample on September 22, 1997 at Site #2. Site #1’s fecal coliform counts were below the detection limit on the same date. Site #2 was closer to the Owen’s Creek inlet and was most likely effected by the high fecal coliform samples from a runoff event just prior to the lake sample. The average fecal coliform bacteria count was 27 counts/100. Figure 35 shows the inlake average each date samples were collected. The peaks in Figure 35 typically coincide with runoff events in the watershed. However, there were times when fecal coliform counts were detected at Site #1 and were not detected at Site #2. This again shows the spatial variability that can be found in a lake. Since high nutrient concentrations usually accompany the fecal bacteria counts, controlling animal waste would decrease both fecal concentrations and nutrient concentrations.

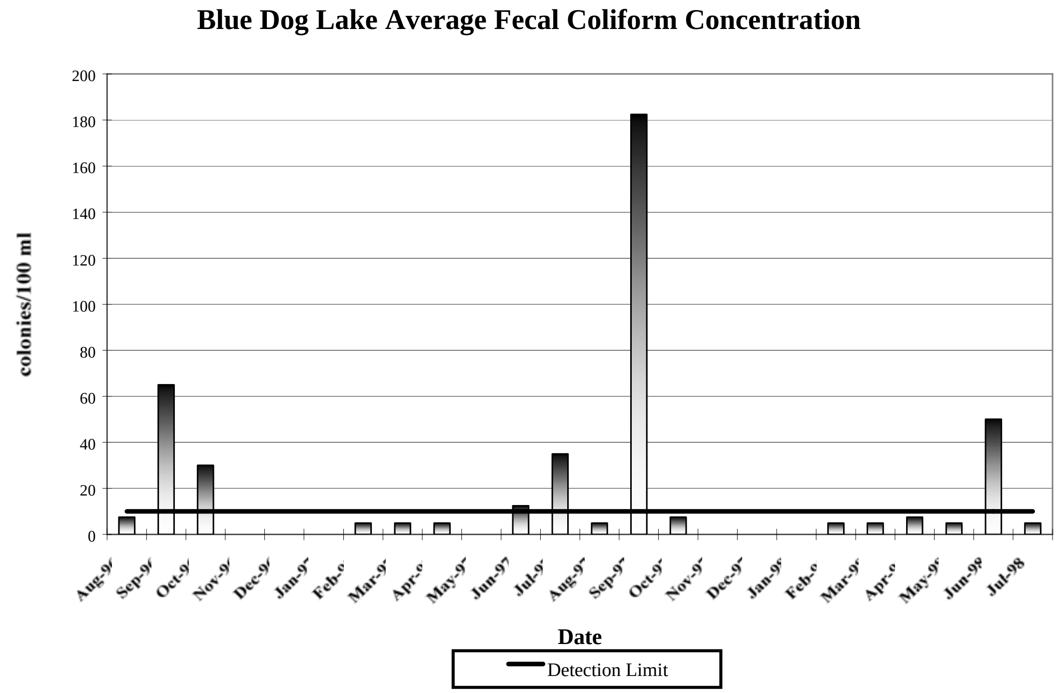


Figure 35.

Chlorophyll *a*

Chlorophyll *a* is a pigment in plants that may be used to estimate the biomass of algae found in a water sample (Brower, 1984). Chlorophyll *a* samples were collected on all of the inlake samples during the project. One sample on February 22, 1997 was not reported on due to laboratory error. Overall, the chlorophyll *a* concentrations in Blue Dog Lake were relatively low (Figure 36). Figure 36 is the average of Site #1 and Site #2 on the date a sample was collected.

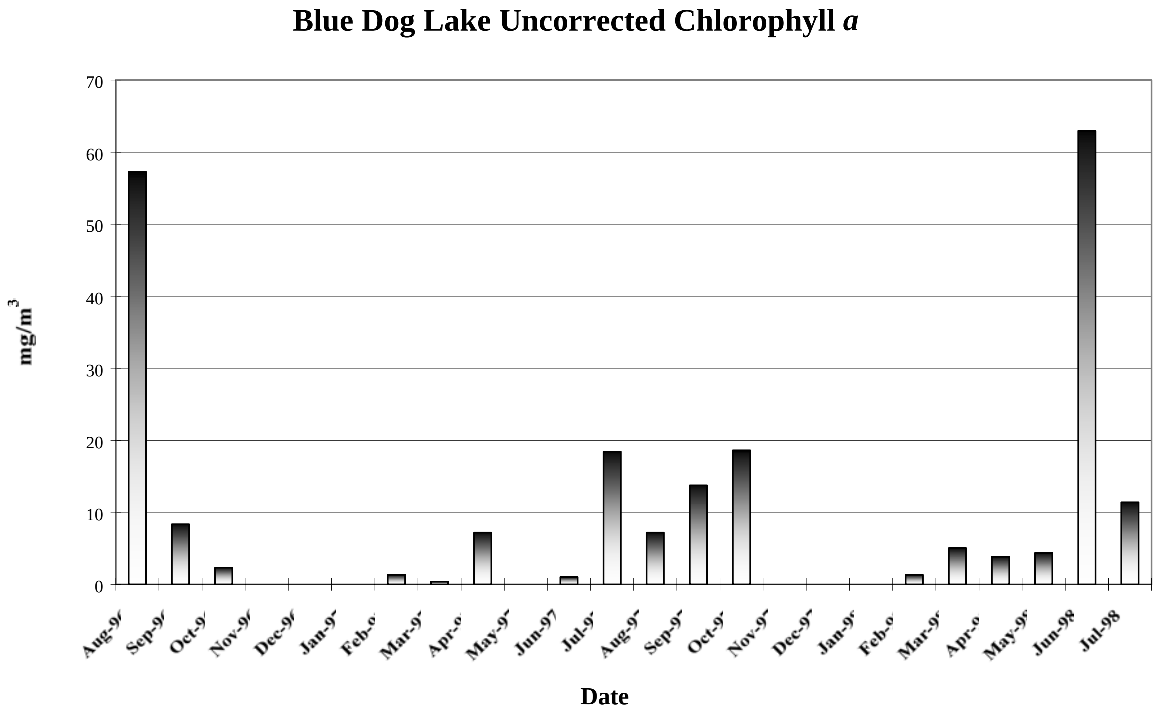


Figure 36.

The date with the highest inlake chlorophyll *a* sample (63 mg/m^3) was collected on June 24, 1998. Figure 36 shows that the high readings found in June 1998 were 5 to six times higher than the project average (13 mg/m^3). The two high sample dates, August 1996 and June 1998, greatly increased the project average chlorophyll *a* concentrations. The median concentration for the project was only 7 mg/m^3.

If chlorophyll *a* were the only parameter used to estimate the eutrophy of a lake, Blue Dog Lake would be rated as borderline mesotrophic (average TSI 47). Two sample dates during the project had TSI levels in the hypereutrophic range. (Figure 37). Just because the chlorophyll *a* concentrations are not high does not mean the lake is not eutrophic to hyper-eutrophic. Suspended sediments or other factors in Blue Dog Lake may be limiting algal growth.

Chlorophyll *a* TSI Values

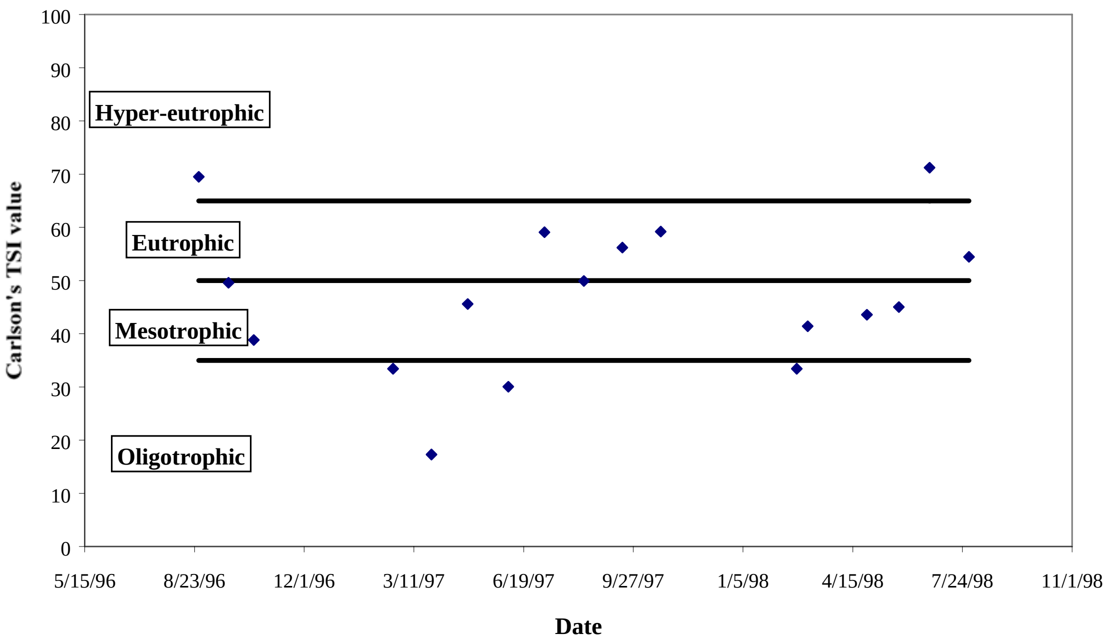


Figure 37.

As can be see in Figure 37, winter samples were oligotrophic and then became more eutrophic as spring and summer progressed. The low chlorophyll *a* concentration in June of 1997 was most likely due to the short water time or the sample may have been collected after a diatom bloom and before a green or blue green algae bloom.

Typically, chlorophyll *a* and total phosphorus have a relationship in regards to increasing concentrations. As total phosphorus increases so does chlorophyll *a*. Each lake usually shows a different relationship because of factors including but not limited to; nutrient ratios, temperature, light, suspended sediment, and water retention time. Such a relationship was attempted using all of the data from the project. However, as can be seen from Figure 38, the data was too scattered to have any kind of relationship (R^2* 0.0335). However, when outliers were removed (mostly winter samples along with fall 1996 fall samples and one 1998 spring sample), a better relationship developed, (R^2 = 0.6224 – Figure 39). Winter chlorophyll *a* samples typically do not follow any standard scenario because of constant changing light conditions, mainly due to snowfall. Extremes in wind condition were the likely cause for the fall and summer outlying data. On a warm day, if there is no wind, algae can produce extremely high chlorophyll *a* conditions. If the wind were blowing extremely strong, suspended sediments could hinder chlorophyll *a* production. A combination of the above factors was the most likely reason Figure 38 had a low R^2 value.

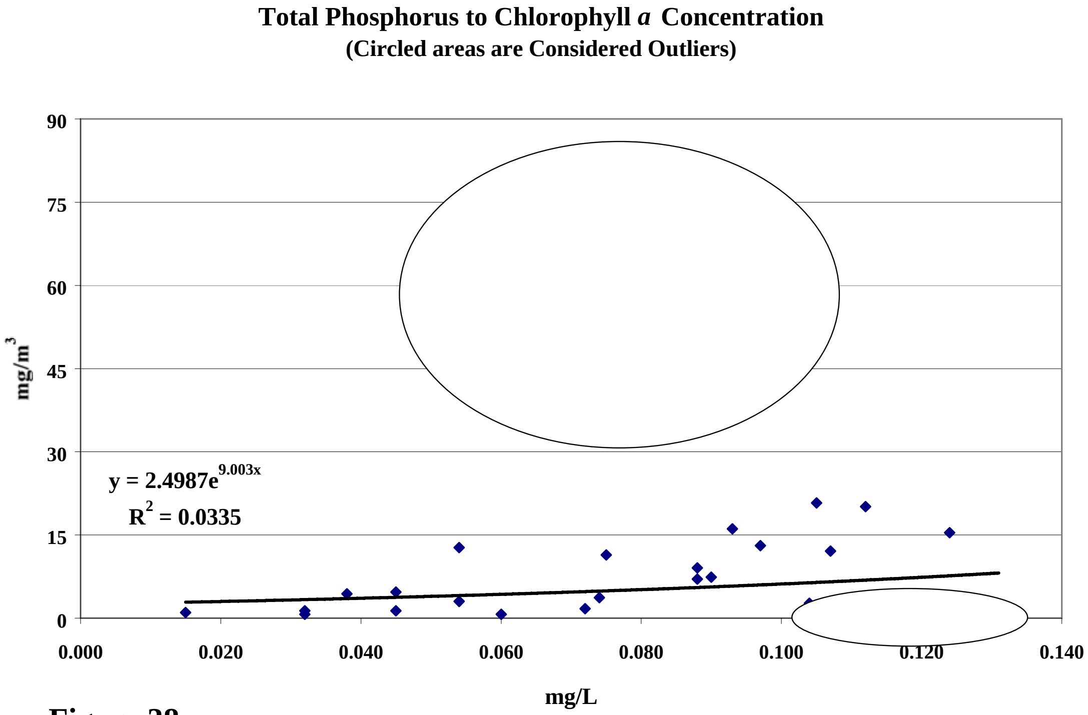


Figure 38.

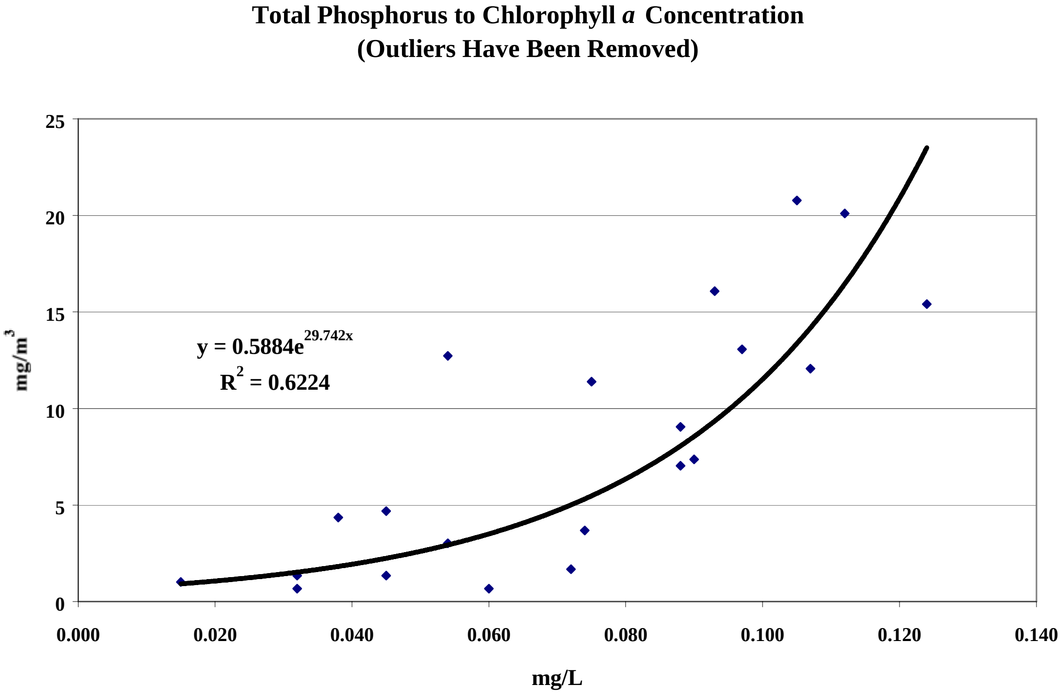


Figure 39.

The relationship between phosphorus and chlorophyll *a* can be used to estimate a reduction in chlorophyll by reducing inlake phosphorus concentrations. The better the relationship the more confident lake managers can be in the expected results. The data will be used in the reduction response model later in the report. The equation for the line in Figure 39 will be used to predict chlorophyll *a* from inlake phosphorus concentrations. The line equation is shown below.

$$y = 0.5884e^{29.724x}$$

{Equation 2} $y = \textit{predicted chlorophyll a concentration}$

$x = \textit{phosphorus concentration}$

Phytoplankton

Planktonic algae collected at two sites in Blue Dog Lake during 1997 and 1998, consisted of 98 taxa which represented 68 genera within seven algal divisions? Green algae (Chlorophyta) were the most diverse group with 41 taxa followed distantly by diatoms (Bacillariophyta) with 18 taxa. The remaining taxa were variously distributed among blue-green algae (Cyanophyta), yellow-brown algae (Chrysophyta), cryptomonads (Cryptophyta), euglenoids (Euglenophyta), and dinoflagellates (Pyrrophyta). Numerically, diatoms were important components of the lake phytoplankton population in spring and fall, blue-green algae during summer, and green algae in autumn (Tables 1and 2). Over all, blue-green algae produced the largest seasonal populations in Blue Dog Lake followed by centric diatoms and motile (flagellated) algae in various divisions. Non-motile green algae represented the least abundant group. This type of algal association is often reported and may be typical of hardwater lakes in north central US. That is, an algal community dominated by blue-greens and diatoms with green algae comprising a relatively small percentage of the total population (Prescott, 1962).

The initial algal samples of this survey were collected on March 27,1997, shortly before breakup of ice cover. Laboratory analysis indicated relatively small algae populations were present in Blue Dog Lake immediately prior to ice out. Total algal densities at the two inlake sites averaged 874 cells per milliliter (ml) which represented the smallest monthly density reported during the 2-year study (Appendix F). The samples contained primarily miscellaneous small algal cells that could not be identified and two taxa of green algae: *Chlamydomonas* sp. and *Ankistrodesmus* sp. Diatoms and blue-green algae were not observed in the late March samples.

The next algae samples taken on April 29,1997, indicated a pronounced bloom of the small (7-10um) centric diatom *Stephanodiscus hantzschii* at an average density of 17,585 cells/ml, which represented nearly 57% of the total algal population at that time. Similar spring pulses of *S. hantzschii* were reported in the past for Lake Poinsett (1976) and recently in Lake Mitchell (1997). A small bloom of this minute diatom was also noted in October 1997 in Blue Dog Lake accompanied by a fall annual maximum for *Stephanodiscus niagarae* (50 um) a much larger-sized species of the genus. Both diatom species frequently occur in eutrophic hardwater lakes (Hutchinson, 1967). A spring/fall abundance pattern was also noted for the cryptomonad flagellates *Cryptomonas* spp. and *Chroomonas* sp. although a spring peak for *Cryptomonas* spp. was not observed in 1998. Other common flagellate taxa during April 1997 were *Chlamydomonas* spp. and *Dinobryon sertularia.*

The following samples on June 5 and July 8, 1997, indicated a decline in mean algal densities from 31,120 cells/ml in April to 23,137 cells/ml in June and 4,900 cells/ml in July. A similar late spring decline in algal numbers and chlorophyll *a* concentration was observed in Lake Poinsett and may be a common phenomenon in eutrophic lakes. The decline is often manifested by a noticeable improvement in lake water transparency for several weeks from late May to mid June that has frequently been observed in otherwise turbid lakes. The algal decrease in the survey could be attributed to the collapse of the spring diatom bloom and the absence of any replacement algal numbers such as greens and blue-greens during that time (Appendix F). The small algae community in early July was characterized by relatively low summer densities of *Aphanizomenon flos-aquae* at 1770 cells/ml (57 filaments/ml) and a moderate bloom of the diatom *Melosira granulata* (mean: 910 cells/ml). *Melosira* frequently becomes common/abundant during summer in eutrophic state lakes.

Algae samples collected on the next sampling date of August 13, 1997, did not indicate the presence of a summer blue-green bloom that would be expected in a highly eutrophic lake. *Aphanizomenon flos-aquae* were present at a rather low density of 33 filaments/ml at Site #1 and at only a trace density of 4 filaments/ml at Site #2. Whereas a very small colonial blue-green taxon, *Aphanocapsa* spp., became common in August, its contribution to summer algal biomass and chlorophyll level was deemed negligible. *Chrysochromulina* sp. represented the only other abundant taxon in August samples. This small pigmented flagellate (5-7 μm) is sometimes overlooked in algal studies of eutrophic lakes. Despite the absence of a definable bloom, total algal numbers in August 1997 had more than doubled over June levels and recorded a mean density of 56,714 cells/ml.

The maximum annual algal density for Blue Dog Lake occurred on September 17,1997 due largely to the presence of high numbers of *Aphanocapsa* spp. at Site #1. *Aphanizomenon* showed only a moderate increase over August levels and could not be considered abundant or in a bloom status. Other nuisance blue-green algae, such as *Anabaena* and *Microcystis* spp., were even less common than *Aphanizomenon.* A diverse assemblage of green algae (Chlorophyta) was present in the lake since August but their combined densities amounted to less than 1400 cells/ml (Table 1). *Chrysochromulina* attained maximum annual abundance during September 1997 at Site #1.

October samples indicated a seasonal decline in total algal numbers to a 2-site mean of 35,836 cells/ml due to a sharp drop in *Aphanocapsa* spp. abundance. Other blue-green algae such as *Aphanizomenon* and *Microcystis* increased in number but did not approach nuisance levels (Appendix F, Table 1). Green algae maintained a diverse population and doubled in abundance during October. Their mean density was relatively moderate (3093 cells/ml) making up about 9% of the total algal community.

The first algal samples of 1998 were collected on April 29. Those samples disclosed a smaller spring diatom pulse of *Stephanodiscus hantzschii* and fewer *Cryptomonas* spp. than in 1997. However, there were more of the diatom taxa *Cyclotella, Asterionella,* and *Nitzschia acicularis,* and green algae than in April 1997 samples (Appendix F, Tables 1 and 2). Total algal density in April 1998 was 68% that of the previous year due to the smaller diatom bloom noted above (Appendix F). These differences between years can be ascribed to natural annual variability in plankton populations commonly reported in the literature.

Late spring samples on May 27, 1998 indicated a somewhat larger population of blue-green algae and smaller numbers of flagellated algae than were present during the comparable period in 1997. The early summer sample collected on June 24, 1998 disclosed a dense bloom of *Aphanizomenon flos-aquae* containing approximately 222,800 cells/ml (9,750 filaments/ml). Those high densities together with large numbers of *Aphanocapsa* spp. present at this time produced a total algal count of 354,635 cells/ml, the maximum monthly density recorded for the study. By the end of July, Aphanizomenon numbers were reduced by more than 90% to 17,890 cells/ml or 720 filaments per milliliter (Appendix F, Table 2).

In eastern South Dakota lakes, summer blue-green blooms typically begin to develop in mid to late June and build up to maximum densities from July through September. The blooms decline steeply in October with the seasonal drop in water temperature - if other growth factors such as nutrients do not become limiting in the meantime. The apparent shorter duration of the nuisance bloom in Blue Dog Lake suggests this lake may be more responsive to nutrient reduction and watershed improvement measures than other blue-green dominated eutrophic lakes.

Trophic State Index

Carlson’s (1977) Trophic State Index (TSI) is an index that can be used to measure the relative trophic state of a waterbody. The trophic state is how much algal production occurs in the waterbody. The smaller the nutrient concentrations are in a waterbody, the lower the trophic level, and the larger the nutrient concentrations the more eutrophic the waterbody. Oligotrophic is the term used to describe the least productive lakes and hyper-eutrophic is the term used to describe lakes with excessive nutrients and production. Table 10 describes the different numeric limits applied to various levels of the Carlson Index.

Three different parameters can be used to compare the trophic index of a lake; 1) total phosphorus, 2) Secchi disk, and 3) chlorophyll *a*. The TSI levels are shown in Table 11 and a graph showing all of the TSI readings is shown in Figure 40.

Table 10. Trophic Level Ranges

Trophic Level	Numeric Range
Oligotrophic	0 – 35
Mesotrophic	36 – 50
Eutrophic	51 – 65
Hyper-eutrophic	66 – 100

Table 11. Blue Dog Lake Trophic State.

Parameter → Calculation ↓	Chlorophyll *a*	Total Phosphorus	Secchi Depth	Parameters Combined
Mean TSI	46.83	65.86	73.82	61.36
Median TSI	49.71	68.66	77.14	65.36
Standard Deviation	14.80	7.26	8.04	15.47

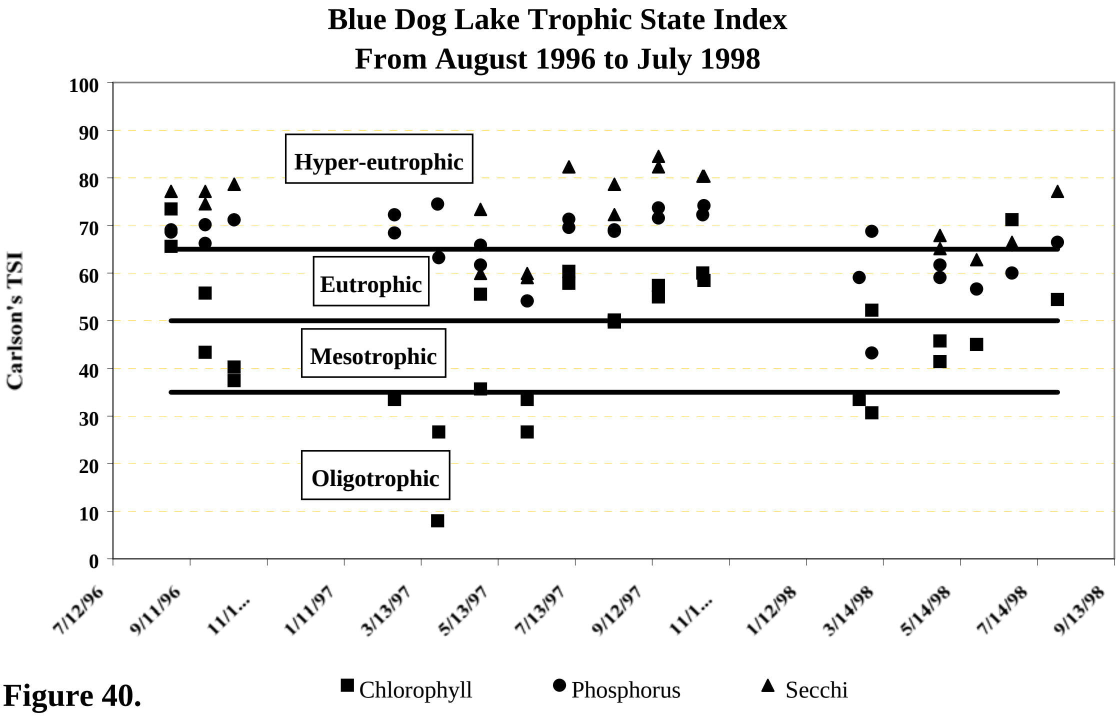


Figure 40.

The mean and median for Secchi TSI were far into the hyper-eutrophic range of the index. The mean phosphorus TSI was just above the eutrophic level and the chlorophyll *a* TSI average was in the mesotrophic range. The Secchi TSI levels were an indication that shallow depths and re-suspension of bottom sediments were adding to the eutrophication of Blue Dog Lake. The bottom sediments carry phosphorus into the water column; sediments also limit light penetration and hinder algal growth. The average TSI rating over the entire project was 61.36, the upper end of the eutrophic range.

Long-Term Trends

Because there were a number of samples collected from this study and the Statewide Lake Assessment (Stueven, 1996), it is possible to make some assumptions about the water quality trends in Blue Dog Lake over time. Since the samples taken from 1989 to 1993 were collected in the summer, only summer samples collected during the project will be used in the trend analysis (Figure 41). Carlson's TSI index will be used for the comparison.

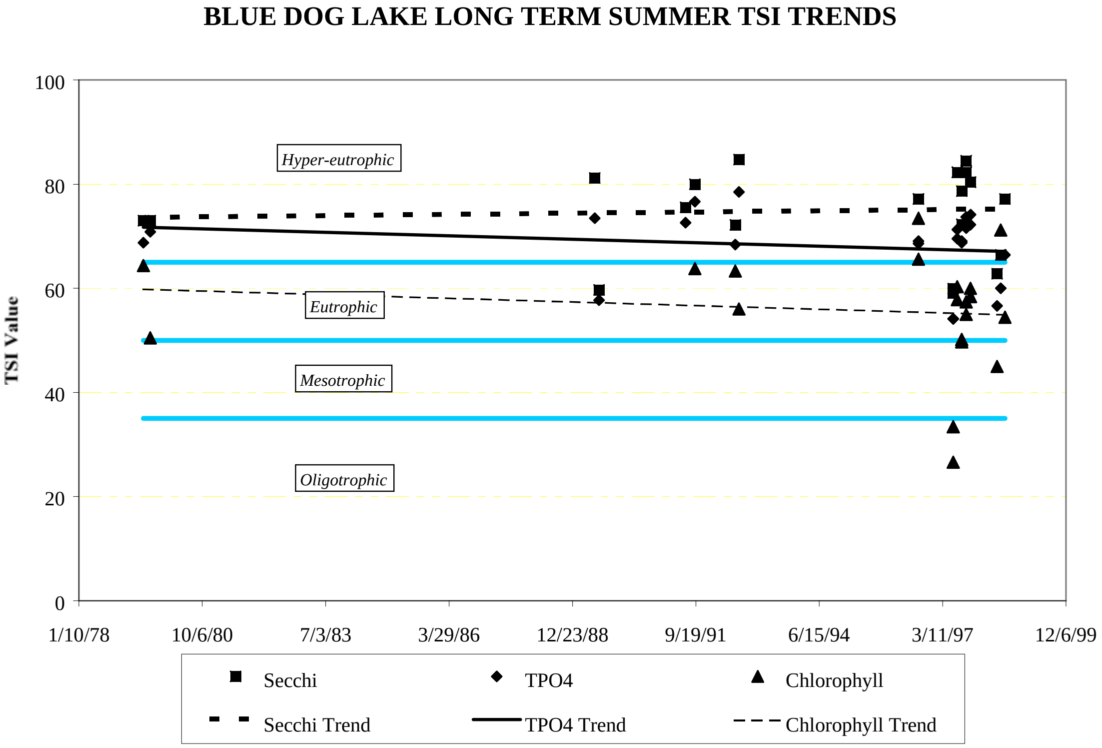


Figure 41.

The trends for chlorophyll *a* and total phosphorus were slightly declining. The phosphorus decline may be due to the increased volume of water in Blue Dog Lake diluting the phosphorus concentrations. There may also be fewer nutrients coming in from the watershed due to better farming practices, or the installation of a central sewer system around the lake in the early 1990's. The decline in chlorophyll *a* TSI levels was most likely a result of fewer nutrients in the lake (i.e. decreased phosphorus concentrations) or a result of increased suspended solids reducing algal production. The Secchi disk TSI trend was slightly increasing meaning there were more suspended sediments in the water that limit light penetration by creating more water turbidity.

The increasing suspended sediments in the lake were most likely from shoreline erosion and re-suspension of bottom sediment due to wind and wave action. As stated earlier, the suspended sediments could be blocking sunlight and limiting algal production, thus reducing chlorophyll *a* concentrations. Increasing sedimentation usually increases the total phosphorus concentrations in a lake. In Blue Dog Lake however, the trend is decreasing phosphorus concentrations. The installation of the central sewer system around Blue Dog Lake may have had an effect on reducing phosphorus concentrations. With further work in the watershed and the stabilization of the shoreline, phosphorus TSI levels in Blue Dog Lake will continue to decrease. However, if wind and wave action continue to suspend the bottom sediments, Secchi TSI levels in Blue Dog Lake will not improve. After the wet years of 1997 and 1998, it remains to be seen what effects the large loading of nutrients will have on the lake once the water levels subside. Algae production, in years following an extremely wet year increases dramatically as the lake makes use of the increased nutrient concentrations. Long-term monitoring is the best way to track the TSI trends in Blue Dog Lake.

Limiting Factor for Chlorophyll Production

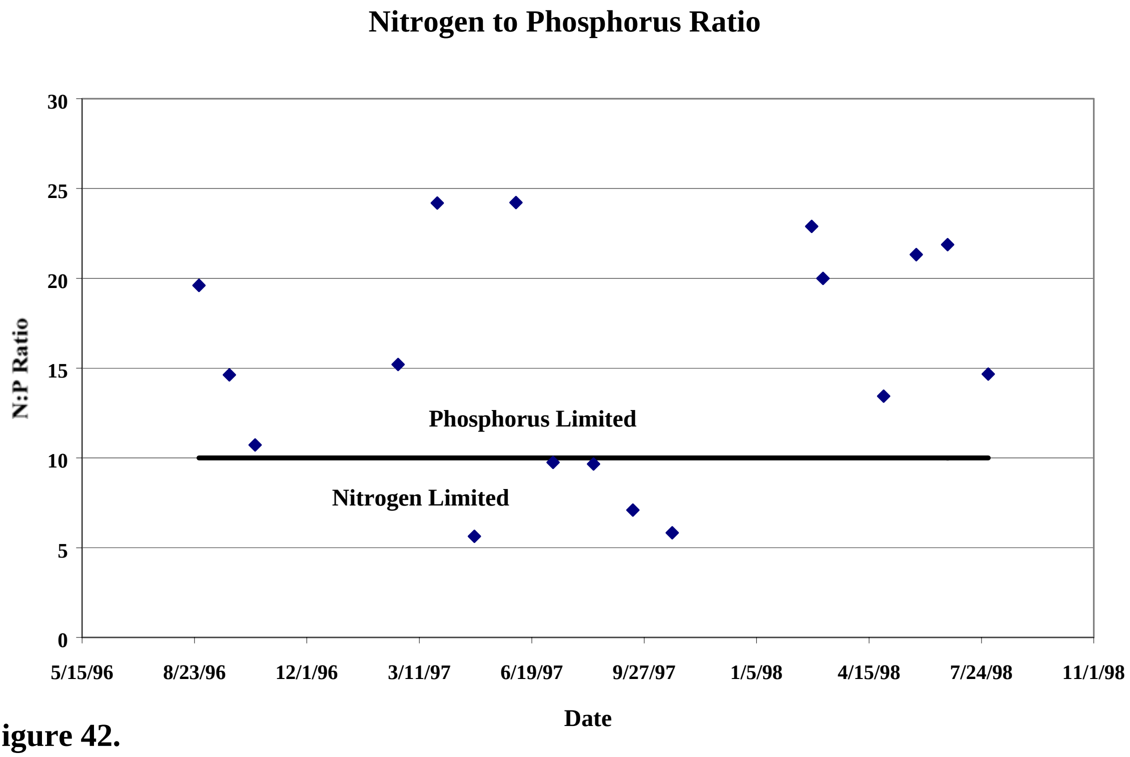


Figure 42.

For an organism (algae) to survive in a given environment, it must have the necessary nutrients and environment to maintain life and to be able to reproduce. If an essential component approaches a critical minimum, this component will become the limiting factor (Odum, 1959). Nutrients such as phosphorus and nitrogen are most often the limiting factor in highly eutrophic lakes. Typically, phosphorus is the limiting nutrient for algal growth. However, in many highly eutrophic lakes with an overabundance of phosphorus, nitrogen can become the limiting factor.

In order to determine which nutrient will be the limiting factor, EPA (1990) has suggested a total nitrogen to total phosphorus ratio of 10:1. If the total nitrogen concentration divided by the total phosphorus concentration on a given sample data is greater than 10 the lake is said to be phosphorus limited. If the ratio is less than the above-mentioned scenario, the waterbody is said to be nitrogen limited.

From Figure 42, the majority of the time Blue Dog Lake was a phosphorus-limited lake. The average total nitrogen to total phosphorus ratio in Figure 42 is 15.3 (phosphorus limited above 10) with a standard deviation of 6.5. Blue Dog Lake was only nitrogen limited on four dates during the summer of 1997, on two of these dates the ratio was extremely close to the phosphorus limited line.

As stated earlier, limiting factors can be anything physical or chemical that limits the growth or production of an organism. Even though phosphorus limitation may be affecting algal growth, other factors, such as light-blocking sediments, can be more limiting than nutrient concentrations. If the suspended sediment concentrations subsided and did not block light, chlorophyll *a* concentrations in Blue Dog Lake would most likely increase.

Reduction Response Model

Inlake total phosphorus concentrations are a function of the total phosphorus load delivered to the lake by the watershed. Vollenweider and Kerekes (1980) developed a mathematical relationship for inflow of total phosphorus and the inlake total phosphorus concentration. They assumed that if you change the inflow of total phosphorus, you change inlake phosphorus concentrations by a corresponding but steady amount. The variables used in the relationship are:

1) $[\overline{P}]\lambda$ = Average inlake total phosphorus concentration
2) $[\overline{P}]i$ = Average concentration of total phosphorus that flows into the lake
3) $\overline{T}p$ = Average residence time of inlake total phosphorus
4) $\overline{T}w$ = Average residence time of lake water

Data collected in 1997 during the Blue Dog Lake Watershed Assessment Project provided enough information to estimate $[\overline{P}]\lambda$, $[\overline{P}]i$, and $\overline{T}w$. In order to estimate the residence time of total phosphorus ($\overline{T}p$) it was necessary to back calculate Equation 3 below, and solve for $\overline{T}p$ by forming Equation 4 (Wittmuss, 1996):

{Equation 3} $$[\overline{P}]\lambda = \left[\frac{\overline{T}p}{\overline{T}w}\right][\overline{P}]i$$

{Equation 4} $$(\overline{T}p) = \frac{[\overline{P}]\lambda}{[\overline{P}]i}(\overline{T}w)$$

Values for $[\overline{P}]\lambda$, $[\overline{P}]i$, and $\overline{T}w$ were determined in the following manner:

$[\overline{P}]\lambda$ was determined by averaging all of the surface total phosphorus samples from 1997.

$[\overline{P}]i$ was determined by adding all of the input loadings for total phosphorus in milligrams and dividing that number by the total number of liters that entered the lake. The values for both of these numbers came from tributaries, ungauged runoff, ground water, and the atmosphere.

$\overline{T}w$ was determined by averaging the total volume of Blue Dog Lake (10,390 acre-feet) by the total outputs of water from the lake (34,498 acre-feet/days).

$$\overline{T}w = {}^{10{,}390/acre/\ feet}\Big/_{34{,}498/acre/\ feet} = 46\ days = 0.13\ years$$

The final values for $[\overline{P}]\lambda$ and $[\overline{P}]i$ are:

$[\overline{P}]\lambda$ = 0.089 mg/L $[\overline{P}]i$ = 0.086

By inserting the numbers in the proper places as discussed in Equation 5, $\overline{T}p$ would be:

$$(\overline{T}p) = \left[\frac{0.089}{0.083}\right](0.13) = 0.13\ years = 47\ days$$

Once all factors for the four variables are calculated, certain variables can be changed to show a response of another variable. For our reduction model, the phosphorus residence time ($\overline{T}p$) divided by the hydrologic residence time ($\overline{T}w$) is a standard coefficient and will not change (1.03). With only one year of sampling, there is no way to estimate the reduction in the retention time of total phosphorus. This leaves two factors; average phosphorus inputs ($[\overline{P}]i$) and average inlake phosphorus concentration ($[\overline{P}]\lambda$). By inserting a reduced value for $[\overline{P}]i$ in Equation 4, a reduction in inlake phosphorus ($[\overline{P}]\lambda$) can be calculated. This is assuming constant inputs of water. Theoretically, the phosphorus retention time should also be reduced. Table 12 shows that a reduction in phosphorus inputs to Blue Dog Lake by 35% will reduce the inlake phosphorus to 0.067 mg/L.

Table 12. Effects of Reducing Phosphorus Inputs on TSI

Reduction of Phosphorus Inputs	Predicted Phosphorus Input Concentration Reduction	Predicted Phosphorus Inlake Concentration Reduction	Predicted Chlorophyll *a* Reduction	Predicted Phosphorus TSI	Predicted Chlorophyll *a* TSI
0%	0.086	0.089	8.30	68.91	51.33
10%	0.077	0.080	6.37	67.39	48.73
20%	0.069	0.071	4.89	65.69	46.14
30%	0.060	0.062	3.75	63.76	43.54
40%	0.052	0.053	2.88	61.54	40.94
50%	0.043	0.044	2.21	58.91	38.35
60%	0.034	0.036	1.70	55.69	35.75
70%	0.026	0.027	1.30	51.54	33.16
80%	0.017	0.018	1.00	45.69	30.56

As discussed in the chlorophyll *a* section of the report, there is a good relationship between chlorophyll *a* and total phosphorus (Figure 38). Using the equation for the line in Figure 38, a chlorophyll *a* reduction can also be predicted.

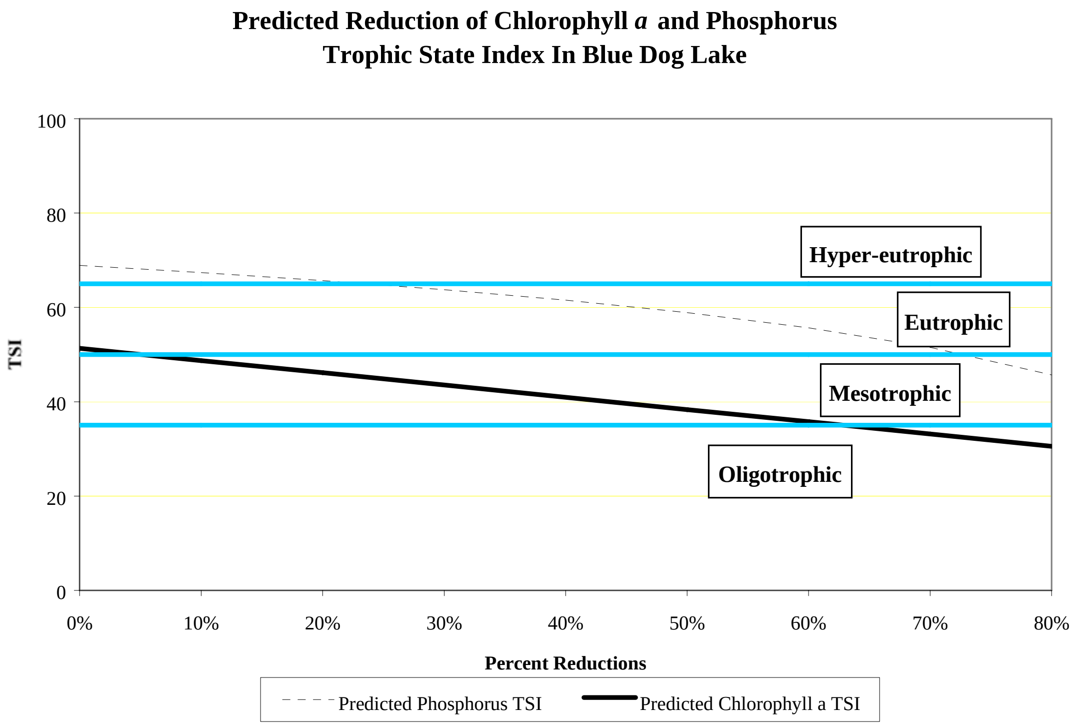


Figure 43.

Recommended Targeted Reduction

The phosphorus concentrations in Blue Dog Lake were 4 times greater than the amount needed for an algal bloom. Typically, targets for nutrient reduction are linked to chlorophyll *a* TSI levels. Although sediments are most likely playing a role in limiting algal growth and chlorophyll *a* production, there is still a good phosphorus to chlorophyll *a* relationship. However, Blue Dog Lake's TSI level during the project was already almost mesotrophic, and improving chlorophyll *a* to an oligotrophic level is unrealistic. The TSI level for phosphorus in Blue Dog Lake is slightly above the hypereutrophic and eutrophic boundary. The phosphorus TSI can be lowered to the eutrophic level. To accomplish this goal, SD DENR is recommending a total phosphorus reduction to a TSI level of 63.75. A 30% reduction of the incoming phosphorus load will be needed to reach this goal (Figure 44). After implementing the BMPs needed to reduce phosphorus loads, long-term monitoring should be conducted to see if the target has been reached.

Targeted Phosphorus Reduction

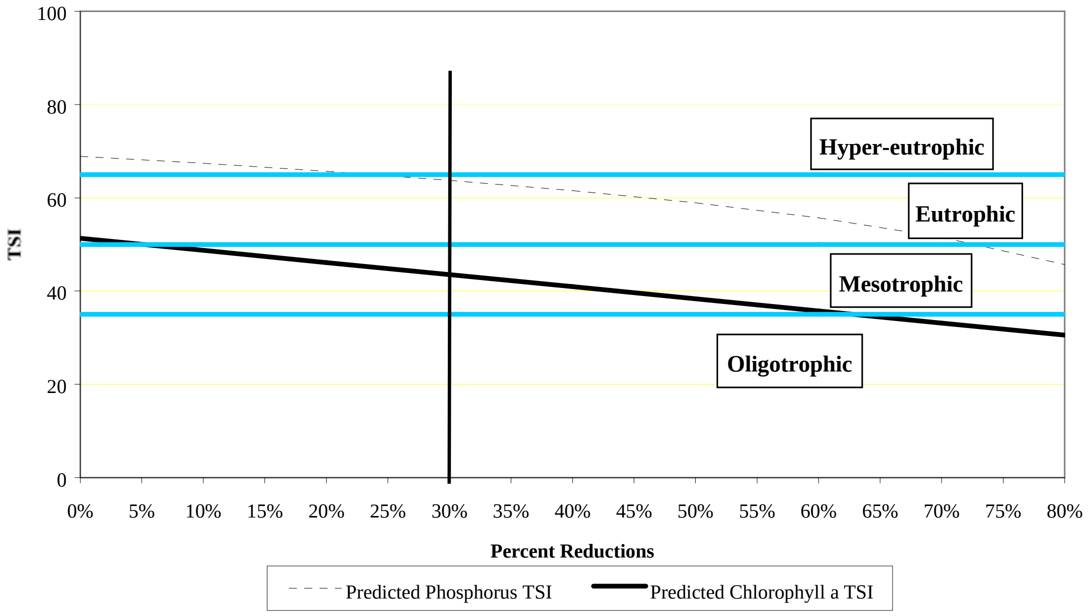


Figure 44.

This target was established because the AGNPS model estimated a 35% reduction of phosphorus in the watershed by eliminating discharge from selected feeding areas and improving manure and crop management in other areas. It is also recommended that an attempt be made to establish shoreline vegetation around the perimeter of Blue Dog Lake. Established littoral vegetation would reduce shoreline erosion, reduce re-suspension of bottom sediments, and provide fishery habitat. It must be remembered, however, if sedimentation is reduced, algal growth may increase. Because the success of the vegetative plantings is not predictable, a targeted amount of sediment reduction will not be included in the report.

Conclusions

AGNPS

The complete AGNPS model can be found in Appendix A.

Nutrient Analysis

The suspected sources of elevated nutrient loads to the Blue Dog Lake watershed were animal feeding areas and the application of unincorporated fertilizers on croplands and areas of highly erodible soils or lands with slopes greater than 7%. It is recommended that the implementation of the appropriate best management practices be targeted to the critical cells and priority animal feeding areas.

Animal feeding areas with an AGNPS rating of 55 or greater should be evaluated for potential operational or structural modifications in order to minimize nutrient yields. The model suggested that a reduction of 7.5% in nitrogen load and 17% in phosphorus load could be realized if animal waste management systems were implemented on these feedlots.

The tillage practices on critical cells having a high c-factor and a slope 7% or greater should also be modified to include conservation tillage practices to better incorporate applied fertilizers. These practices might include strip cropping, limited-till and no-till. The modification of the c-factor (representing no-till) on 41 cells in the watershed produced reductions in the model output of 18% for phosphorus and 8% reduction in nitrogen. All cells should be field verified for accuracy before implementation of Best Management Practices (BMPs).

Sediment Analysis

The AGNPS data indicated that the Blue Dog Lake watershed had a low sediment deliverability rate at both the inlets and the outlet of Blue Dog Lake. The AGNPS model estimated the sediment deliverability to the lake was .026 ton/acre/year. This corresponds to 1,465 tons of sediment entering Blue Dog Lake resulting from one year’s average rainfall events. The estimated load was quite low when compared to other watersheds in northeast South Dakota.

An analysis of the Blue Dog Lake watershed indicated that there were approximately 55 cells with erosion rates greater than 5 ton/acre. This was only 4% of the total number of cells found in the Blue Dog watershed. The model indicated that the majority of these cells were located in areas that have a landslope of 7% or greater and have a c-factor of 0.19 or more. The high c-factors can be a product of limited or non-existent conservation tillage practices. The AGNPS model was run with 41 cells having the c-factors changed to represent a no-till practice. These 41 cells are equal to 1,640 acres of cropland. The model showed a 35% reduction in sediment delivered to Blue Dog Lake.

To reduce sediment loads to Blue Dog Lake, it is recommended those areas having landslopes greater than 7% and limited or non-existent conservation tillage practices be modified to represent no-till or limited-till practices. Cells should be field verified before any BMPs are utilized.

Feedlot Analysis

Twenty-five animal feeding areas were identified by AGNPS as being potential sources of nonpoint pollution. The AGNPS model ranked the animal feeding areas utilizing data collected and then inputted into the model. Of the twenty-five animal feeding areas defined, twelve feedlots had an AGNPS rating of 55 or greater when using a 25-year frequency storm event. Seven feeding areas have a rating of 64 or greater.

To analyze the impacts of these animal feeding areas on the watershed, the model was run after removing the feedlots that ranked 55 or greater. The model was then run by removing the feeding areas that ranked greater than 64. The resulting data was then compared to the output data from the model run with the original data. Reductions in nutrients delivered to the watershed could were then calculated. The results of this action on the model indicated that when those cells that rated 55 or greater were removed, a 17% reduction in phosphorus could be realized as well as a 7.5% reduction in nitrogen delivered to the watershed. Removing all feedlots from the model that had a rating of 64 or greater (seven cells) produced a 2% net reduction in total phosphorus and a 4% reduction in total nitrogen.

It is recommended that the twelve feedlots with an AGNPS rating of 55 or greater have animal waste management systems constructed to lower nutrient yields to Blue Dog Lake.

General Data

Historical Information

Since the earliest records, Blue Dog Lake has been a place for social gatherings and recreation. Cabins located along the south and east shorelines were joined with a central wastewater collection system in 1992. Water elevations in Blue Dog Lake have varied greatly since the lake was almost dry in the 1930's. During the project, the lake was at its highest recorded elevation. The fluctuation in water levels has caused severe shoreline erosion in Blue Dog Lake.

Fishery

The latest fish survey in 1996 found yellow perch populations low. Although there was good reproduction, year-classes never seem to materialize into a significant catchable fish population. White bass populations were doing very well in Blue Dog Lake and may soon develop into an angling opportunity. The younger white bass might be serving as important forage for walleyes. Carp populations sampled were low, however, carp are believed to exist in larger populations. Northern pike and walleye were the predominant and preferred species of fish in Blue Dog Lake. Both game fish species show good size structure and good-year class development. South Dakota GF&P recommends Blue Dog Lake have carp removed, be managed for walleye and northern pike, and also be surveyed annually.

Shoreline Erosion

Blue Dog Lake had excessive shoreline erosion. The erosion in Blue Dog Lake was caused by the increased lake elevations, and wind and wave action. Bank pins were placed around the Blue Dog Lake shoreline in late summer of 1997. By the summer of 1998, all of the pins were either totally exposed or missing. It was estimated that approximately 20,813 m^3 (5.1 acre-feet) of shoreline fell into the lake during that time. As very little suspended solids were entering the lake through the watershed; most of the inlake suspended solids appeared to be from the shoreline and suspended solids from shallow areas along the shoreline.

Little aquatic vegetation was found along the shores of Blue Dog Lake and riparian vegetation has been altered or removed along the lake's populated south shore. Shoreline erosion can be expected to continue until the lake level lowers by natural means or flooding is relieved through downstream drainage.

It should be noted, Blue Dog Lake property owners have expressed interest in dredging Blue Dog Lake to reclaim depth lost to present and past shoreline erosion and sedimentation.

Tributary Water Quality Sampling

Seasonal Water Quality

Due to heavy flow (mostly from snowmelt runoff), the loadings of nutrients and sediment to Blue Dog Lake were higher in the spring than at any other season of the year. Spring loadings (March 1 to May 31) made up close to 85% of all the loads for all of the parameters to Blue Dog Lake. Concentrations varied with season. Fall nutrient concentrations were higher, most likely because of less dilution.

Site #10

Site #10 was located on the smallest drainage in the Blue Dog Lake watershed (2,950 hectares or 7,290 acres). The loadings from all of the parameters of concern, except nitrate, were low relative to the other sites in the watershed. The high nitrate concentrations found at Site #10 were most likely from two irrigation pivots in the upper part of the watershed.

Site #7

Site #7 was located between Site #10 and the main inlet to Blue Dog Lake (Site #5). The total watershed for Site #7 is 4,745 hectares (11,720 acres). The 1,795 hectares between Site #10 and Site #7 have higher nutrient and sediment inputs per-acre than the area upstream of Site #10. There are more animal feeding areas, intense grazing, and cropland in the areas between the sites. These land use are most likely the source of the increased sediment and nutrient loads.

Site #9

Site #9 was located on the upper most branch of the north fork of Owens's Creek. The drainage of Site #9 (3,756 hectares or 9,280 acres) consist of Hurricane Lake which most likely is the settling basin for suspended solids coming through the site. The suspended solids coming through Site #9 had the lowest average concentration of any other site. Site #9 had approximately 45% of the sediment load to the next downstream site, Site #6. There were a few higher fecal coliform samples at Site #9 that point to animal waste as a source of nutrients.

Site #8

Site #8 was located downstream of Site #9, however, due to beaver dams backing-up water at Site #8, no loadings could be calculated.

Site #6

The watershed area for Site #6 is approximately 8,353 hectares (20,640 acres) and drains the largest subtributary of Owen's Creek. Site #6 had the highest nutrient loads of any sub-tributary in Owen's Creek. Irrigation pivots located between Site #9 and Site #6 were most likely a source of high nitrate concentrations and loads. Site #6 consistently had a high fecal coliform count. High phosphorus concentrations coincided with the high fecal coliform counts. The fecal coliform bacteria counts point to animal feeding areas as the most likely source of the high phosphorus concentrations.

Site #5

Site #5 was on the main inlet to Blue Dog Lake, encompassing most of the Owen's Creek drainage. Two main subwatersheds, Site #6 and Site #7, were the source of the nutrients and sediment to Site #5, however, there was a source of ammonia in the watershed area that ran directly to Site #5. The loading to Blue Dog Lake through Site #5 was between 40% and 50% of the total load for most of the parameters sampled. A small pond upstream of Site #5 may be settling out suspended solids and producing organic nitrogen. Site #5 has five highly rated feedlots in its immediate watershed.

Site #4

Site #4 is on the other main tributary to Blue Dog Lake. The watershed acreage for Site #4 is 3,383 hectares (8,360 acres). If the watershed from Enemy Swim were included in the total watershed for Site #4, the watershed size would be 12,415 hectares (30,680 acres). Due to the high water during the project, Enemy Swim Lake was dumping large quantities of water into the Site #4 drainage. Using AGNPS runoff coefficients, 77% of the hydrologic load from the watershed was estimated to come from Enemy Swim Lake. Overall, the water quality coming from Enemy Swim Lake was good; however, the hydrologic loading from Site #4 was so large, Enemy Swim may have been contributing up to 50% of the nutrients at Site #4. Suspended solids loads and other nutrient loads at Site #4 were high considering the relatively small area of the watershed.

Ungauged Tributaries

Sixteen percent of the tributary area in the Blue Dog watershed was ungauged. Percentages from the AGNPS model estimated that an additional 17% of the total came from these ungauged areas. The estimated loadings of sediment and nutrients were relatively low for the size of the drainage area; however, there were two animal feeding areas in these drainages ranked higher than 50. It is highly likely that these areas are a source of nutrients to Blue Dog Lake.

Hydrologic and Nutrient Loads

Overall suspended sediment load to Blue Dog Lake was low according to from data collected in the 1997 sampling season. Including an estimated loading from shoreline erosion, approximately 1.7 acre-feet of sediment was calculated as entering the lake. Approximately 0.5 acre-foot was calculated leaving through the outlet of Blue Dog Lake. Since more sediment is entering than leaving Blue Dog Lake, shoreline erosion is the most likely source of the additional sediment. Table 13 summarizes the loading to or out of Blue Dog Lake in the 1997 sampling season.

All of the nutrient parameters were accumulating in Blue Dog Lake in 1997. As can be seen in the table below, 73.6% of the ammonia that entered Blue Dog Lake was retained. Only 5% of the total phosphorus loads to Blue Dog Lake were retained in the lake. The suspended solids leaving the lake most likely carried attached phosphorus through the outlet. There is still more than enough phosphorus left in Blue Dog Lake for nuisance algal blooms and unless the loadings are reduced, Blue Dog Lake will remain in a hypereutrophic condition.

Table 13. Loadings to Blue Dog Lake

Parameter	Total Inputs	Total Outputs	Increase to Blue Dog Lake		Net Loss from Blue Dog Lake	
	(kg)	(kg)	(kg)	%	(kg)	%
Suspended Solids	856,369	1,339,671	--	--	481,302	56.1
Ammonia	1,723	456	1,267	73.6	--	--
TKN-N	28,852	22,387	6,465	22.4	--	--
Nitrate-Nitrite	8,806	7,646	1,160	13.2	--	--
Total Nitrogen	37,658	30,033	7,625	20.2	--	--
Total Phosphorus	3,504	3,306	198	5.7	--	--
Total Diss. Phos.	1,398	1,073	325	23.2	--	--

Inlake

Blue Dog Lake is a well-mixed lake with very little difference in surface and bottom chemical composition. Oxygen levels are sufficient through the water column and temperatures do not increase to the point where fish would be impacted. At times, the suspended sediment levels in Blue Dog Lake were quite high, but as a whole were not excessive. Suspended sediment does appear to be one of the factors in limiting the algal blooms. The particles block sunlight and restrict algal growth.

The average ammonia concentration in Blue Dog Lake was 0.05 mg/L with the highest concentrations found in the spring. The average concentration of nitrate-nitrite was 0.23 mg/L. The average total phosphorus concentration in Blue Dog Lake was 0.080 mg/L. The phosphorus concentration is high enough to produce large algal blooms if favorable conditions exist.

Fecal coliform bacteria counts were below detection limits in 60% of the samples. The most likely source of fecal coliform was from animal feeding areas in the watershed due to the large concentrations found at the inlet sites.

Chlorophyll *a* concentrations were relatively low with respect to the nutrient concentrations found in Blue Dog Lake. When high nutrient concentrations are found in other lakes, algal blooms persist throughout the summer months and many times occur in the winter. The production of chlorophyll *a* in Blue Dog Lake may be limited by light-blocking sediments.

Phytoplankton species in Blue Dog Lake were typical of eastern prairie lakes in South Dakota. However, the algal counts showed that the blooms occurred for a shorter duration and with less intensity than some other eutrophic lakes previously studied, that had similarly high nutrient concentrations available for algal growth.

Trophic State Index

The average TSI in Blue Dog Lake was 61.36 ranking Blue Dog Lake as eutrophic. However, there was quite a large range of values for the three parameters used to calculate TSI. The average chlorophyll *a* TSI was 46.83 (mesotrophic), the average phosphorus TSI was 65.86 (slightly hyper-eutrophic), and the average Secchi disk TSI was 73.82 (hyper-eutrophic). It appears that the suspended sediments were restricting chlorophyll *a* production even through there was plenty of available phosphorus for prolonged nuisance algal blooms.

Long-Term Trends

The long-term trends in Blue Dog Lake from 1979 to 1998 appeared to show slight to moderate improvement. The late 1980's were drought years and nutrients may have been concentrated in lakes. The wet years of 1993 – 1998 may have flushed many of the nutrients out of the lake producing apparent improvement. The Secchi disk trend remained flat over the years. The most likely reason was the shallow depth of Blue Dog Lake has not changed over the years and was still subject to wind and waves suspending bottom sediments.

Reduction Response Model

To accurately calculate a reduction response model there needs to be a good relationship between phosphorus and chlorophyll *a* concentrations. The R^2 value for the chlorophyll to total phosphorus concentration was 0.62 (zero being the worst and 1.0 being the best). Any correlating reduction of phosphorus should reduce chlorophyll *a* the calculated amount.

Limiting Factor for Chlorophyll *a* Production

Blue Dog Lake is phosphorus limited; meaning a reduction of phosphorus should reduce chlorophyll *a* production. There were four instances in 1997 when chlorophyll was nitrogen limited. These instances may have been caused by high water increasing ground water flow into Blue Dog Lake. Ground water upstream of Blue Dog Lake has high nitrate levels.

Recommended Targeted Reduction

It is recommended that a target reduction of 30% in phosphorus inputs to Blue Dog Lake should be reached. The 30% reduction will most likely move the average phosphorus TSI level downward from hypereutrophic to eutrophic. After implementing best management practices in the watershed, long-term monitoring should be conducted to see if the target has been reached.

Recommendations

According to the water quality monitoring data and the AGNPS model, animal feeding areas and manure management were the most likely source of nutrients to Blue Dog Lake. It is recommended that the twelve feeding areas with AGNPS ratings greater than 50 have animal waste systems constructed to eliminate nutrient and sediment runoff. These livestock concerns should also implement NRCS approved manure management plans.

It is also recommended that the croplands targeted by the AGNPS model with slopes greater than 7% be placed under minimum tillage or be seeded to grass.

Once the lake water level stops increasing in elevation, an attempt should be made to establish shoreline and littoral (emergent) vegetation around Blue Dog Lake. Stabilization can be from “hard or soft practices. Hard practices include rip rap, gabion baskets and other inert materials. Soft practices include trees and vegetation. The vegetation would reduce shoreline erosion, reduce re-suspension of bottom sediments, and provide better fish habitat. Lake managers should be reminded that the improved light penetration in Blue Dog Lake might cause an increase in algal production until inlake nutrient concentrations are reduced.

REFERENCES CITED

Brower, J.E., and Zar, J.H., 1984. Field & Laboratory Methods for General Ecology, 2nd Edition. Wm. C. Brown Publishers, Dubuque, IA.

Carlson, R. E., 1977. A Trophic State Index for Lakes. Limnology and Oceanography. 22:361 - 369.

Gilbertson, J. P., 1996. Investigation of Ground Water Resources in Portions of Roberts County, South Dakota. SD DENR Open File Report 81-UR. Geological Survey Science Center University of South Dakota, Vermillion, SD.

Hutchinson, G.E., 1957. A Treatise on Limnology. Wiley, New York and London.

Kuck M., 1998. Personal conversation.

Leap, 1988. Geology and Hydrology of Day County, South Dakota. Department of Water and Natural Resources Division of Geological Survey, Bulletin, 24.

Lind, O. T., 1985. Handbook of Common Methods used in Limnology, 2nd Edition. Kendall/Hunt Publishing Company, Dubuque, Iowa.

Odum, E. P., 1959. Fundamentals of Ecology, 2nd Edition. W.B. Saunders Co., Philadelphia, Pennsylvania.

Oschenreiter, L.G., 1926. History of Day County From 1873 to 1926. Educator Supply Company, Mitchell, SD.

Reid, G.K., 1961. Ecology of Inland Waters and Estuaries. Reinhold Publishing Company.

South Dakota Department of Environment and Natural Resources, 1991. Water quality sample on July 16, 1991.

Spuhler W. and Lytle, W. F., 1971. Climate of South Dakota. Bulletin 582, Agricultural Experiment Station South Dakota State University. South Dakota State University, Brookings, South Dakota.

Stueven E. and Stewart, W.C., 1996. 1995 South Dakota Lakes Assessment Final Report. South Dakota Department of Environment and Natural Resources, Watershed Protection Program.

Stueven, 1999, Standard Operating Procedures for Field Samplers. South Dakota Department of Environment and Natural Resources. Unpublished.

U.S. Environmental Protection Agency, 1990. Clean Lakes Program Guidance Manual. EPA-44/4-90-006. Washington, D.C.

Vollenwieder, R.A. and J. Kerekes, 1980. The Loading Concept as a Basis for Controlling Eutrophication Philosophy and Preliminary Results of the OECD Programme on Eutrophication. Prog. Water Technol. 12:3-38.

Wetzel, R.G., 1983. Limnology 3rd Edition. Saunders College Publishing, Philadelphia.

Wittmuss, A. L., 1996. Phase I Diagnostic Feasibility Study Final Report. South Dakota Department of Environment and Natural Resources, Watershed Protection Program. 77 pp.

Young, R.A., C.A. Onstad, D.D. Bosh, and W.P. Anderson. 1986. AGNPS, Agricultural Nonpoint Source Pollution Model. USDA-ARS Conservation Research Report 35.

Appendix A

Agricultural Non-Point Source Model (AGNPS)

REPORT ON THE
AGRICULTURAL NONPOINT SOURCE (AGNPS) ANALYSIS OF THE BLUE DOG LAKE WATERSHED DAY/ROBERTS COUNTIES, SOUTH DAKOTA

SOUTH DAKOTA WATER RESOURCES PROTECTION PROGRAM
DIVISION OF FINANCIAL & TECHNICAL ASSISTANCE
SOUTH DAKOTA DEPARTMENT OF ENVIRONMENT AND NATURAL RESOURCES

SEPTEMBER 1999

EXECUTIVE SUMMARY

The Blue Dog Lake watershed is located on the eastern edge of Day County and the western portion of adjoining Roberts County. The size of the Blue Dog Lake watershed area modeled is 56,840 acres. The modeled area is defined by the area from the outlet of Enemy Swim Lake in the northwest corner of the watershed to the Owl Lake and Hurricane Lake areas in the northeast corner. The watershed outlet is located at the Blue Dog Lake outlet that drains into Little Rush Lake in the southwest corner.

In order to further evaluate the water quality status of the Blue Dog Lake watershed, land use and geotechnical information was compiled. This information was then incorporated into a computer model. The primary objective of utilizing a computer model on the Blue Dog Lake watershed was to:

1) Evaluate and quantify Nonpoint Source (NPS) yields from each subwatershed and determine the net loading to Blue Dog Lake.
2) Define critical NPS cells within each subwatershed (elevated sediment, nitrogen and phosphorus).
3) Prioritize and rank each animal feeding area and quantify the nutrient loadings from each area.

Based on the results of the computer model, the following conclusions were formulated:

1. ***Watershed / Subwatershed Analysis***

Sediment

The AGNPS data indicated that the Blue Dog Lake watershed had a low sediment deliverability rate at both the inlets and the outlet of Blue Dog Lake. The AGNPS model estimated the sediment deliverability to the lake was .026 ton/acre/year. This corresponded to 1,465 tons of sediment entering Blue Dog Lake resulting from one year's average rainfall events. This estimate was quite low when compared to other watersheds in northeast South Dakota.

The sediment load leaving Blue Dog Lake at the outlet was calculated by AGNPS as having a value of .004 ton/acre/year. This number, when multiplied by the total acreage of the watershed, resulted in 232 tons of sediment leaving Blue Dog Lake in an average year. Considering the lake input load of 1,465 tons of sediment, the lake's sediment trapping efficiency is 84%.

When sediment analysis was performed on subwatersheds located within the Blue Dog Lake watershed, the model indicated that five of the twelve delineated subwatersheds appeared to have high sediment deliverability rates. The following values apply:

CRITICAL SEDIMENT SUBWATERSHEDS

Sub-watershed #	Outlet Cell #	Annual Sediment Yield (tons/acre)
7	930	0.08
9	1060	0.10
10	1085	0.08
11	1315	0.09
12	1342	0.13

These five subwatersheds contributed 68% of the sediment while occupying only 16% of the watershed. The suspected source of the sediment is from agricultural land which has a slope greater than 9% and is currently in crop production or has poor vegetative cover on rangeland.

Nutrients

Using the AGNPS model, the resulting data showed 2.42 lbs/acre of nitrogen and 0.58 lbs/acre of phosphorus enter Blue Dog Lake annually. The nitrogen deliverability rate was comparable to other watersheds in the area while the phosphorus was relatively low. Both nitrogen and phosphorus loads were calculated using the sum of sediment bound and soluble forms of the respective nutrients. As with the sediment load, the annual nutrient loads were made up of a series of average annual rainfall events that may have incurred in the region.

The nutrient load leaving Blue Dog Lake at the outlet, as calculated by AGNPS, was 2.28 lbs/acre of nitrogen and 0.36 lbs/acre of phosphorus. This correlates to a nutrient trapping efficiency for nitrogen of 6% and a trapping efficiency for phosphorus of 38%. The analysis of subwatershed loadings using the model produced the following results:

CRITICAL PHOSPHORUS SUBWATERSHEDS

Sub-watershed #	**Outlet Cell #**	**Annual Total Phosphorus (lbs/acre)**
7	930	1.05
9	1060	1.29
10	1085	1.05
12	1342	1.07

CRITICAL NITROGEN SUBWATERSHEDS

Sub-watershed #	**Outlet Cell #**	**Annual Total Nitrogen (lbs/acre)**
5	723	3.92
7	930	4.02
9	1060	5.19
10	1085	4.20
12	1342	3.86

In comparison of the total twelve delineated subwatersheds in the Blue Dog Lake drainage, four subwatersheds had significantly higher phosphorus yields. These four watersheds listed above deliver 7,867.6 lbs. of phosphorus to the watershed. This cumulative load represents 37% of the total phosphorus load delivered to the watershed while occupying only 20 % of the total subwatershed acreage.

The nitrogen analysis for the subwatersheds shows five critical subwatersheds in the drainage. These five subwatersheds produce 43,277.2 lbs. of nitrogen, which is 51% of the total nitrogen delivered to the watershed.

These five subwatersheds occupy approximately 29% of the total subwatershed acreage. The AGNPS model indicated that a possible source of elevated nutrient runoff is from cropland where applied fertilizer is left unincorporated in the soil or only slightly incorporated. The model also suggested that the presence of an animal feeding area with an AGNPS feedlot rating of 50 or greater in the subwatershed would greatly increase the nutrient load delivered from the subwatershed.

2. ***Critical NPS Cells***

Sediment

Analysis of the AGNPS data concerning individual forty-acre cells in the Blue Dog Lake watershed indicated that of the 1,421 cells, 55 cells had erosion rates of greater than 5 ton/acre/year. These 55 cells represent only 4% of the entire Blue Dog Lake drainage area. The suspected sources of the elevated erosion rate were landslopes greater than 7% as well as cropland with high c-factors. The high c-factors can be a product of limited or non-existent conservation tillage practices. The AGNPS model was run with 41 cells having the c-factors changed to represent a no-till practice. These 41 cells equal 1,640 acres of cropland. The model showed an 18% reduction in phosphorus and a 35% reduction in sediment delivered to Blue Dog Lake. The data also indicated that an 8% reduction in nitrogen supplied to the lake could be realized by implementing no-till practices on high c-factor croplands (c-factor > 0.19).

Nutrients

Analysis of the AGNPS data with respect to phosphorus yields indicated that of the 1,421 cells located in the Blue Dog watershed, 78 cells had nutrient yields (sediment bound and water soluble) greater than 3.5 lb/acre/year. This was less than 6% of the total number of cells contained in the watershed. The AGNPS data suggests that 63% of the phosphorus load was sediment bound and 37% was water-soluble.

Seven percent of the cells contained in the watershed had elevated nitrogen levels. One hundred cells had a total nitrogen (sediment bound and water-soluble) yield of more than 10 lb/acre/year. The AGNPS data suggested that only 34% of the nitrogen yield was sediment bound while 66% was water-soluble nitrogen.

The suspected sources of elevated nutrient loads to the Blue Dog Lake watershed were animal feeding areas, the application of unincorporated fertilizers on croplands, and areas of highly erodible soils or lands with slopes greater than 7%.

3. ***Feeding Area Evaluation***

Upon analysis of the twenty-five animal feeding areas found within the watershed, it was determined that twelve animal feeding areas had an AGNPS rating of 55 or greater. Of these twelve, six feeding areas had an AGNPS rating of 64 or greater when the model was run using a storm similar in severity to a twenty five year event.

In order to evaluate what impact these animal feeding areas had on the nutrient load delivered to the lake, the model was run with the twelve feedlots rated greater than 55 removed from the data file. The total phosphorus yield delivered to Blue Dog Lake was reduced from 30,756 lb/year to 25,526 lb/year. This represented a 17% reduction in total phosphorus. The nitrogen yield, when the feedlots were removed, dropped from 127,462 lb/year to 117,841 lb/year, or a 7.5% reduction in total nitrogen delivered to the lake.

To further evaluate the nutrient impacts, the model was run again. This time, the just the seven feedlots with an AGNPS rating of 64 or greater were removed. The data indicates that the total phosphorus load delivered by the subwatersheds dropped only 2% while the total nitrogen load delivered was reduced by 4%.

4. ***Conclusions***

It is recommended that the implementation of the appropriate best management practices be targeted to the critical cells and priority animal feeding areas . Animal feeding areas with an AGNPS rating of 55 or greater should be evaluated for potential operational or structural modifications in order to minimize or eliminate nutrient yields. The model suggested that a reduction of 7.5% in nitrogen load and 17% in phosphorus load could be realized if these feedlots were modified to include runoff containment systems and buffer zones (cell # 35, 459, 505, 623, 627, 797, 876, 1099, 1255, 1264, 1357, 1360).

The tillage practices on critical cells having a high c-factor and a slope of 7% or greater should also be modified to conservation tillage practices. These practices might include strip cropping, limited-till and no-till. The modification of the c-factor (representing no-till) on 41 cells in the watershed produced reductions in the model output of 35% for sediment, 18% for phosphorus and 8% reduction in nitrogen. The reduction in nutrients and sediment could be less or more depending on crop producer participation and modification costs. It is highly recommended that all critical cells and animal feeding areas be field verified in advance of implementing best management practices.

Potential contributions of sediment from gully, riparian areas, wind erosion and nutrients from septic systems within the Blue Dog lake watershed were not evaluated as part of the computer modeling assessment phase.

BLUE DOG LAKE WATERSHED AGNPS ANALYSIS

In order to complement existing water quality data in the Blue Dog Lake watershed, a computer model was selected in order to asses the nonpoint source (NPS) loadings throughout the drainage. The model selected was the Agricultural Nonpoint Source Pollution Model (AGNPS) version 3.65. This model was developed by the USDA - Agricultural Research Service to analyze the water quality of runoff events in the watershed. The model predicts runoff volume and peak rate, eroded and delivered sediment, nitrogen, phosphorus, and chemical oxygen demand (COD) concentrations in the runoff and sediment. The model was designed to run utilizing a single storm event of equal magnitude for all acreage in the watershed. The model then analyzes the runoff data from the headwaters of the watershed to the outlet. The pollutants are routed in a step-wise fashion so the flow at any point may be examined. The AGNPS model was to be used to objectively compare different subwatersheds and individual cells within a watershed to other watersheds within a drainage basin.

The Blue Dog Lake watershed was located in the eastern edge of Day County and the western portion of adjoining Roberts County. The size of the Blue Dog Lake watershed modeled was 56,840 acres. The modeled area was defined by the area from the outlet of Enemy Swim Lake in the northwest corner of the watershed to the Owl Lake and Hurricane Lake areas in the northeast corner. The watershed outlet is located at the Blue Dog Lake outlet that drains into Little Rush Lake in the southwest corner. Initially, the watershed was divided into cells each of which had an area of 40 acres with the dimensions of 1,320 feet by 1,320 feet. The dominant fluid flow direction within each cell was then determined. Based on the fluid flow directions and drainage patterns, twelve subwatersheds were delineated. Along with the dominant fluid flow direction, 21 watershed parameters were collected and entered into the model for each cell. The model then calculated the nonpoint source pollution loadings for each cell and subwatershed, animal feeding area and estimated hydrology runoff volume for each of the storm events modeled.

AGNPS GOALS

The primary objectives of running the AGNPS model on the Blue Dog Lake watershed was to:

1. Evaluate and quantify NPS loadings from each subwatershed.
2. Define critical NPS cells within each subwatershed (elevated sediment, nitrogen, phosphorus).
3. Priority ranking of each animal feeding area and quantify the nutrient loadings from each area.

The following is a brief overview of each objective:

OBJECTIVE 1 - EVALUATE AND QUANTIFY SUBWATERSHED LOADINGS

DELINEATION OF SUBWATERSHEDS

- Based upon the fluid flow directions and drainage patterns, twelve subwatersheds were delineated:

SUBWATERSHED #	DRAINAGE AREA (acres)	OUTLET CELL #
1	5600	232
2	6160	483
3	2640	587
4	1400	608
5	3240	723
6	2480	831
7	1360	930
8	5840	1007
9	1320	1060
10	2840	1085
11	1640	1315
12	1640	1342

Blue Dog Lake AGNPS model subwatersheds and diagnostic feasibility water quality monitoring site subwatersheds nutrient and sediment loadings:

NITROGEN ANALYSIS

SUB-WATERSHED OUTLET CELL #	DRAINAGE AREA (acres)	1 MONTH EVENT Total Nit. (lbs/acre)	6 MONTH EVENT Total Nit. (lbs/acre)	1 YEAR EVENT Total Nit. (lbs/acre)	ANNUAL Total Nit. (lbs/acre)	ANNUAL Total Nit. (lbs)	% of Total Nitrogen Yield	% of Water-shed Area	25 YEAR EVENT Total Nit. (lbs/acre)	% of Total Nitrogen Yield
232	5600	0.08	0.33	0.49	2.03	11368.00	13.45	9.85	1.04	5.11
483	6160	0.06	0.25	0.39	1.55	9548.00	11.30	10.84	1.12	5.50
587	2640	0	0.04	0.09	0.17	448.80	0.53	4.64	0.34	1.67
608	1400	0.03	0.15	0.25	0.88	1232.00	1.46	2.46	0.76	3.73
723	3240	0.15	0.65	0.97	3.92	12700.80	15.03	5.70	2.26	11.11
831	2480	0.07	0.36	0.56	2.05	5084.00	6.02	4.36	1.41	6.93
930	1360	0.15	0.67	1.03	4.02	5467.20	6.47	2.39	2.78	13.66
1007	5840	0.05	0.24	0.41	1.44	8409.60	9.95	10.27	1.34	6.58
1060	1320	0.2	0.86	1.27	5.19	6850.80	8.11	2.32	2.96	14.55
1085	2840	0.18	0.64	0.94	4.2	11928.00	14.11	5.00	1.97	9.68
1315	1640	0.12	0.51	0.8	3.14	5149.60	6.09	2.89	2.39	11.74
1342	1640	0.17	0.57	0.85	3.86	6330.40	7.49	2.89	1.98	9.73
				TOTALS	**32.45**	**84517.20**	**100.00**	**63.62**	**20.35**	**100.00**

DIAGNOSTIC FEASIBILITY MONITORING (site #) cell #	DRAINAGE AREA (acres)	1 MONTH EVENT Total Nit. (lbs/acre)	6 MONTH EVENT Total Nit. (lbs/acre)	1 YEAR EVENT Total Nit. (lbs/acre)	ANNUAL Total Nit. (lbs/acre)	ANNUAL Total Nit. (lbs)	% of Total Nitrogen Yield	% of Water-shed Area	25 YEAR EVENT Total Nit. (lbs/acre)	% of Total Nitrogen Yield
(9) 534	9280	0.04	0.18	0.28	1.08	10022.40	4.20	16.33	0.85	9.53
(4) 658	8360	0.07	0.28	0.43	1.76	14713.60	6.16	14.71	0.99	11.10
(8) 90	13560	0.08	0.35	0.53	2.11	28611.60	11.98	23.86	1.32	14.80
(6) 993	20640	0.1	0.39	0.6	2.48	51187.20	21.43	36.31	1.43	16.03
(10) 1005	7280	0.08	0.34	0.54	2.1	15288.00	6.40	12.81	1.55	17.38
(5) 1038	37960	0.1	0.41	0.63	2.55	96798.00	40.52	66.78	1.53	17.15
(7) 1291	11720	0.07	0.32	0.49	1.9	22268.00	9.32	20.62	1.25	14.01
				TOTALS	**13.98**	**238889**	**100.00**	**191.41**	**8.92**	**100.00**

Annual loadings were estimated by calculating the NPS loadings for an accumulation of rainfall events during an average year. This includes a 1 year 24 hour event of 2.1 inches (EI = 24.3), two semi-annual, or 6 month, rainfall events of 1.6 inches (EI = 13.4), and a series of eleven smaller, 1 month rainfall events of .9 inches (EI = 3.9) for a total "R" factor of 94.
The 25 year event was modeled using a single rainfall event of 4.3 inches (EI = 120). Rainfall events of less than .9 inches were modeled and found to produce insignificant amounts of sediment and nutrient yields.

Blue Dog Lake AGNPS model subwatersheds and diagnostic feasibility water quality monitoring site subwatersheds nutrient and sediment loadings (CONTD.):

PHOSPHORUS ANALYSIS

SUB-WATERSHED OUTLET CELL #	DRAINAGE AREA (acres)	1 MONTH EVENT Tot. Phos. (lbs/acre)	6 MONTH EVENT Tot. Phos. (lbs/acre)	1 YEAR EVENT Tot. Phos. (lbs/acre)	ANNUAL Tot. Phos. (lbs/acre)	ANNUAL Tot. Phos. (lbs)	% of Total Phos. Yield	% of Water-shed Area	25 YEAR EVENT Tot. Phos. (lbs/acre)	% of Total Phos. Yield
232	5600	0.02	0.06	0.10	0.44	2464.00	11.48	9.85	0.22	3.78
483	6160	0.02	0.06	0.10	0.44	2710.40	12.63	10.84	0.31	5.33
587	2640	0	0.01	0.02	0.04	105.60	0.49	4.64	0.04	0.69
608	1400	0	0.03	0.04	0.10	140.00	0.65	2.46	0.13	2.23
723	3240	0.03	0.14	0.23	0.84	2721.60	12.69	5.70	0.58	9.97
831	2480	0.02	0.09	0.13	0.53	1314.40	6.13	4.36	0.40	6.87
930	1360	0.04	0.17	0.27	1.05	1428.00	6.66	2.39	0.89	15.29
1007	5840	0.02	0.07	0.12	0.48	2803.20	13.07	10.27	0.43	7.39
1060	1320	0.05	0.21	0.32	1.29	1702.80	7.94	2.32	0.94	16.15
1085	2840	0.05	0.14	0.22	1.05	2982.00	13.90	5.00	0.51	8.76
1315	1640	0.03	0.13	0.22	0.81	1328.40	6.19	2.89	0.80	13.75
1342	1640	0.05	0.15	0.22	1.07	1754.80	8.18	2.89	0.57	9.79
					TOTAL	**21455.20**	**100.00**	**63.62**	**5.82**	**100.00**

DIAGNOSTIC FEASIBILITY MONITORING (site #) cell #	DRAINAGE AREA (acres)	1 MONTH EVENT Tot. Phos. (lbs/acre)	6 MONTH EVENT Tot. Phos. (lbs/acre)	1 YEAR EVENT Tot. Phos. (lbs/acre)	ANNUAL Tot. Phos. (lbs/acre)	ANNUAL Tot. Phos. (lbs)	% of Total Phos. Yield	% of Water-shed Area	25 YEAR EVENT Tot. Phos. (lbs/acre)	% of Total Phos. Yield
(9) 534	9280	0.01	0.04	0.06	0.25	2320.00	4.06	16.33	0.22	9.32
(4) 658	8360	0.01	0.06	0.08	0.31	2591.60	4.53	14.71	0.19	8.05
(8) 890	13560	0.02	0.09	0.12	0.52	7051.20	12.33	23.86	0.37	15.68
(6) 993	20640	0.02	0.09	0.14	0.54	11145.60	19.49	36.31	0.37	15.68
(10) 1005	7280	0.02	0.08	0.14	0.52	3785.60	6.62	12.81	0.48	20.34
(5) 1038	37960	0.03	0.09	0.14	0.65	24674.00	43.14	66.78	0.4	16.95
(7) 1291	11720	0.02	0.07	0.12	0.48	5625.60	9.84	20.62	0.33	13.98
					TOTAL	**57194**	**100.00**		**2.36**	**100**

Annual loadings were estimated by calculating the NPS loadings for an accumulation of rainfall events during an average year. This includes a 1 year 24 hour event of 2.1 inches (EI = 24.3), two semi-annual, or 6 month, rainfall events of 1.6 inches (EI = 13.4), and a series of eleven smaller, 1 month rainfall events of .9 inches (EI = 3.9) for a total "R" factor of 94.

The 25 year event was modeled using a single rainfall event of 4.3 inches (EI = 120). Rainfall events of less than .9 inches were modeled and found to produce insignificant amounts of sediment and nutrient yields.

Blue Dog Lake AGNPS model subwatersheds and diagnostic feasibility water quality monitoring site subwatersheds nutrient and sediment loadings (CONTD.):

SEDIMENT ANALYSIS

SUB-WATERSHED OUTLET CELL #	DRAINAGE AREA (acres)	1 MONTH EVENT yield (tons)	6 MONTH EVENT yield (tons)	1 YEAR EVENT yield (tons)	ANNUAL yield (tons/acre)	ANNUAL yield (tons)	% of Total Sediment Yield	% of Water-shed Area	25 YEAR EVENT yield (tons)	% of Total Sediment Yield
232	5600	5.59	12.25	24.1	0.02	110.09	5.82	9.9	132.09	3.54
483	6160	13.05	40.29	78.21	0.05	302.34	15.97	10.8	503.76	13.49
587	2640	0.34	2.6	4.6	0.01	13.54	0.72	4.6	12.72	0.34
608	1400	0.39	1.3	3.03	0.01	9.92	0.52	2.5	15.11	0.40
723	3240	5.25	25.93	51.41	0.05	161.02	8.51	5.7	327.24	8.77
831	2480	2.85	16.15	35.98	0.04	99.63	5.26	4.4	249.21	6.68
930	1360	3.17	17.54	41.3	0.08	111.25	5.88	2.4	377.73	10.12
1007	5840	9.67	63.42	134.61	0.06	367.82	19.43	10.3	818.58	21.93
1060	1320	4.29	21.35	47.78	0.10	137.67	7.27	2.3	388.63	10.41
1085	2840	10.01	30.85	55.53	0.08	227.34	12.01	5.0	272.64	7.30
1315	1640	4.18	22.03	52.63	0.09	142.67	7.54	2.9	456.87	12.24
1342	1640	11.74	22.66	35.44	0.13	209.9	11.09	2.9	178.46	4.78
				TOTALS	**0.71**	**1893.19**	**100.00**	**63.6**	**3733.04**	**100.00**

DIAGNOSTIC FEASIBILITY MONITORING (site #) cell #	DRAINAGE AREA (acres)	1 MONTH EVENT yield (tons)	6 MONTH EVENT yield (tons)	1 YEAR EVENT yield (tons)	ANNUAL yield (tons/acre)	ANNUAL yield (tons)	% of Total Sediment Yield	% of Water-shed Area	25 YEAR EVENT yield (tons)	% of Total Sediment Yield
(9) 534	9280	8.67	33.84	69.73	0.03	232.78	6.35	16.33	475.44	6.31
(4) 658	8360	6.92	11.58	20.83	0.01	120.11	3.28	14.71	124.13	1.65
(8) 890	13560	19.42	77.81	153.67	0.04	522.91	14.26	23.86	1060.87	14.08
(6) 993	20640	31.36	115.14	217.42	0.04	792.66	21.62	36.31	1354.71	17.98
(10) 1005	7280	9.7	59.51	137.74	0.05	363.46	9.91	12.81	1020.84	13.55
(5) 1038	37960	43.83	195.6	396.94	0.03	1270.27	34.64	66.78	2780.09	36.90
(7) 1291	11720	13.76	54.15	105.29	0.03	364.95	9.95	20.62	717.82	9.53
				TOTALS	**0.23**	**3667.1**	**100.00**		**7533.9**	**100.00**

Annual loadings were estimated by calculating the NPS loadings for an accumulation of rainfall events during an average year. This includes a 1 year 24 hour event of 2.1 inches (EI = 24.3), two semi-annual, or 6 month, rainfall events of 1.6 inches (EI = 13.4), and a series of eleven smaller, 1 month rainfall events of .9 inches (EI = 3.9) for a total "R" factor of 94.
The 25 year event was modeled using a single rainfall event of 4.3 inches (EI = 120). Rainfall events of less than 0.9 inches were modeled and found to produce insignificant amounts of sediment and nutrient yields.

SEDIMENT YIELD RESULTS

The AGNPS model calculated that the Blue Dog Lake watershed had a moderate to low sediment deliverability rate to the lake. The estimated annual load delivered to the lake was 1,465 ton/year or 0.04 lb/acre/year. A comparison of the subwatershed total sediment yield to its' aerial size follows:

SUBWATERSHED number (cell #)	% OF TOTAL SUBWATERSHED SEDIMENT LOAD	% OF WATERSHED AREA	# OF CRITICAL CELLS (cell erosion > 5 ton/acre)
1 (#232)	5.82	9.9	5
2 (#483)	15.97	10.8	2
3 (#587)	.72	4.6	-
4 (#608)	.52	2.5	1
5 (#723)	8.51	5.7	6
6 (#831)	5.26	4.4	2
7 (#930)	5.88	2.4	5
8 (#1007)	19.43	10.3	3
9 (#1060)	7.27	2.3	-
10 (#1085)	12.01	5.0	1
11 (#1315)	7.54	2.9	1
12 (#1342)	11.09	2.9	-
TOTAL	**100**	**63.6**	**26 of 55**

Subwatersheds 2 (#483), 5 (#723), 8 (#1007), 10 (#1085) and 12 (#1342) appeared to be delivering the largest amount of sediment to the watershed. The five subwatersheds yield 67 % of the sediment delivered by the subwatersheds while occupying 55 % of the total subwatershed acreage. The five subwatersheds contained 22% of the critical cells with high cell erosion. The high sediment yield can be attributed to land use and land slope. The source is primarily from agricultural land with slopes of 7 % or more and a c-factor of greater than 0.19. The conversion of this acreage to a high residue management system or rangeland (slopes > 7 %) should reduce the volume of sediment delivered to Blue Dog Lake.

The data generated by the model indicated that over 50% of the critical erosion cells do not lie within any delineated watershed. The remainder of critical cells lie within the main drainage leading to Blue Dog Lake. These areas which have high land slopes (slope > 7 %) and lie within a drainage having tributary runoff events of more than 200 cfs should be considered for riparian area improvement to limit sediments entering the drainage system.

When the total sediment load yielded by the twelve subwatersheds was compared with the sediment load actually entering the lake according to the model, the load appeared to be over estimated. The total sediment yield from the twelve subwatersheds totals to 1,894 ton/year while the sediment load at the Blue Dog Lake inlets totals only 1,465 ton/year. The over estimation becomes evident considering that the twelve subwatersheds contained only 64 % of the total acreage associated with the watershed and account for only 47 % of the critical erosion cells.

SEDIMENT ANALYSIS - BLUE DOG LAKE INPUT vs OUTLET

LAKE INPUT CELL #	DRAINAGE AREA (acres)	1 MONTH EVENT yield (tons)	6 MONTH EVENT yield (tons)	1 YEAR EVENT yield (tons)	ANNUAL sediment yield (tons/acre)	ANNUAL sediment yield (tons)	% of Total Sediment Yield	% of Water-shed Area
757	920	0.13	0.63	1.20	0.00	3.89	0.27	1.62
760	8920	2.95	5.72	12.20	0.01	56.09	3.83	15.69
1034	42840	48.38	216.02	440.68	0.03	1404.90	95.91	75.37
INLET	**52680**	**51.46**	**222.37**	**454.08**	**0.04**	**1464.88**	**100.00**	**92.68**
OUTLET	56840				0.004	232.24	15.85	100

NUTRIENT YIELD RESULTS

The AGNPS model suggested that the Blue Dog Lake watershed had a total nitrogen deliverability rate of 2.42 lb/acre/year (equivalent to 127,462.4 tons) and a total phosphorus deliverability rate of .58 lb/acre/year (equivalent to 30,756.4 tons).

Subwatersheds 5(#723), 7(#930), 9(#1060), 10(#1085) and 12(#1342) appeared to be contributing higher levels of total nitrogen to the watershed. These five subwatersheds contained 61% of the critical nitrogen level cells within in the Blue Dog Lake subwatersheds and 34% of the critical nitrogen cells found in the watershed.

SUBWATERSHED number (cell #)	% OF TOTAL SUBWATERSHED NITROGEN LOAD	% OF WATERSHED AREA	# OF CRITICAL CELLS (total nitro. > 10 lbs/acre)
1 (#232)	13.5	9.85	8
2 (#483)	11.3	10.84	2
3 (#587)	0.5	4.64	-
4 (#608)	1.5	2.46	-
5 (#723)	15.0	5.70	3
6 (#831)	6.0	4.36	3
7 (#930)	6.5	2.39	5
8 (#1007)	10.0	10.27	3
9 (#1060)	8.1	2.32	10
10 (#1085)	14.1	5.00	9
11 (#1315)	6.1	2.89	6
12 (#1342)	7.5	2.89	7
TOTAL	**100**	**63.6**	**56 of 100**

Cumulatively, the critical subwatersheds deliver 36,499 lbs. of nitrogen to the watershed in an average year. This nitrogen load is 43% of the total load produced by the twelve subwatersheds in the drainage.

NITROGEN ANALYSIS - BLUE DOG LAKE INPUTS vs OUTPUTS

LAKE INPUT CELL #	DRAINAGE AREA (acres)	1 MONTH EVENT Total Nit. (lbs/acre)	6 MONTH EVENT Total Nit. (lbs/acre)	1 YEAR EVENT Total Nit. (lbs/acre)	ANNUAL Total Nit. (lbs/acre)	ANNUAL Total Nit. (lbs)	% of Total Nitrogen Yield	% of Water-shed Area
757	920	0.03	0.13	0.21	0.80	736.00	0.58	1.62
760	8920	0.07	0.27	0.41	1.72	15342.40	12.04	15.69
1034	42840	0.10	0.43	0.64	2.60	111384.00	87.39	75.37
INLET	**52680**	**0.20**	**0.83**	**1.26**	**5.12**	**127462.4**	**100.00**	**92.68**
OUTLET	56840				2.28	129595.2	102	100

Only seven of the twenty-five designated animal feeding sites inputted in the model exist in these five watersheds. Just two have an AGNPS rating of 55 or greater, which points toward crop fertilization levels and fertilizer incorporation rates as a possible source of elevated nitrogen. A large portion of each of these five subwatersheds was made of cells having nitrogen applications over 100 lbs/acre and fertilization availability greater than 65%.

Subwatersheds 5(#723), 7(#930), 9(#1060), 10(#1085), 11(#1315) and 12(#1342) appeared to be contributing high levels of phosphorus to the watershed. These six subwatersheds contained 69% of the critical phosphorus level cells contained in all of the subwatersheds but only 35% of the critical phosphorus level cells contained in the Blue Dog Lake watershed.

SUBWATERSHED number (cell #)	% OF TOTAL SUBWATERSHED PHOSPHORUS LOAD	% OF WATERSHED AREA	# OF CRITICAL CELLS (total phos. > 3.5 lbs/acre)
1 (#232)	11.5	9.85	7
2 (#483)	12.6	10.84	2
3 (#587)	0.5	4.64	-
4 (#608)	0.7	2.46	-
5 (#723)	12.7	5.70	1
6 (#831)	6.1	4.36	2
7 (#930)	6.7	2.39	2
8 (#1007)	13.1	10.27	1
9 (#1060)	7.9	2.32	7
10 (#1085)	13.9	5.00	7
11 (#1315)	6.2	2.89	5
12 (#1342)	8.2	2.89	5
TOTAL	**100**	**63.6**	**39 of 78**

These critical subwatersheds delivered 11,918 lbs/year to the Blue Dog drainage. This rate was 56% of the cumulative phosphorus yield delivered by the twelve delineated subwatersheds and was 39% of the total phosphorus load that entered Blue Dog Lake.

PHOSPHORUS ANALYSIS - BLUE DOG LAKE INPUTS vs OUTPUTS

LAKE INPUT CELL #	DRAINAGE AREA (acres)	1 MONTH EVENT Tot. Phos. (lbs/acre)	6 MONTH EVENT Tot. Phos. (lbs/acre)	1 YEAR EVENT Tot. Phos. (lbs/acre)	ANNUAL Tot. Phos. (lbs/acre)	ANNUAL Tot. Phos. (lbs)	% of Total Phosphorus Yield	% of Water-shed Area
757	920	0.00	0.02	0.04	0.08	73.60	0.24	1.62
760	8920	0.01	0.04	0.08	0.27	2408.40	7.83	15.69
1034	42840	0.03	0.09	0.15	0.66	28274.40	91.93	75.37
INLET	**52680**	**0.04**	**0.15**	**0.27**	**1.01**	**30756.4**	**100.00**	**92.68**
OUTLET	56840				0.36	20462	66.53	100

Nearly the same characterization of the relationship of feedlots to subwatersheds existed between the critical phosphorus subwatersheds as the critical nitrogen subwatersheds. Again, there were few animal feeding areas contained within the critical subwatersheds which means that the high phosphorus loads could be attributed to fertilizer applications.

OBJECTIVE 2 - IDENTIFICATION OF CRITICAL NPS CELLS (ANNUALIZED)

Critical Cell #	Cell Erosion (ton/acre)	Critical Cell #	Total Phosphorus (lbs/acre)	Critical Cell #	Total Nitrogen (lbs/acre)
1085	20.75	383	10.25	627	40.06
583	15.47	1261	8.97	383	26.68
1314	8.42	1258	8.97	1360	25.36
1261	8.42	124	8.97	1284	24.32
1258	8.42	774	8.45	1261	24.12
1224	8.42	985	8.23	1258	24.12
955	8.42	915	8.23	1224	24.12
636	8.42	627	8.11	532	24.04
631	8.42	504	7.75	774	23.09
383	8.42	725	7.41	1255	22.66
1008	7.65	1360	7.05	985	22.63
1007	7.65	30	6.8	915	22.63
774	7.65	778	6.44	504	21.67
574	7.65	861	6.41	725	20.9
1289	7.26	532	6.08	724	20.9
985	7.26	1379	6.06	677	20.63
915	7.26	1378	6.06	30	19.78
879	7.26	1376	6.06	861	19.03
861	7.26	1274	6.06	778	18.94
1221	6.55	1244	6.06	1379	18.31
1172	6.55	1242	6.06	1378	18.31
1128	6.55	1109	6.06	1376	18.31
504	6.55	775	6.06	1274	18.31
242	6.55	430	6.06	1244	18.31
160	6.55	337	6.06	1242	18.31
725	6.03	328	6.06	1109	18.31
724	6.02	169	6.06	775	18.31
946	6.02	29	6.06	430	18.31
945	6.02	1120	6.01	337	18.31
772	6.02	1420	5.98	38	18.31
730	6.02	1417	5.98	169	18.31
728	6.02	1284	5.93	29	18.31
680	6.02	1346	5.79	1120	18.07
679	6.02	339	5.79	1420	18.06
674	6.02	128	5.79	1417	18.06
630	6.02	57	5.79	339	17.76
625	6.02	28	5.79	1346	17.73
472	6.02	1289	5.57	128	17.73
436	6.02	1314	5.18	57	17.73
435	6.02	1247	4.97	28	17.73
298	6.02	1396	4.83	1289	17.33
257	6.02	1384	4.83	1314	16.52
249	6.02	1349	4.83	1247	16.02
126	6.02	1333	4.83	1396	15.83
90	6.02	1332	4.83	1384	15.83
1259	5.99	1077	4.75	1349	15.83

Cell #	Erosion (ton/acre)	Critical Cell #	Total Phosphorus (lbs/acre)	Critical Cell #	Total Nitrogen (lbs/acre)
1093	5.25	1220	4.74	1333	15.83
881	5.25	428	4.67	1332	15.83
880	5.25	1282	4.6	1221	15.83
770	5.25	1281	4.6	1077	15.57
716	5.25	1255	4.6	1220	15.54
656	5.25	1245	4.53	428	15.54
554	5.25	1169	4.52	1282	15.47
408	5.25	821	4.52	1281	15.47
276	5.25	677	4.33	1245	15.36
		946	4.14	1169	15.2
		945	4.14	821	15.2
		630	4.14	1283	15.18
		298	4.14	876	15.01
		876	4.07	1264	14.66
		482	4.04	1132	14.59
		432	4.04	482	14.24
		1309	4.01	432	14.24
		1308	4.01	1212	14.13
		1111	4.0	1158	14.07
		1212	3.97	1309	14.06
		1201	3.93	1308	14.06
		1221	3.91	1256	13.96
		1158	3.89	1201	13.93
		1264	3.82	35	13.69
		656	3.77	1180	13.46
		1361	3.65	202	13.45
		1180	3.64	1400	13.32
		1400	3.62	752	13.18
		202	3.62	1361	12.95
		1172	3.58	789	12.71
		1198	3.56	713	12.6
		1283	3.53	1356	12.58
				1246	12.58
				1243	12.58
				1156	12.58
				788	12.58
				382	12.58
				372	12.58
				1366	12.55
				1301	12.55
				1402	12.54
				714	12.46
				565	12.46
				514	12.46
				1257	12.28
				566	12.28
				1288	12.24
				685	12.24
				901	12.05
				846	12.05
				375	12.05

Critical Cell #	**Total Nitrogen (lbs/acre)**
515	11.93
1157	11.87
1058	11.86
1173	11.76
1136	11.76
1401	11.62
131	11.45
130	11.42
381	11.37
1172	11.36
1240	11.34
32	11.34
60	11.33
1241	11.23
293	11.11
172	11.09
481	11.08
62	11.08
1200	11.07
1181	11.07
294	11.07
213	11.07
63	11.07
33	10.93
953	10.92
522	10.9
59	10.89
1313	10.67
1137	10.6
1307	10.58

An analysis of the Blue Dog Lake watershed indicated that there were approximately 55 cells having erosion rates greater than 5 ton/acre. This was only 4% of the total number of cells found in the Blue Dog watershed. The model indicated that the majority of these cells were located areas that had a landslope of 7% or greater and had a c-factor of 0.19 or more.

The model output reported that there were 78 cells that would qualify as critical phosphorus yield cells. These cells comprised 5.5% of the watershed. There were also 135 cells having a critical status with regards to nitrogen. The critical nitrogen cells occupied 9.5% of the Blue Dog Lake watershed. Similar to the critical sediment cells, the majority of the critical nutrient cells were found in areas of cropland that had a landslope greater than 7%.

These designated critical cells should be considered for modification through implementation of BMPs. They should be field verified for correctness before any installation of BMPs.

OBJECTIVE 3 - PRIORITY RANKING OF ANIMAL FEEDING AREAS

Twenty-five animal feeding areas were identified by AGNPS as being a potential source of non-point pollution. The AGNPS model ranked the animal feeding areas utilizing data collected and then inputted into the model. Below is a listing of the AGNPS analysis of each feeding area:

Cell # 35

Nitrogen concentration (ppm)	23.807
Phosphorus concentration (ppm)	4.635
COD concentration (ppm)	443.923
Nitrogen mass (lbs)	462.066
Phosphorus mass (lbs)	89.956
COD mass (lbs)	8616.050
Animal feedlot rating number	**63**

Cell # 88

Nitrogen concentration (ppm)	20.293
Phosphorus concentration (ppm)	3.874
COD concentration (ppm)	340.910
Nitrogen mass (lbs)	87.276
Phosphorus mass (lbs)	16.660
COD mass (lbs)	1466.182
Animal feedlot rating number	**34**

Cell # 158

Nitrogen concentration (ppm)	33.474
Phosphorus concentration (ppm)	6.093
COD concentration (ppm)	517.128
Nitrogen mass (lbs)	219.510
Phosphorus mass (lbs)	39.957
COD mass (lbs)	3391.171
Animal feedlot rating number	**47**

Cell # 768

Nitrogen concentration (ppm)	15.117
Phosphorus concentration (ppm)	2.791
COD concentration (ppm)	207.797
Nitrogen mass (lbs)	134.004
Phosphorus mass (lbs)	24.740
COD mass (lbs)	1841.987
Animal feedlot rating number	**37**

Cell # 797

Nitrogen concentration (ppm)	82.804
Phosphorus concentration (ppm)	19.860
COD concentration (ppm)	1435.241
Nitrogen mass (lbs)	718.820
Phosphorus mass (lbs)	172.403
COD mass (lbs)	12459.230
Animal feedlot rating number	**66**

Cell # 876

Nitrogen concentration (ppm)	14.120
Phosphorus concentration (ppm)	3.139
COD concentration (ppm)	203.081
Nitrogen mass (lbs)	270.447
Phosphorus mass (lbs)	60.131
COD mass (lbs)	3889.782
Animal feedlot rating number	**51**

Cell # 299

Nitrogen concentration (ppm)	26.538
Phosphorus concentration (ppm)	5.394
COD concentration (ppm)	605.769
Nitrogen mass (lbs)	80.942
Phosphorus mass (lbs)	16.452
COD mass (lbs)	1847.599
Animal feedlot rating number	**38**

Cell # 321

Nitrogen concentration (ppm)	11.607
Phosphorus concentration (ppm)	2.197
COD concentration (ppm)	102.288
Nitrogen mass (lbs)	86.423
Phosphorus mass (lbs)	16.359
COD mass (lbs)	761.633
Animal feedlot rating number	**21**

Cell # 343

Nitrogen concentration (ppm)	17.110
Phosphorus concentration (ppm)	3.352
COD concentration (ppm)	329.143
Nitrogen mass (lbs)	53.701
Phosphorus mass (lbs)	10.520
COD mass (lbs)	1033.075
Animal feedlot rating number	**30**

Cell # 419

Nitrogen concentration (ppm)	36.645
Phosphorus concentration (ppm)	8.355
COD concentration (ppm)	561.998
Nitrogen mass (lbs)	178.122
Phosphorus mass (lbs)	40.611
COD mass (lbs)	2731.706
Animal feedlot rating number	**43**

Cell # 887

Nitrogen concentration (ppm)	101.720
Phosphorus concentration (ppm)	20.128
COD concentration (ppm)	2175.600
Nitrogen mass (lbs)	254.499
Phosphorus mass (lbs)	50.359
COD mass (lbs)	5443.259
Animal feedlot rating number	**52**

Cell # 1099

Nitrogen concentration (ppm)	38.813
Phosphorus concentration (ppm)	9.020
COD concentration (ppm)	680.234
Nitrogen mass (lbs)	323.546
Phosphorus mass (lbs)	75.192
COD mass (lbs)	5670.377
Animal feedlot rating number	**55**

Cell # 1117

Nitrogen concentration (ppm)	34.500
Phosphorus concentration (ppm)	7.012
COD concentration (ppm)	787.500
Nitrogen mass (lbs)	116.688
Phosphorus mass (lbs)	23.718
COD mass (lbs)	2663.539
Animal feedlot rating number	**43**

Cell # 1132

Nitrogen concentration (ppm)	81.900
Phosphorus concentration (ppm)	15.406
COD concentration (ppm)	1433.250
Nitrogen mass (lbs)	276.680
Phosphorus mass (lbs)	52.046
COD mass (lbs)	4841.894
Animal feedlot rating number	**51**

Cell # 459

Nitrogen concentration (ppm)	60.227
Phosphorus concentration (ppm)	10.115
COD concentration (ppm)	956.964
Nitrogen mass (lbs)	433.501
Phosphorus mass (lbs)	72.806
COD mass (lbs)	6888.053
Animal feedlot rating number	**57**

Cell # 505

Nitrogen concentration (ppm)	43.497
Phosphorus concentration (ppm)	6.791
COD concentration (ppm)	715.551
Nitrogen mass (lbs)	527.834
Phosphorus mass (lbs)	82.408
COD mass (lbs)	8683.223
Animal feedlot rating number	**62**

Cell # 529

Nitrogen concentration (ppm)	21.833
Phosphorus concentration (ppm)	3.934
COD concentration (ppm)	358.396
Nitrogen mass (lbs)	243.531
Phosphorus mass (lbs)	43.884
COD mass (lbs)	3997.617
Animal feedlot rating number	**50**

Cell # 623

Nitrogen concentration (ppm)	114.480
Phosphorus concentration (ppm)	22.389
COD concentration (ppm)	2003.400
Nitrogen mass (lbs)	1370.309
Phosphorus mass (lbs)	267.993
COD mass (lbs)	23980.400
Animal feedlot rating number	**77**

Cell # 1255

Nitrogen concentration (ppm)	83.662
Phosphorus concentration (ppm)	14.067
COD concentration (ppm)	1464.085
Nitrogen mass (lbs)	791.759
Phosphorus mass (lbs)	133.126
COD mass (lbs)	13855.780
Animal feedlot rating number	**68**

Cell # 1264

Nitrogen concentration (ppm)	129.766
Phosphorus concentration (ppm)	31.061
COD concentration (ppm)	2238.673
Nitrogen mass (lbs)	995.691
Phosphorus mass (lbs)	238.328
COD mass (lbs)	17177.260
Animal feedlot rating number	**70**

Cell # 1284

Nitrogen concentration (ppm)	65.302
Phosphorus concentration (ppm)	10.160
COD concentration (ppm)	1112.566
Nitrogen mass (lbs)	316.627
Phosphorus mass (lbs)	49.262
COD mass (lbs)	5394.445
Animal feedlot rating number	**53**

Cell # 1357

Nitrogen concentration (ppm)	110.400
Phosphorus concentration (ppm)	22.270
COD concentration (ppm)	1932.000
Nitrogen mass (lbs)	410.700
Phosphorus mass (lbs)	82.847
COD mass (lbs)	7187.244
Animal feedlot rating number	**57**

Cell # 627

Nitrogen concentration (ppm)	118.383
Phosphorus concentration (ppm)	21.745
COD concentration (ppm)	2004.934
Nitrogen mass (lbs)	671.452
Phosphorus mass (lbs)	123.334
COD mass (lbs)	11371.660
Animal feedlot rating number	**64**

Cell # 1360

Nitrogen concentration (ppm)	21.124
Phosphorus concentration (ppm)	5.918
COD concentration (ppm)	311.105
Nitrogen mass (lbs)	612.550
Phosphorus mass (lbs)	171.611
COD mass (lbs)	9021.528
Animal feedlot rating number	**65**

Cell # 1369

Nitrogen concentration (ppm)	10.781
Phosphorus concentration (ppm)	2.191
COD concentration (ppm)	246.094
Nitrogen mass (lbs)	63.201
Phosphorus mass (lbs)	12.846
COD mass (lbs)	1442.621
Animal feedlot rating number	**36**

Of the twenty-five animal feeding areas defined, twelve feedlots had an AGNPS rating of 55 or greater when modeled using a 25-year frequency storm event. Seven feeding areas had a rating of 64 or greater. An analysis to evaluate the impacts of these animal feeding areas on the watershed was performed by alternately running the model with the feedlots ranked 55 or greater removed from the model and then those ranked 64 or greater. The resulting data was then compared to the data output from the model run with the original data. Reductions in nutrients delivered to the watershed could then be calculated. The results of the calculation showed that when those cells with a ranking of 55 or greater were removed, a 17% reduction in phosphorus could be realized as well as a 7.5% reduction in nitrogen delivered to the watershed. Removing all feedlots from the model that had a rating of 64 or greater (7 cells) produces a 2% net reduction in total phosphorus and a 4% reduction in total nitrogen. It is recommended that the twelve feedlots with an AGNPS rating of 55 or greater be evaluated for potential operational or structural modifications in order to minimize nutrient yields to the watershed.

The implementation of appropriate BMPs targeting these high nutrient yield feedlot areas, upon the completion of a field verification process, should produce the most cost effective treatment plan in reducing the nutrient yields.

In case of questions regarding this analysis, please contact the Department of Environment and Natural Resources at (605) 773-4254.

RAINFALL SPECS FOR THE BLUE DOG LAKE STUDY

EVENT	**RAINFALL**	**ENERGY INTENSITY**
monthly	.9 inches	3.9
semi-annual	1.6 inches	13.4
1 year	2.1 inches	24.3
25 year	4.3 inches	120

NRCS R-factor for the Blue Dog Lake watershed = 94

Annual Loadings Calculations

monthly events = 11 events X 3.9 = 42.9

semi-annual event = 2 events X 13.4 = 26.8

1 year event = 1 event X 24.3 = 24.3

TOTAL = 94.0

OVERVIEW OF AGNPS DATA INPUTS

OVERVIEW

Agricultural Nonpoint Source Pollution Model (AGNPS) is a computer simulation model developed to analyze the water quality of runoff from watersheds. The model predicts runoff volume and peak rate, eroded and delivered sediment, nitrogen, phosphorus, and chemical oxygen demand concentrations in the runoff and the sediment for a **single** storm event for all points in the watershed. Proceeding from the headwaters to the outlet, the pollutants are routed in a step-wise fashion so the flow at any point may be examined. AGNPS to be used to objectively evaluate the water quality of the runoff from agricultural watersheds and to present a means of objectively comparing different watersheds throughout the state. The model is intended for watersheds up to about 320,000 acres (8000 cells @ 40 acres/cell).

The model works on a cell basis. These cells are uniform square areas that divide the watershed (figure 1). This division makes it possible to analyze any area, down to 1.0 acres, in the watershed. The basic components of the model are hydrology, erosion, sediment transport, nitrogen (N), phosphorus (P), and chemical oxygen demand (COD) transport. In the hydrology portion of the model, calculations were made for runoff volume and peak concentration flow. Total upland erosion, total channel erosion, and a breakdown of these two sources into five particle size classes (clay, silt, small aggregates, large aggregates, and sand) for each of the cells are calculated in the erosion portion. Sediment transport is also calculated for each of the cells in the five particle classes as well as the total. The pollutant transport portion is subdivided into one part handling soluble pollutants and another part handling sediment attached pollutants (figure 2).

PRELIMINARY EXAMINATION

A preliminary investigation of the watershed is necessary before the input file can be established. The steps to this preliminary examination are:

1) Detailed topographic map of the watershed (USGS map 1:24,000)
2) Establish the drainage boundaries.
3) Divide watershed up into cells (40 acre, 1320 X 1320). Only those cells with greater than 50% of their area within the watershed boundary should be included.
4) Number the cells consecutively from one to the number of cells (begin at NW corner of watershed and precede west to east then north to south.
5) Establish the watershed drainage pattern from the cells.

DATA FILE

Once the preliminary examination is completed, the input data file can be established. The data file is composed of the following 21 inputs per cell :

Data input for watershed

1) a) Area of each cell (acres)
   b) Total number of cells in watershed
   c) Precipitation for a ___ year, 24 hour rainfall
   d) Energy intensity value for storm event previously selected

Data input for each cell

1) **Cell number**
2) **Receiving cell number**
3) **SCS number**: runoff curve number (use antecedent moisture condition II)
4) **Land slope** (topographic maps) average slope if irregular, water or marsh = 0
5) **Slope shape factor** water or marsh = 1 (uniform)
6) **Field slope length** water or marsh = 0, for S.D. assume slope length area 1
7) **Channel slope** (average), topo maps, if no definable channel, channel slope = 1/2 land slope, water or marsh = 0
8) **Channel sideslope**, the average sideslope (%), assume 10% if unknown, water or marsh=0
9) **Manning roughness coefficient for the channel** If no channel exists within the cell, select a roughness coefficient appropriate for the predominant surface condition within the cell
10) **Soil erodibility factor** water or marsh = 0
11) **Cropping factor** assume conditions at storm or worst case condition (fallow or seedbed periods), water or marsh = .00, urban or residential = .01
12) **Practice factor** worst case = 1.0, water or marsh = 0 ,urban or residential = 1.0
13) **Surface condition constant** a value based on land use at the time of the storm to make adjustments for the time it takes overland runoff to channelize.
14) **Aspect** a single digit indicating the principal direction of drainage from the cell (if no drainage = 0)
15) **Soil texture**, major soil texture and number to indicate each are:

Texture	Input Parameter
Water	0
Sand	1
Silt	2
Clay	3
Peat	4

16) **Fertilization level**, indication of the level of fertilization on the field.

	Assume Fertilization (lb./acre)		
Level	N	P	Input
No fertilization	0	0	0
Low Fertilization	50	20	1
Average Fertilization	100	40	2
High Fertilization	200	80	3

avg. manure - low fertilization
high manure - avg.fertilization
water or marsh = 0
urban or residential = 0 (for average practices)

17) **Availability factor**, the percent of fertilizer left in the top half inch of soil at the time of the storm. Worst case 100%, water or marsh = 0, urban or residential = 100%.
18) **Point source indicator**: indicator of feedlot within the cell (0 = no feedlot, 1 = feedlot)

.

19) **Gully source level**: tons of gully erosion occurring in the cell or input from a sub-watershed.

20) **Chemical oxygen demand (COD) demand**, a value of COD for the land use in the cell.
21) **Impoundment factor**: number of impoundment's in the cell (max. 13)
    a) Area of drainage into the impoundment
    b) Outlet pipe (inches)
22) **Channel indicator**: number which designates the type of channel found in the cell

DATA OUTPUT AT THE OUTLET OF EACH CELL

Hydrology

Runoff volume
Peak runoff rate
Fraction of runoff generated within the cell

Sediment Output

Sediment yield
Sediment concentration
Sediment particle size distribution
Upland erosion
Amount of deposition
Sediment generated within the cell
Enrichment ratios by particle size
Delivery ratios by particle size

Chemical Output

Nitrogen

Sediment associated mass
Concentration of soluble material
Mass of soluble material

Phosphorus

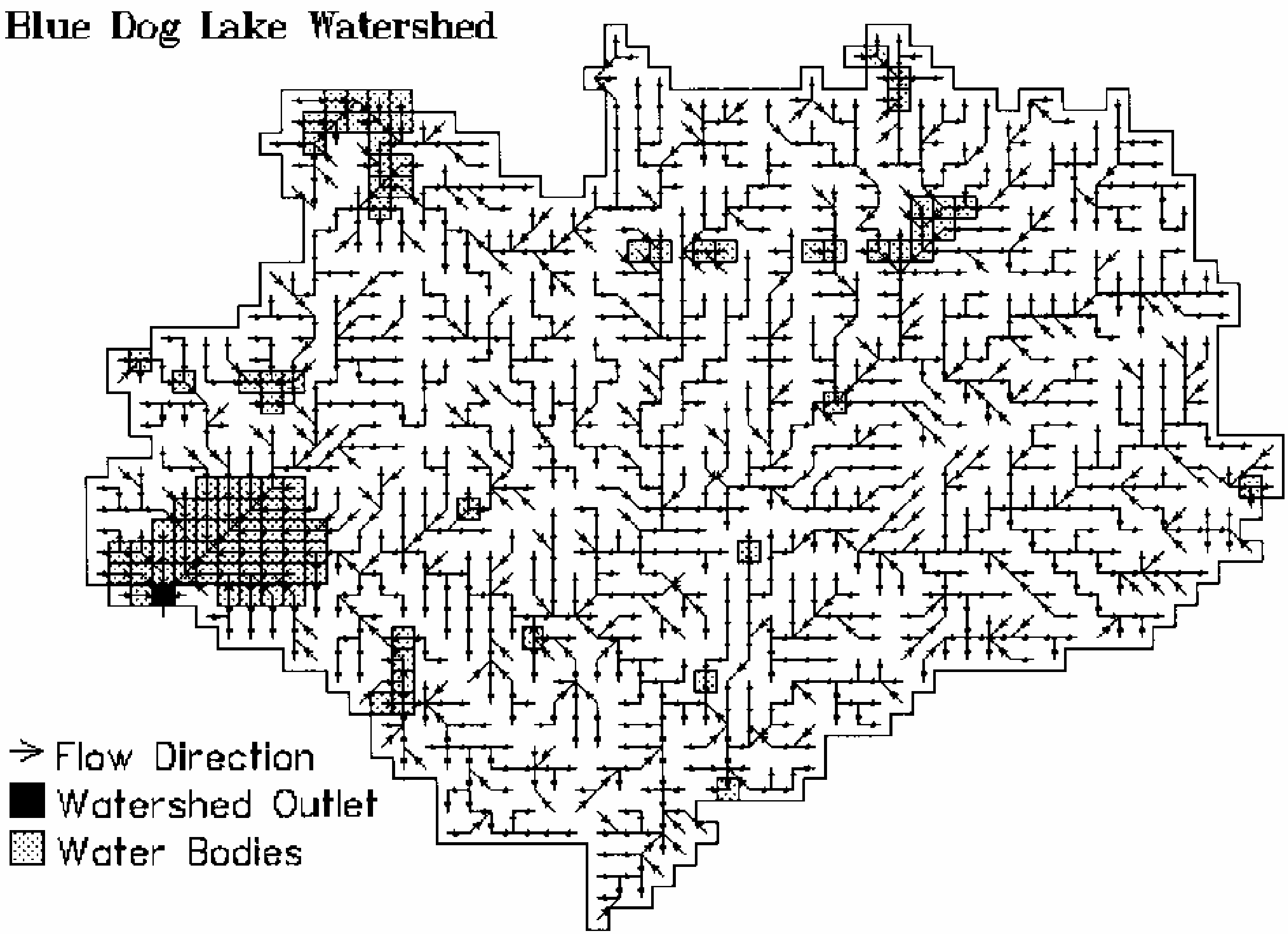
Sediment associated mass
Concentration of soluble material
Mass of soluble material

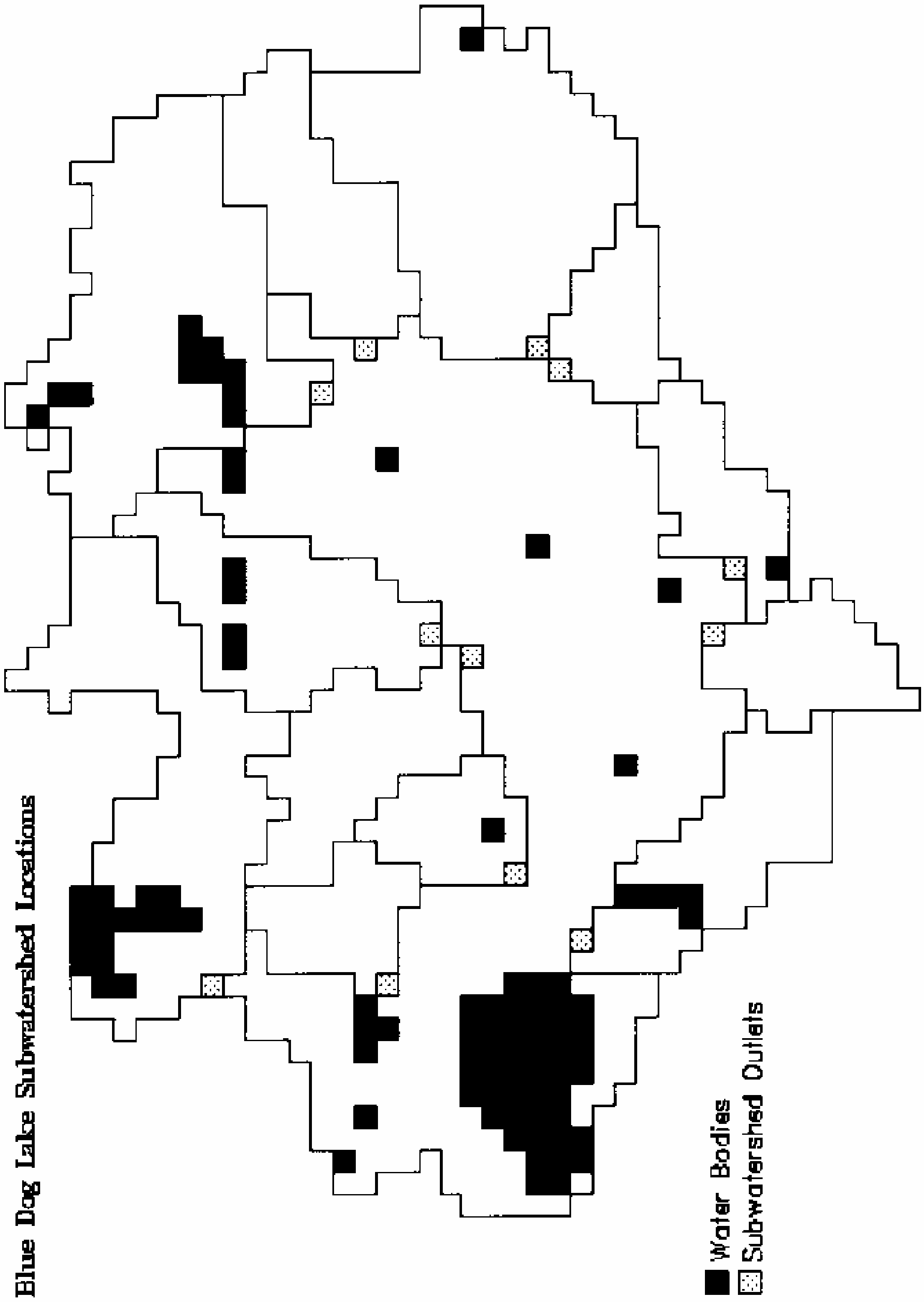
Chemical Oxygen Demand

Concentration
Mass

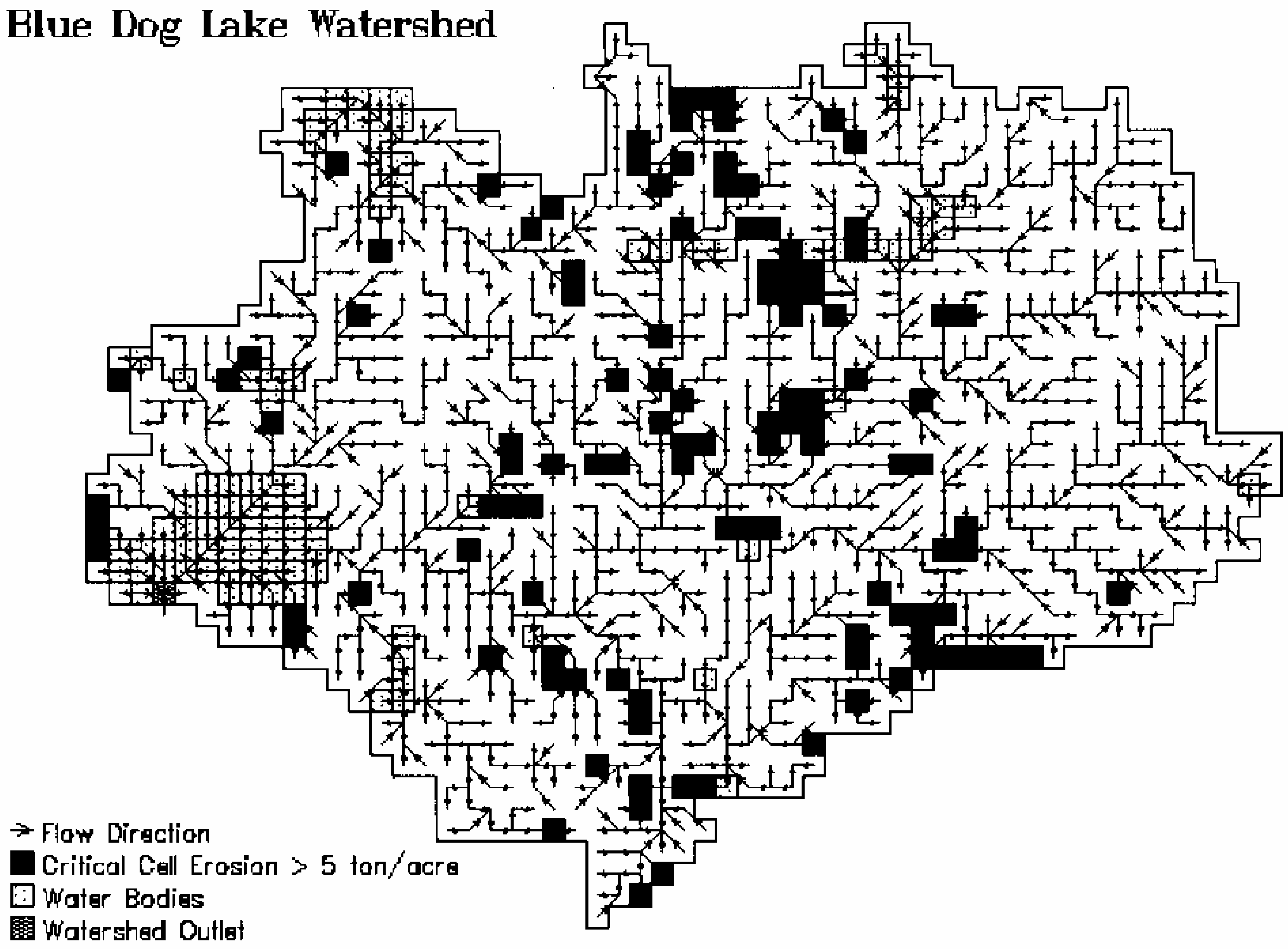
PARAMETER SENSITIVITY ANALYSIS

The most sensitive parameters affecting sediment and chemical yields are:
Land slope (LS)
Soil erodibility (K)
Cover-management factor (C)
Curve number (CN)
Practice factor (P)


Blue Dog Lake Watershed
→ Flow Direction
■ Watershed Outlet
▨ Water Bodies



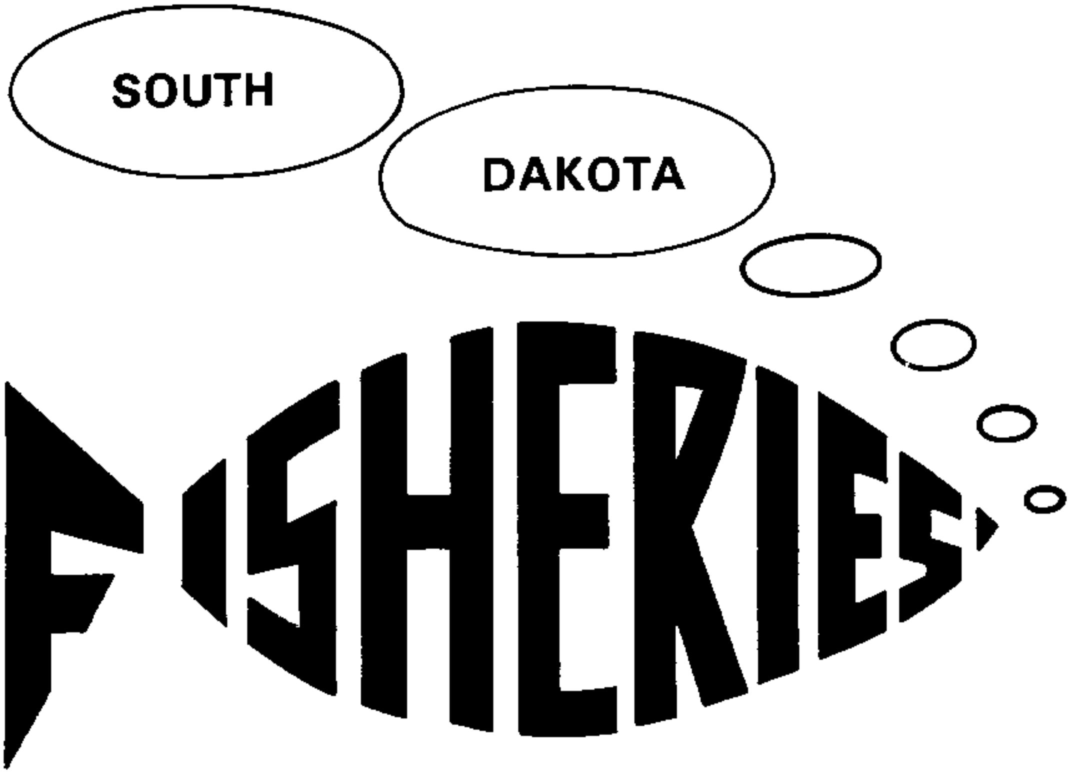
Blue Dog Lake Subwatershed Locations



Blue Dog Lake Watershed

Appendix B

Blue Dog Lake Fisheries Report



STATEWIDE FISHERIES SURVEYS, 1996
SURVEY OF PUBLIC WATERS
Part 1
Lakes-Region IV

**South Dakota
Department of
Game, Fish and Parks**
Wildlife Division
Joe Foss Building
Pierre, South Dakota 57501-3182

**Annual Report
No. 97-12**

STATEWIDE FISHERIES SURVEYS, 1996

SURVEYS OF PUBLIC WATERS

edited by
Ronald J. Meester

(Annual Report)

Part 1 Lakes
Region IV

Date .... April 1997

John Cooper, Secretary
South Dakota Department of Game, Fish and Parks

Dave Hamm
Grants Coordinator

Doug Hansen
Director, Wildlife Division

Dennis Unkenholz
Fisheries Division Staff Specialist

SOUTH DAKOTA STATEWIDE FISHERIES SURVEY

2102 - F21-R- 29

Name: Bluedog Lake County(ies): Day
Legal description: 122N,53W,SEC,9,10,15,16; 122N,54W,SEC,21,27,28
Location from nearest town: 1/2 North of Waubay
Dates of present survey: July 2-3,1996
Date last surveyed: July 6-7, 1995
Most recent lake management plan: F21-R-24 Date: 1989-90
Management classification: Warm water permanent
Contour mapped: Date: 1964
Report prepared by: Matthew Hubers
Scales read and digitized by: Randy Mount

Primary Species: (game and forage)

1. Walleye (WAE)
2. Yellow Perch (YEP)
3. Northern Pike (NOP)
4. Smallmouth Bass (SMB)
5. Fathead Minnows (FHM)
6. Emerald shiners (EMS)

Secondary and other species:

1. Rock Bass (RKB)
2. White Bass (WHB)
3. Common Carp (COC)
4. Black Crappie (BLC)
5. Lake Herring (LKH)
6. White Sucker (WHS)

PHYSICAL CHARACTERISTICS

Surface Area: 1502 acres; Watershed: 73811 acres
Maximum depth: 7 feet; Mean depth: 6 feet
Lake elevation at survey (from known benchmark): full feet

1. Describe ownership of lake and adjacent lakeshore property:

Bluedog Lake is a meandered lake owned by the State of South Dakota and managed by the Dept. of Game, Fish and Parks. Lakeshore property is private, GF&P and the City of Waubay.

2. Describe watershed condition and percentages of land use:

Land use is estimated to be 39% crop and 61% pasture.

3. Describe aquatic vegetative condition:

Less than 5% of the shoreline has emergents. At high water levels the lake connects with sloughs on the east and north-west side of the lake. Few submergents are present.

4. Describe pollution problems:

Severe shoreline erosion occurs and turbidity is a problem.

5. Describe condition of all structures:

All structures including the spillway are in good condition.

BIOLOGICAL DATA

Methods:

Bluedog Lake was netted on July 2-3, 1996. Three 45.7 m (150 ft) long and 1.8 m (6 ft) deep monofilament gill nets consisting of six 7.6 m (25 ft) panels of 1.3 cm (1/2 in), 1.9 cm (3/4 in), 2.5 cm (1 in), 3.2 cm (1 1/4 in), 3.8 cm (1 1/2 in), and 5.1 cm (2 in) were used. Eight 1.9 cm (0.75) mesh double frame 1.5 m x 1.2 m (3 ft x 5 ft) trap net sets were also utilized. The three gill nets and eight trap nets were fished for three 24 hr periods with nets being relocated after each period. Approximate net locations are shown in figure 4. A 0.6 cm x 1.8 m x 30.5 m (1/4 in x 72 in x 1200 in) bag seine was used to assess young-of-year and forage fish on August 30, 1995 (Figure 3). Scales were taken from all walleye sampled behind the left pectoral fin below the lateral line and analyzed using the DisBcal program (Table 3). Lengths (mm) of 100 fish and weights (g) of 50 fish were taken from a sub-sample when fish numbers permitted. PSD, RSD, and WR were calculated from this sub-sample using the Fishcalc program. No calculations were done on samples of less than 25 fish. The results are incorporated into Tables 1 and 2. Confidence intervals were calculated using SAS software.

Results and Discussion:

Walleye comprised 60.2 % of the gill net catch. Gill net CPUE of 20.2 indicates high abundance. Figure 2 shows a length distribution with fish from 13-54 cm present. Frame nets selected for larger fish resulting in a PSD of 100. Gill net catch is more likely to be representative of the actual population as they sampled more length groups. Gill net PSD of 48 indicates good size structure. Nearly 46% of the total catch was comprised of the 1994 year class followed by the 1991 year class which contributed 24%. Growth is slightly slower than that of other area lakes with fish reaching 362 mm at age 4 (Table 3). A Wr value of 97 is very acceptable. Table 3 shows all year classes from 1989-1995. Shoreline seining resulted in two young-of-year being sampled (Figure 4). Recruitment is consistent. Origin of fish can be attributed to a combination of stocking, natural reproduction and escapement from Bluedog State Fish Hatchery. Walleye stocking in Bluedog Lake is very erratic and usually consists of surplus fish. Given size structure and abundance, this population should provide an exemplary fishery.

Northern pike attained the highest frame net CPUE's (5.6) seen of all lakes surveyed. Length of pike ranged from 30-72 cm (Figure 1). Length distribution suggests consistent recruitment over the past several years. Size distribution, as indicated by PSD of 64, is skewed towards larger individuals. Mean Wr value of 84 during a summer survey is acceptable. Elevated waterlevels over the past four years have increased access of northern pike to adjacent sloughs and have greatly facilitated reproduction. Currently Bluedog Lake has a high density of quality length northern pike that should provide fine fishing opportunity.

Yellow perch, despite increasing water levels for four consecutive years, have maintained low population levels. Gill net CPUE fluctuates very little and has ranged from 7.0-6.0 in the past three years. Shoreline seining catches of up to 2504+ (1993) young-of-year have been seen. This indicates that substantial year classes are produced. These, however, do not materialize into acceptable fisheries. Heavy predatory pressure from walleye, northern pike and the expanding white bass populations as well as little escape cover may, in part, be responsible for low abundance. Length of gill net sample ranged from 9-30 cm (Figure 2) and had PSD of 72. The 27 fish frame net sample was comprised totally of larger fish and had PSD of 100 and RSD of 93. The perch population can be characterized as low density and being dominated by large individuals. While size of fish is acceptable to anglers, low abundance limits the contribution that perch make to the fishery.

White bass frame net CPUE of 2.1 is the highest value seen since annual surveys were initiated in 1992. Survey gear usually does not readily sample white bass. It is therefor difficult to ascertain population status. High-water levels, do however, appear to have aided the population. Shoreline seining (Figure 4) produced up to 30 young-of-year white bass. The frame net sample was dominated by quality length fish resulting in a PSD of 96. This population may present angling opportunity and young-of-year may provide important forage for walleye.

Lake herring, sampled since 1991 when they were introduced to Bluedog Lake via Bluedog State Fish Hatchery, reached their peak of abundance in 1994 with a gill net CPUE of 5.6. Natural reproduction has been documented. Normal summer temperatures for he past two years may have reduced the population level of this cold water species. Normal summers and high predator populations in the lake may eventually expunge this cold water fish.

Common carp are thought to be very abundant but are under sampled. White sucker are abundant and are probably an important forage species. Black bullhead, rock bass and black crappie are not very abundant and contribute little to the fishery.

Table 1. Catch of six 150 ft. gill net sets in Bluedog Lake, July 2-3, 1996.

SPECIES	N	% COMP	CPUE (80%C.I)	2-YEAR MEAN	PSD	RSD	WR
WAE	121	60.20	20.2+-4.4	16.6	48	4	97
YEP	38	18.91	6.3+-2.3	6.5	72	52	108
NOP	11	5.47	1.8+-1.0	1.3	-	-	-
WHS	14	6.97	2.3+-2.1	0	-	-	-
COC	5	2.49	0.8+-0.6	0.9	-	-	-
EMS	4	1.99	0.7+-0.6	0.9	-	-	-
LKH	7	3.48	1.2+-1.7	3.7	-	-	-
WHB	1	0.50	0.2+-0.2	0	-	-	-

Table 2. Catch of fifteen 3/4 in. mesh frame net sets in Bluedog Lake, July 2-3, 1996.

SPECIES	N	% COMP	CPUE (80%C.I)	4-YEAR MEAN	PSD	RSD	WR
YEP	4	1.50	0.3+-0.2	1.1	-	-	-
NOP	78	29.32	5.6+-1.3	1.9	64	0	84
WAE	27	10.15	1.9+-0.9	2.6	100	93	-
COC	4	1.50	0.3+-0.2	0.3	-	-	-
WHS	86	32.33	6.1+-1.8	6.0	-	-	-
BLB	13	4.89	0.9+-0.4	0.0	-	-	-
BLC	19	7.14	1.4+-0.6	0.9	-	-	-
WHB	29	10.90	2.1+-0.7	0.2	96	15	98
RKB	5	1.88	0.4+-0.2	0.3	-	-	-
LKH	1	0.38	0.1+-0.1	0.1	-	-	-

Table 3. Average back-calculated lengths for each age class from walleye sampled in Bluedog Lake, 1996.

Year Class	Age	N	1	2	3	4	5	6	7
1995	1	18	147.60						
1994	2	62	147.97	249.81					
1993	3	5	127.65	250.83	332.88				
1992	4	10	137.88	226.74	299.14	355.56			
1991	5	33	155.49	226.18	295.16	361.76	409.87		
1990	6	4	157.15	261.64	324.41	374.58	432.90	475.18	
1989	7	4	143.65	206.03	303.89	371.83	412.45	460.85	496.85
All classes			148.40	240.20	301.95	362.34	412.37	468.01	496.85
N		136	136	18	56	51	41	8	4

Table 4. Stocking records for Bluedog Lake, Day County, 1985-1996.

SPECIES	SIZE	NUMBER	YEAR
BLC	ADT	10,776	1985
YEP	ADT	1,000	1985
YEP	FGL	27,000	1985
BLC	ADT	500	1985
RBT	CAT	12,550	1985
WAE	LFG	5,800	1990
BLC	ADT	1,605	1991
WAE	LFG	5,890	1991
WAE	SFG	6,750	1991
WAE	LFG	2,019	1992
WAE	FGL	4500	1995

RECOMMENDATIONS

(1) Emphasize management of walleye and northern pike.

(2) Encourage commercial removal of carp.

(3) Resurvey annually.

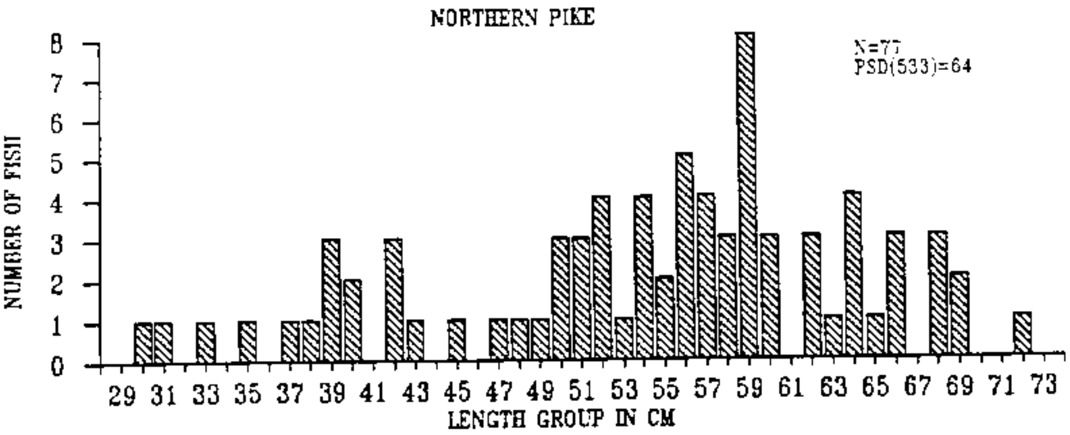


FIGURE1.
LENGTH FREQUENCY OF NORTHERN PIKE FROM 3/4 IN. FRAME NETS IN BLUEDOG LAKE, 1996.

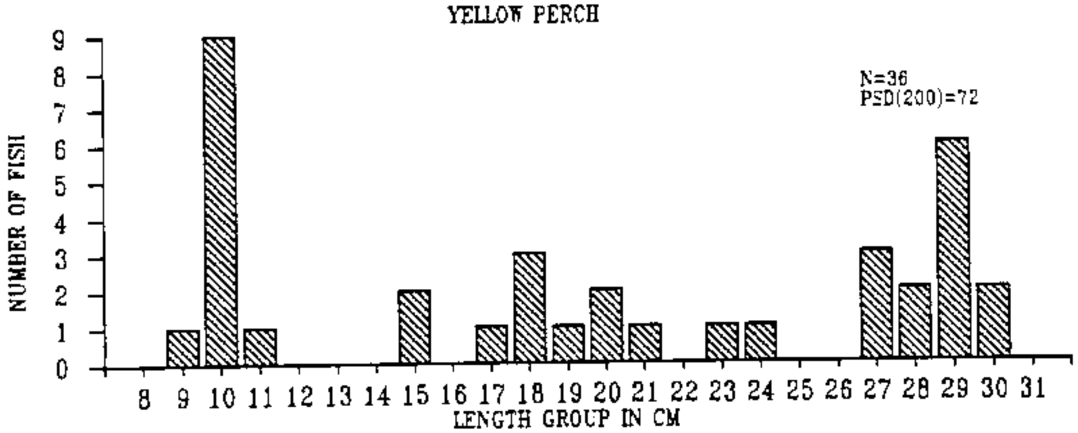


FIGURE 2.
LENGTH FREQUENCY OF YELLOW PERCH FROM 150 FT. GILL NETS IN BLUEDOG LAKE, 1996.

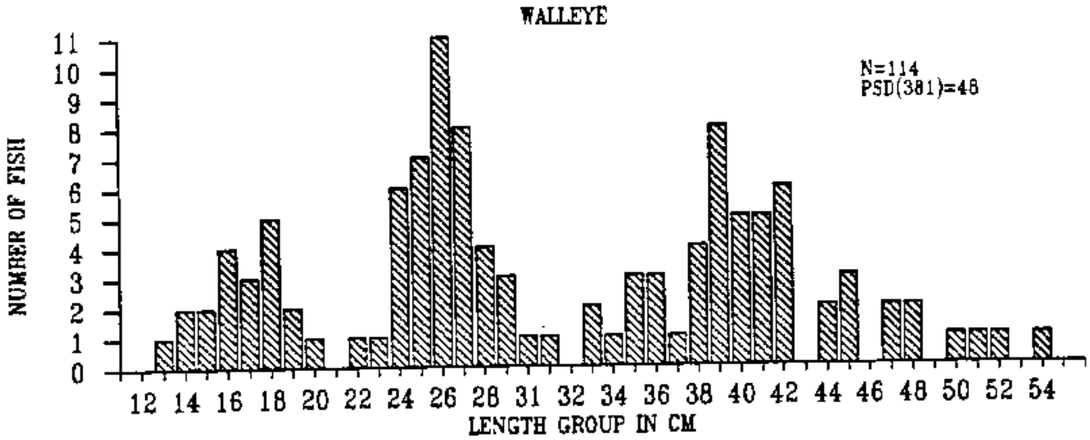


FIGURE 3.
LENGTH FREQUENCY OF WALLYE FROM 150 FT. GILL NETS IN BLUEDOG LAKE, 1996.

Figure 4. Shoreline seining for 1996 lake survey.

SHORELINE SEINING DATA

LAKE Bluedog Lake
COUNTY Day
DATE 8-30-96
CREW Braun, Mount

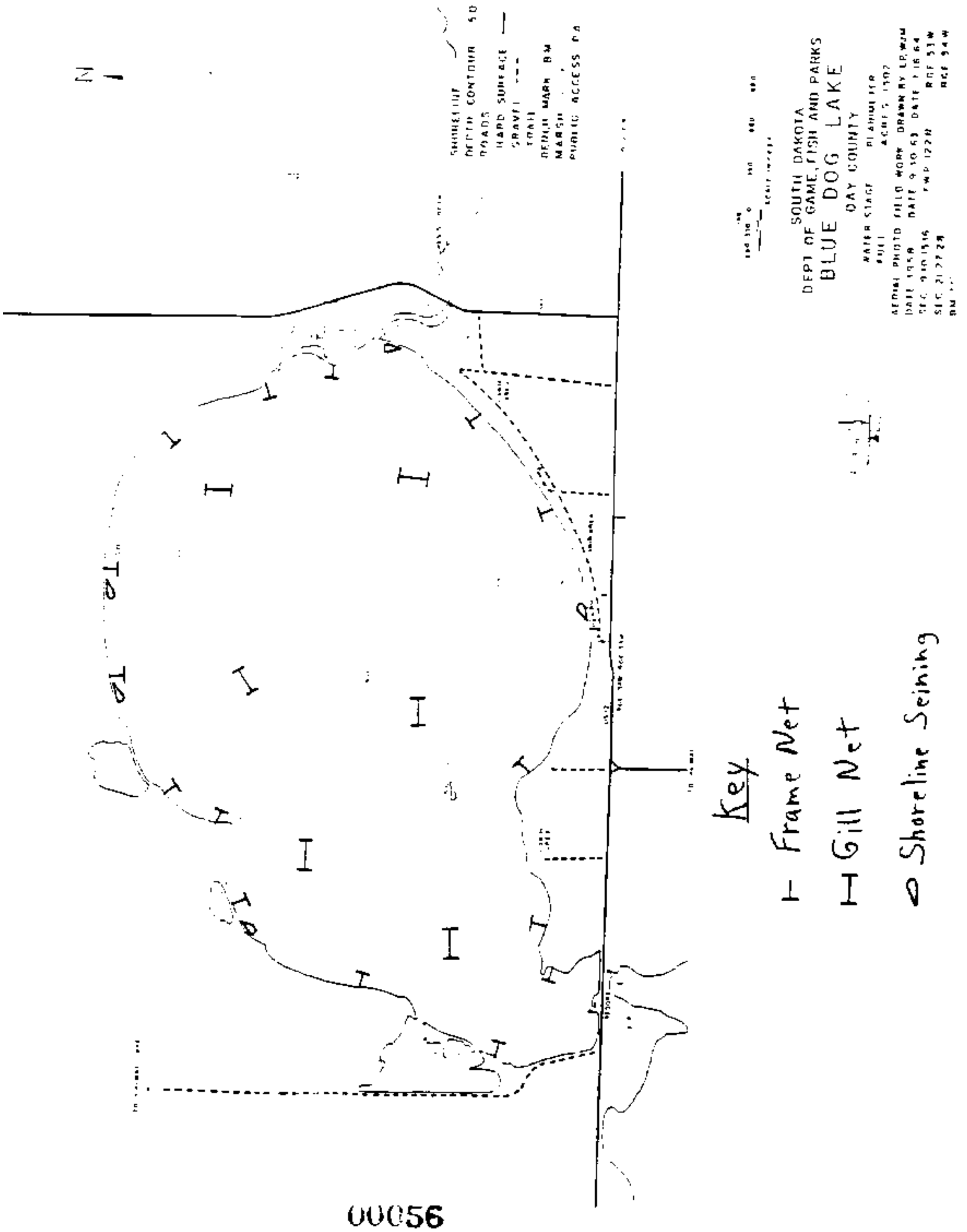
H20 TEMP 74°
CONDITIONS Light wind 80°
SEINE USED 1/4" 100ft.
PULL MADE 1/4 arc back Pull

SITE	1		2		3		4	
SPECIES	YOY	OTHER	YOY	OTHER	YOY	OTHER	YOY	OTHER
EMS	–	5	–	1	–	8	–	6
SPS	–	14	–	–	–	–	–	–
FHM	–	1	–	2	–	–	–	–
WHB	–	–	2	1	–	1	–	–
BLC	–	–	1	–	–	–	–	–
YEP	–	–	–	–	–	–	2	1
COC	–	–	–	–	–	–	–	4
NOP	–	–	–	–	–	–	1	–

SITE	5		6		7		8	
SPECIES	YOY	OTHER	YOY	OTHER	YOY	OTHER	YOY	OTHER
WAE	2	1						
EMS	–	2						
SPS	–	50						
YEP	2	1						
WHB	30	–						
BLC	1	–						

COMMENTS:

Figure 5. Approximate net locations during 1996 lake survey.

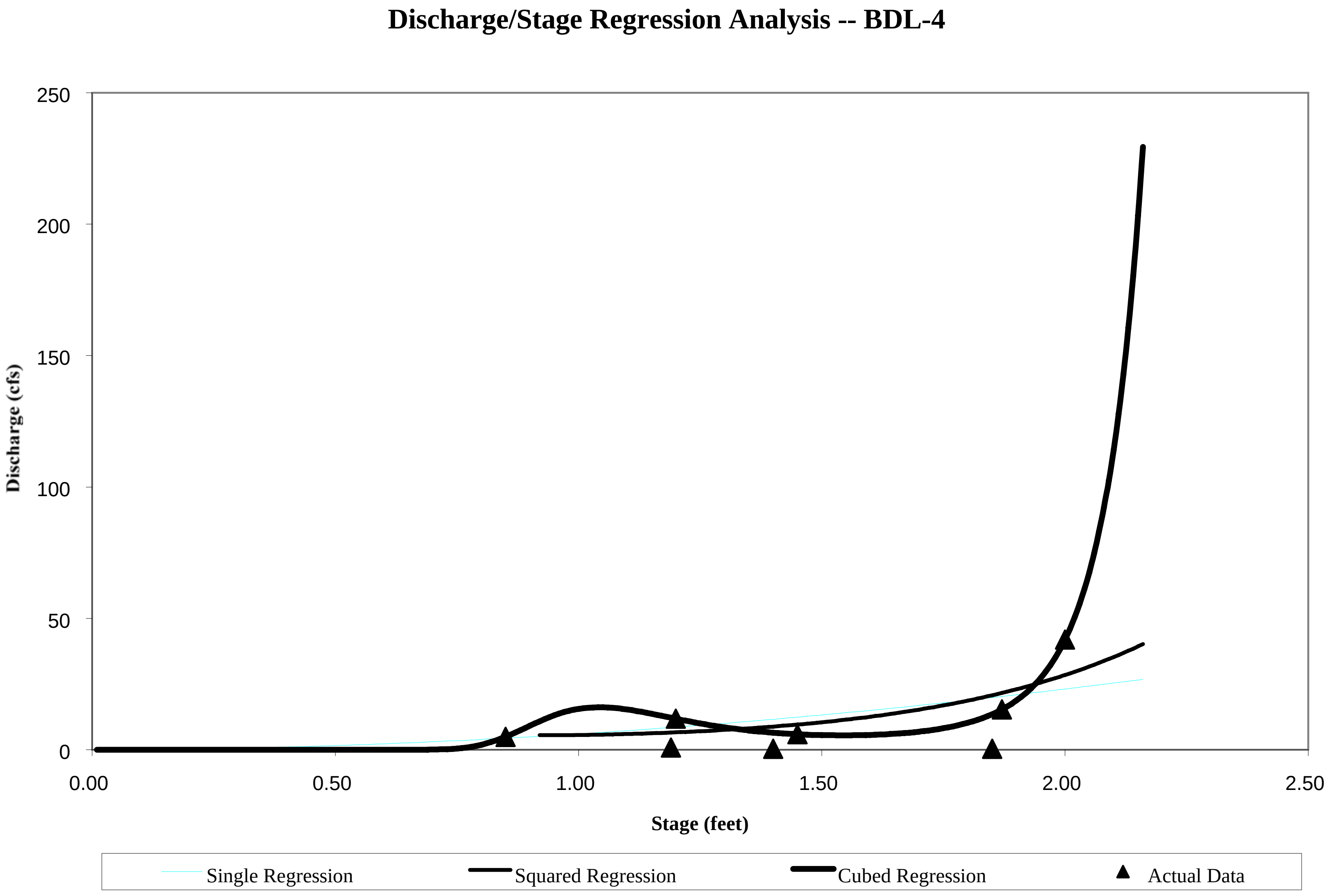


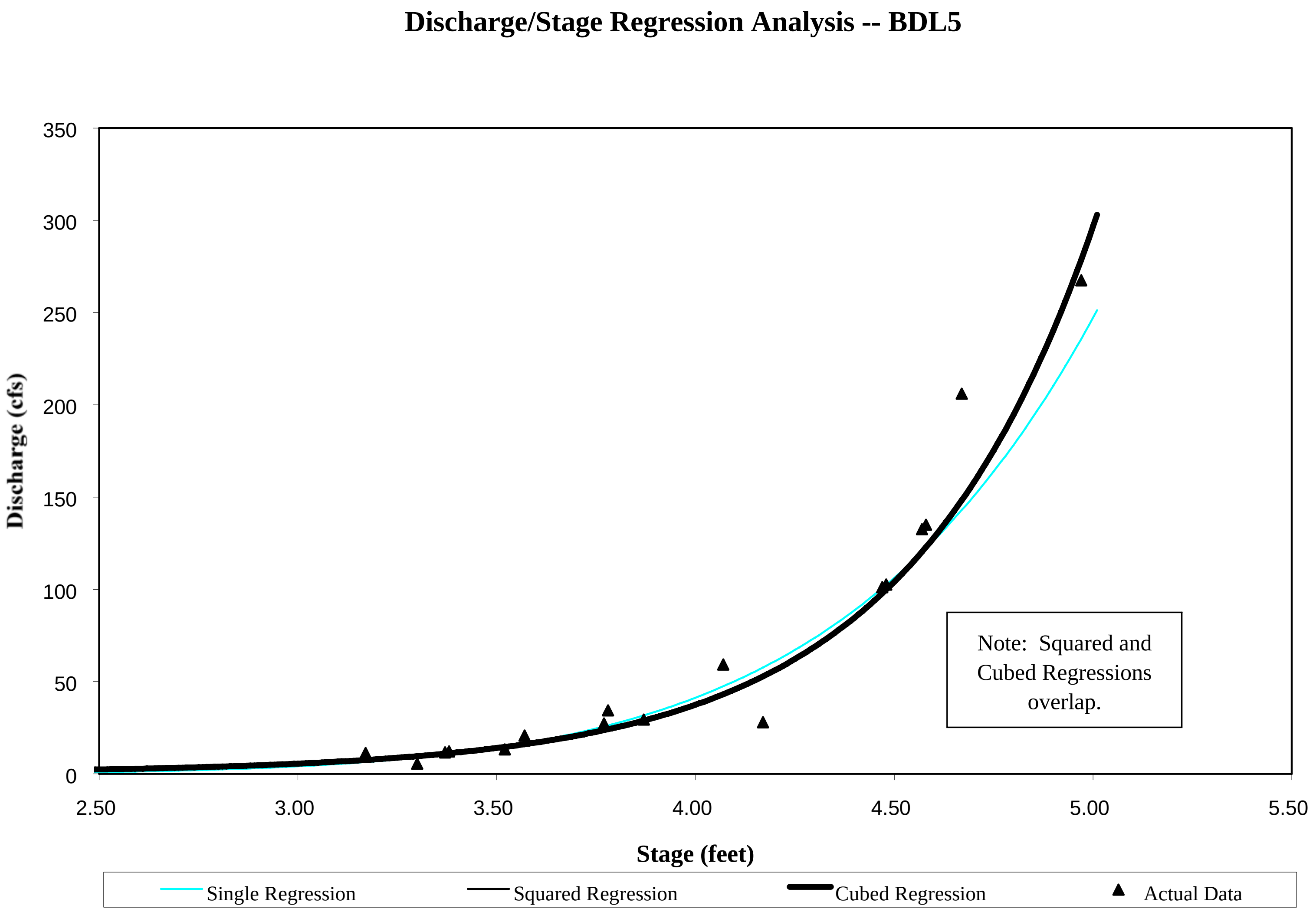
Appendix C

Blue Dog Lake Shoreline Erosion Pictures

Appendix D

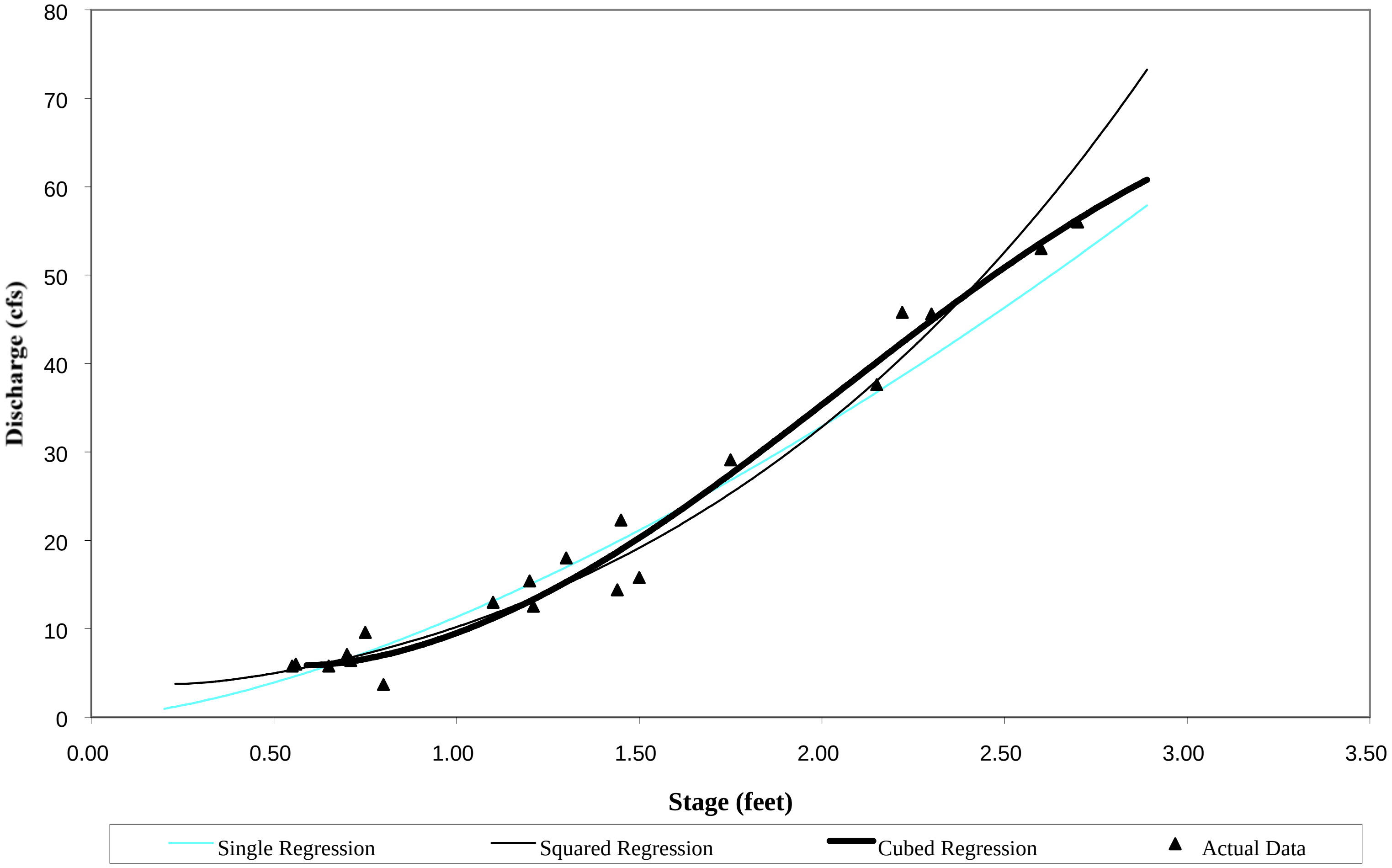
Stage Discharge Tables


Discharge/Stage Regression Analysis -- BDL-4
250
200
150
100
50
0
Discharge (cfs)
0.00
0.50
1.00
1.50
2.00
2.50
Stage (feet)
Single Regression
Squared Regression
Cubed Regression
Actual Data

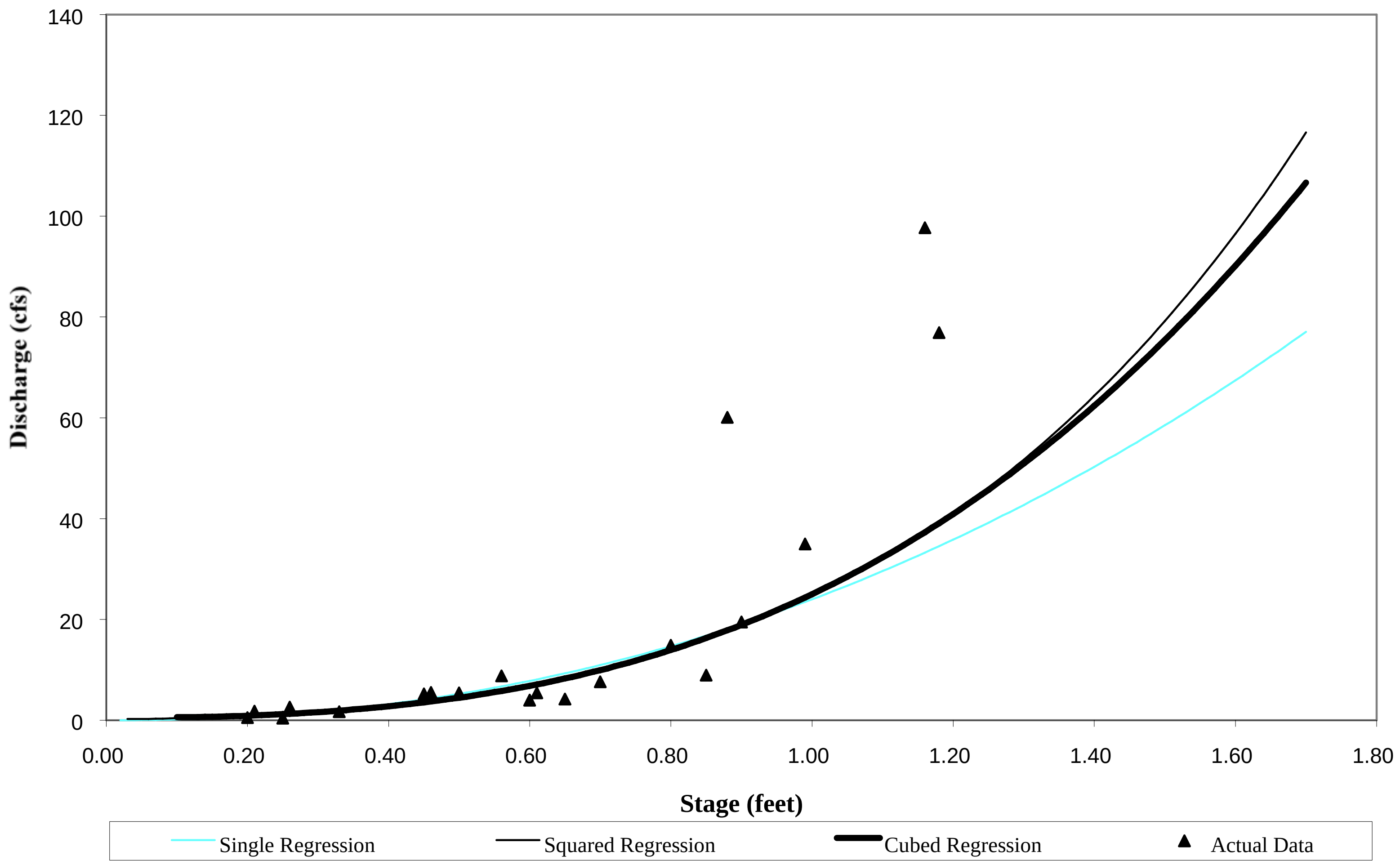


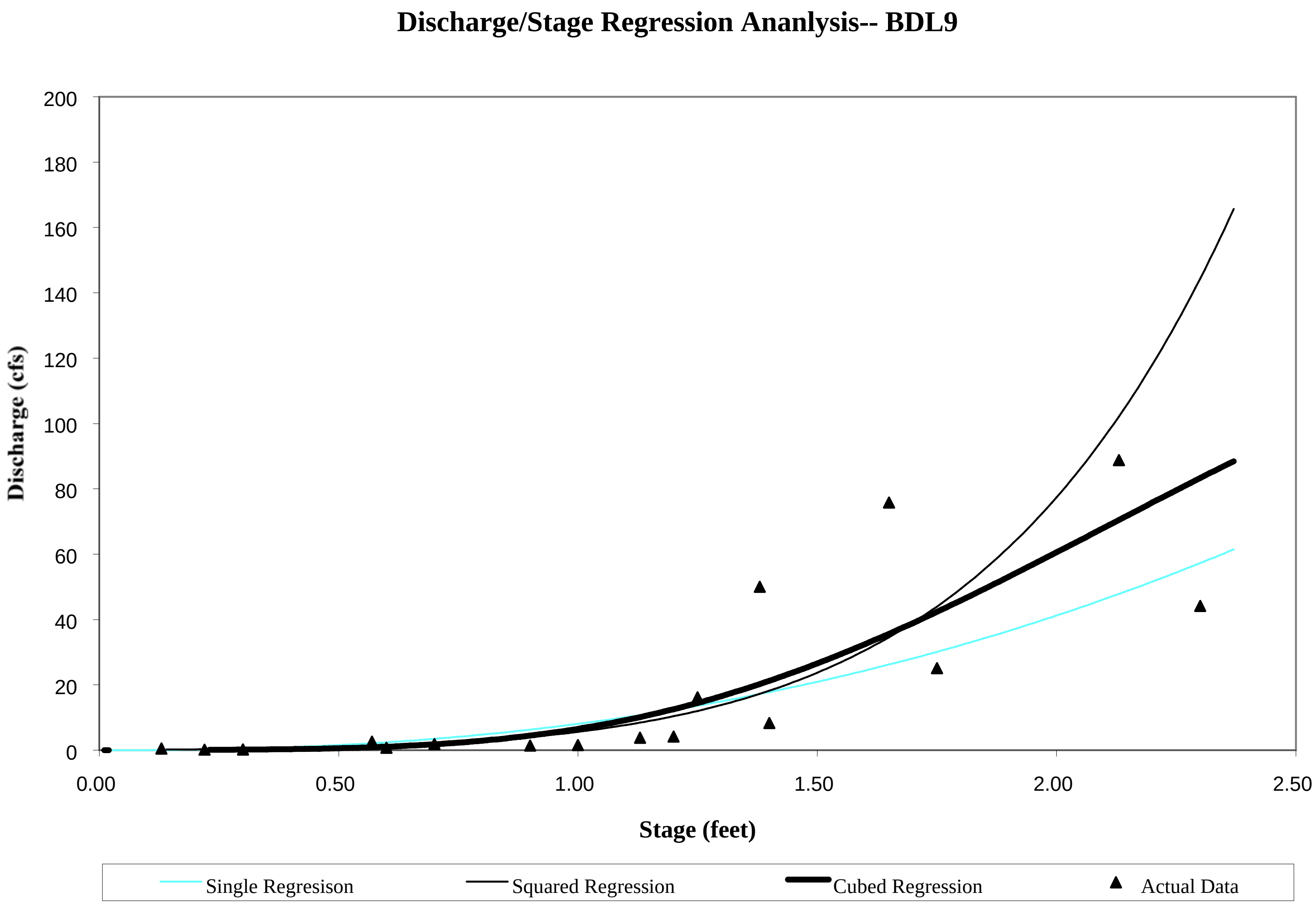
Discharge/Stage Regression Analysis -- BDL5

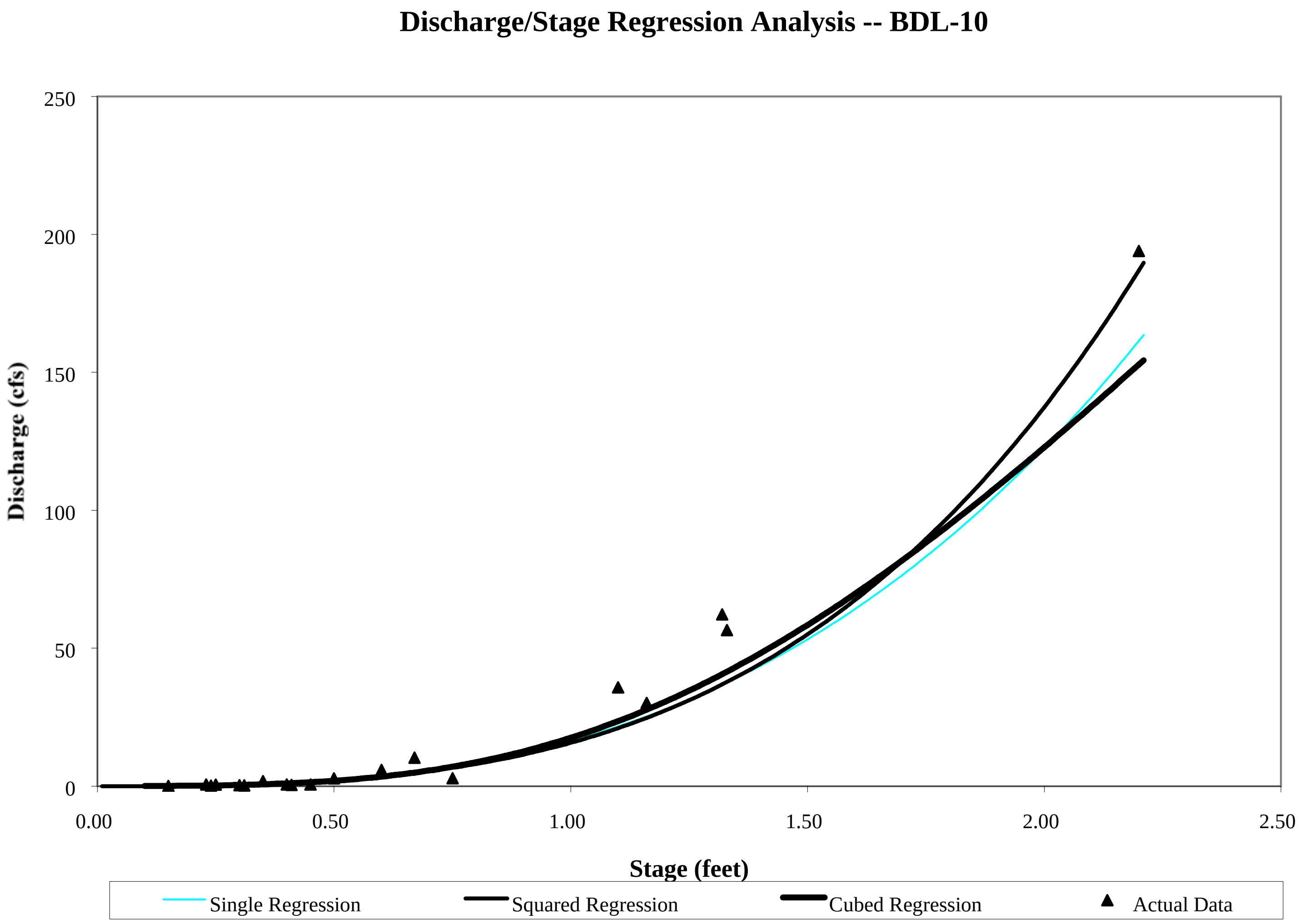
Discharge/Stage Regression Analysis-- BDL6



Discharge/Stage Regression Analysis- BDL7

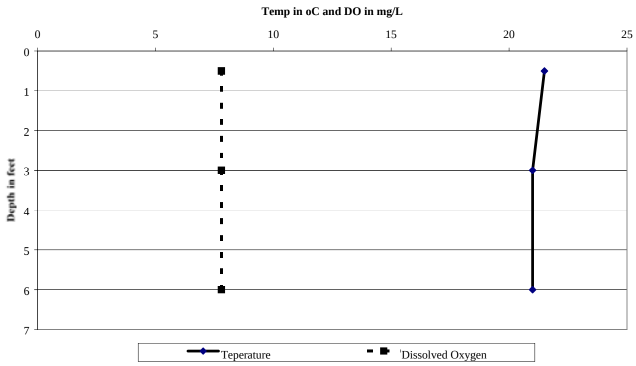



Discharge/Stage Regression Ananlysis-- BDL9
Discharge (cfs)
200
180
160
140
120
100
80
60
40
20
0
0.00
0.50
1.00
1.50
2.00
2.50
Stage (feet)
Single Regresison
Squared Regression
Cubed Regression
▲ Actual Data

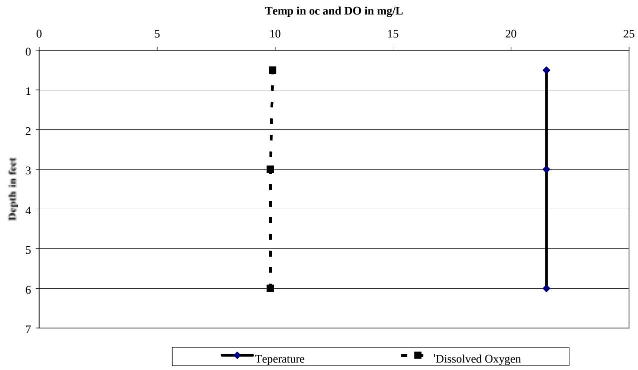

Discharge/Stage Regression Analysis -- BDL-10
Discharge (cfs)
250
200
150
100
50
0
0.00
0.50
1.00
1.50
2.00
2.50
Stage (feet)
Single Regression
Squared Regression
Cubed Regression
▲ Actual Data

Appendix E

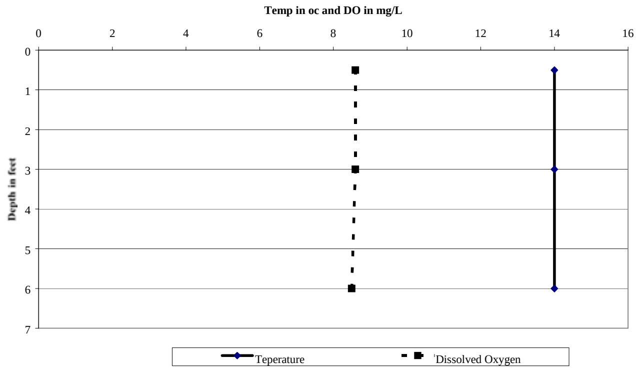
Blue Dog Lake Dissolved Oxygen Profiles



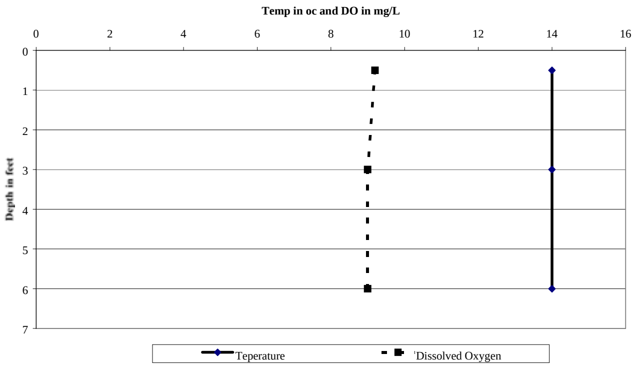
Dissolved Oxygen Profiles for Blue Dog Lake
August 27, 1996 -- Site BDL-1



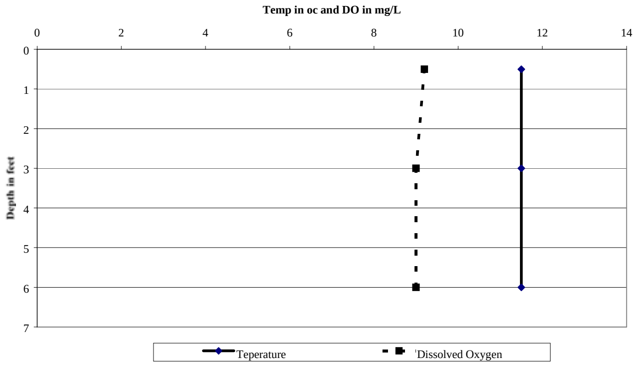
Dissolved Oxygen Profiles for Blue Dog Lake
August 27, 1996 -- Site BDL-2



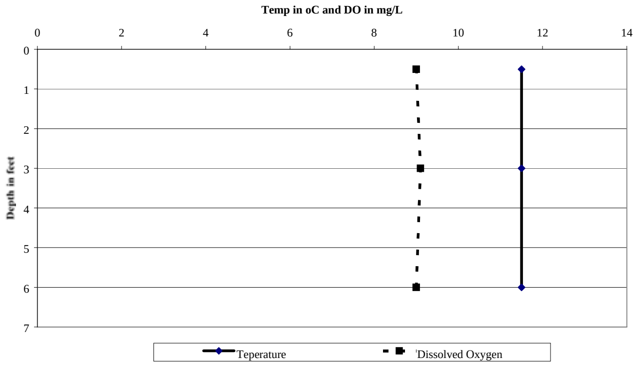
Dissolved Oxygen Profiles for Blue Dog Lake
September 23, 1996 -- Site BDL-1



Dissolved Oxygen Profiles for Blue Dog Lake
September 23, 1996 -- Site BDL-2

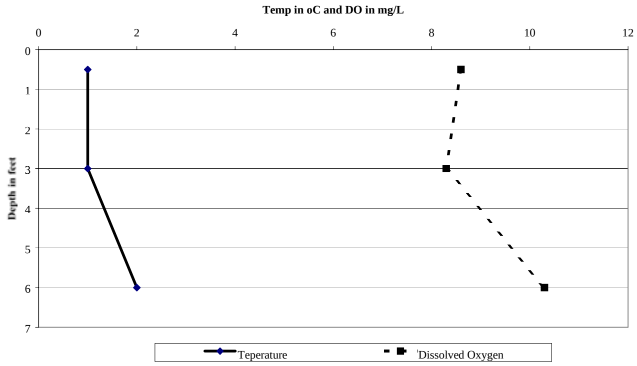


Dissolved Oxygen Profiles for Blue Dog Lake
October 16, 1996 -- Site BDL-1

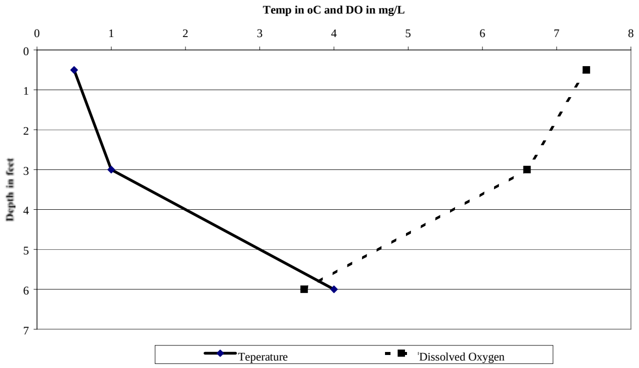


Dissolved Oxygen Profiles for Blue Dog Lake
October 16, 1996 -- Site BDL-2

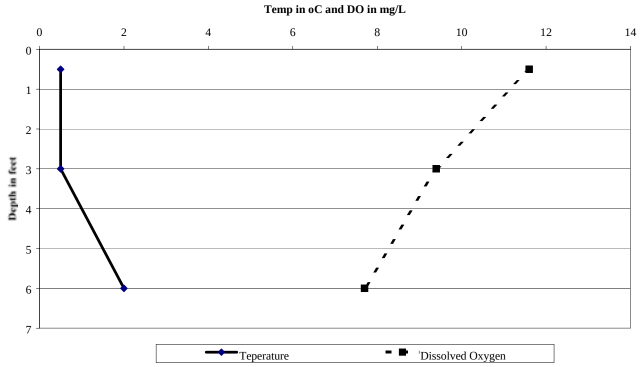
Dissolved Oxygen Profiles for Blue Dog Lake
February 20, 1997 -- Site BDL-1



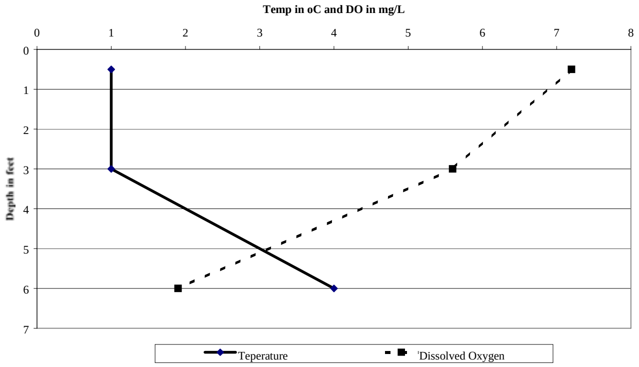
Dissolved Oxygen Profiles for Blue Dog Lake
February 20, 1997 -- Site BDL-2



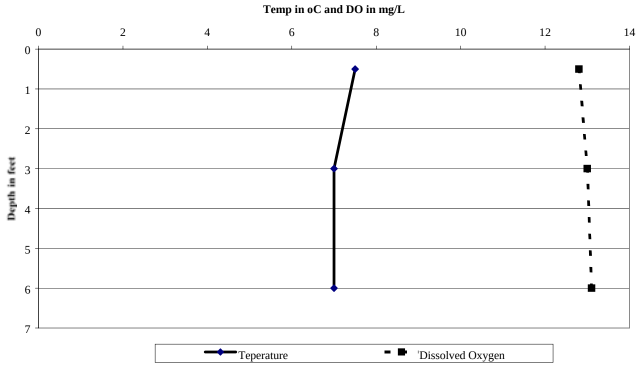
Dissolved Oxygen Profiles for Blue Dog Lake
March 26, 1997 -- Site BDL-1



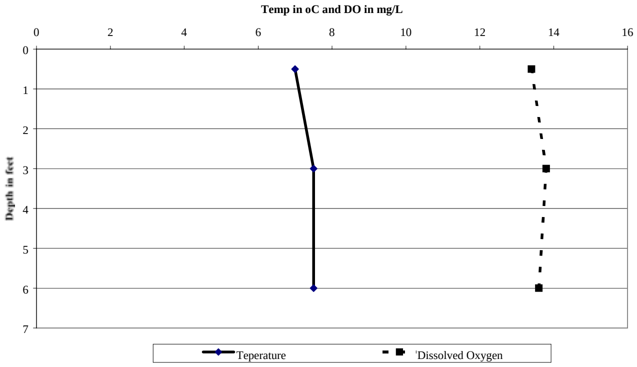
Dissolved Oxygen Profiles for Blue Dog Lake
March 27, 1997 -- Site BDL-2



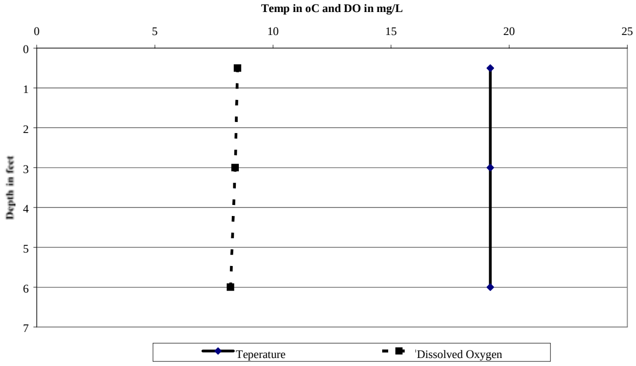
Dissolved Oxygen Profiles for Blue Dog Lake
April 29, 1997 -- Site BDL-1



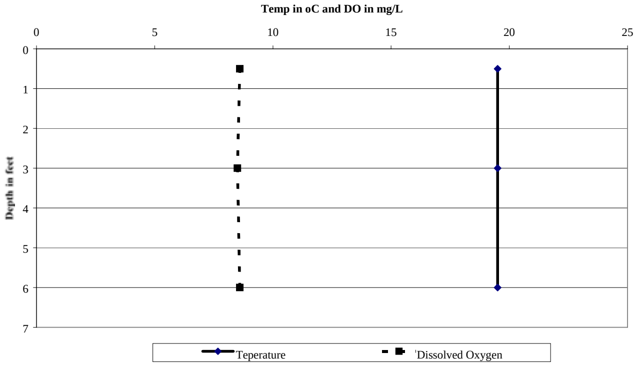
Dissolved Oxygen Profiles for Blue Dog Lake
April 29, 1997 -- Site BDL-2



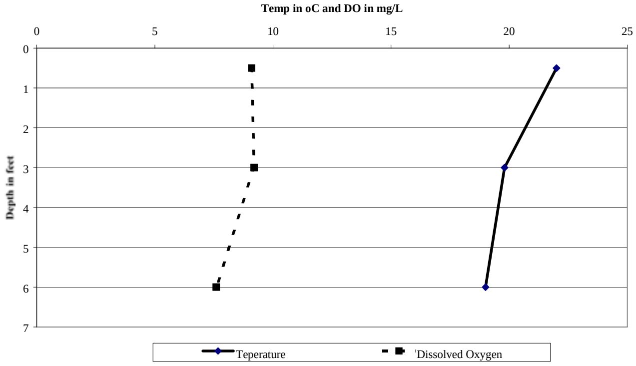
Dissolved Oxygen Profiles for Blue Dog Lake
June 5, 1997 -- Site BDL-1



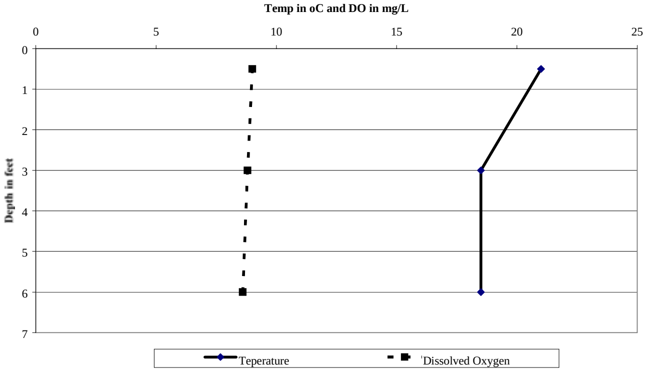
Dissolved Oxygen Profiles for Blue Dog Lake
June 5, 1997 -- Site BDL-2



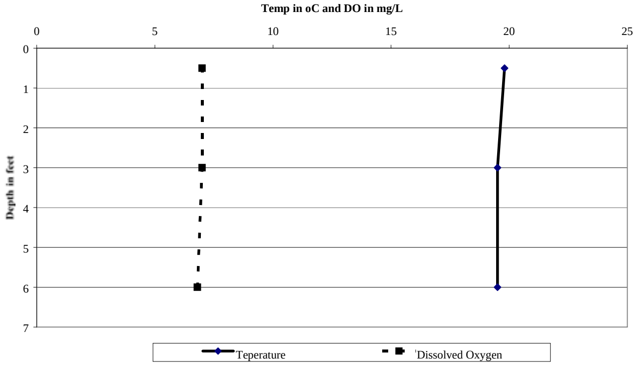
Dissolved Oxygen Profiles for Blue Dog Lake
July 8, 1997 -- Site BDL-1



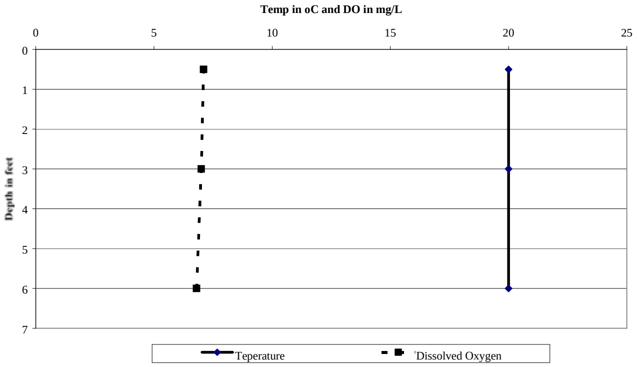
Dissolved Oxygen Profiles for Blue Dog Lake
July 8, 1997 -- Site BDL-2



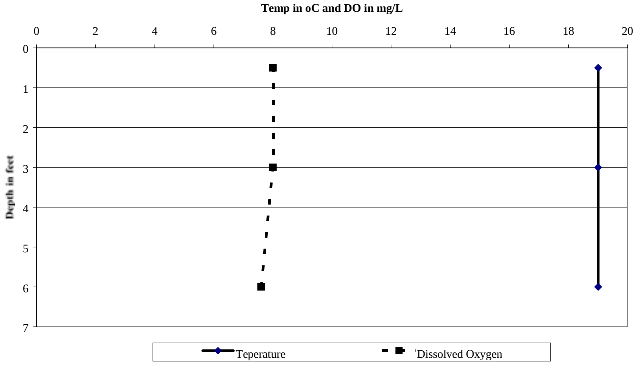
Dissolved Oxygen Profiles for Blue Dog Lake
August 13, 1997 -- Site BDL-1



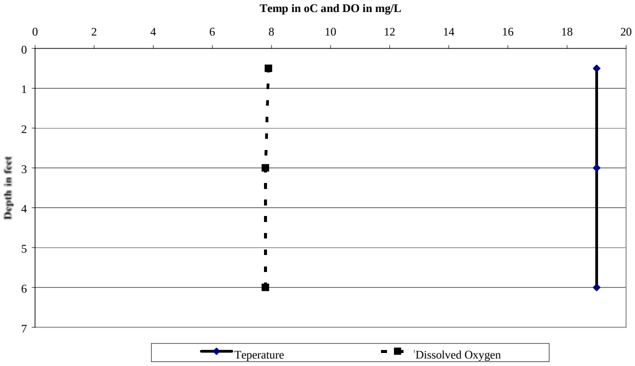
Dissolved Oxygen Profiles for Blue Dog Lake
August 13, 1997 -- Site BDL-2



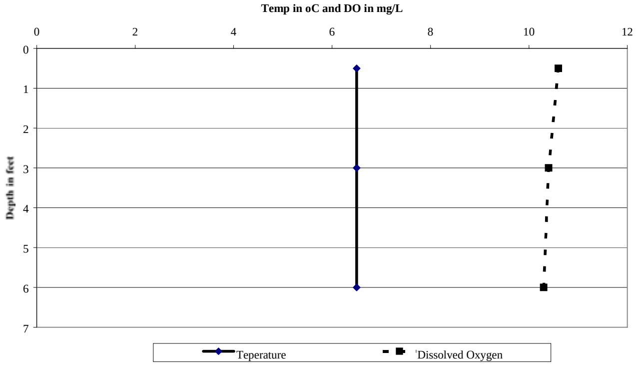
Dissolved Oxygen Profiles for Blue Dog Lake
September 17, 1997 -- Site BDL-1



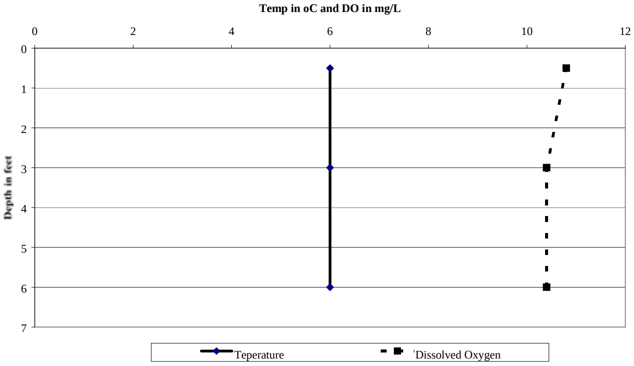
Dissolved Oxygen Profiles for Blue Dog Lake
September 17, 1997 -- Site BDL-2



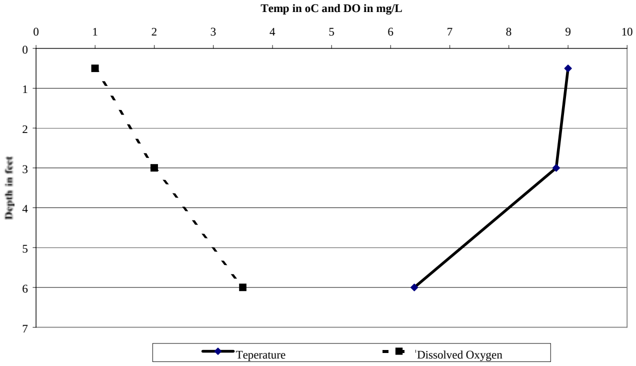
Dissolved Oxygen Profiles for Blue Dog Lake
October 22, 1997 -- Site BDL-1



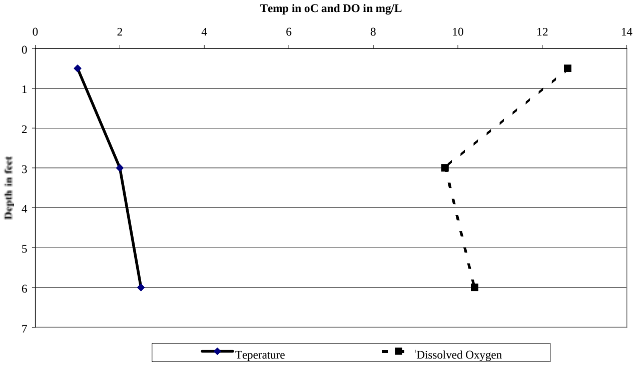
Dissolved Oxygen Profiles for Blue Dog Lake
October 22, 1997 -- Site BDL-2



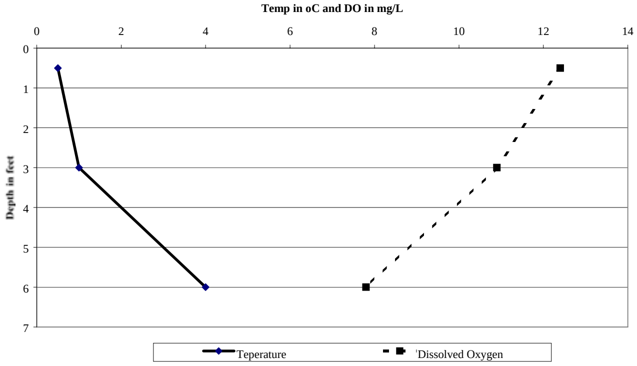
Dissolved Oxygen Profiles for Blue Dog Lake
February 23, 1998 -- Site BDL-1



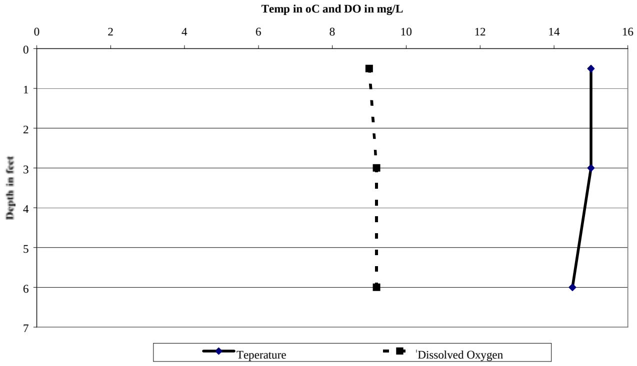
Dissolved Oxygen Profiles for Blue Dog Lake
March 5, 1998 -- Site BDL-1



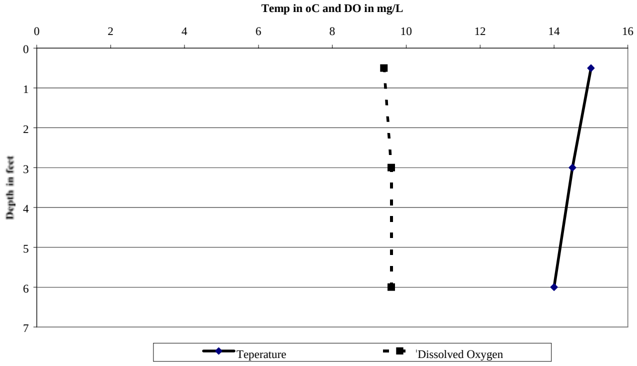
Dissolved Oxygen Profiles for Blue Dog Lake
March 5, 1998 -- Site BDL-2



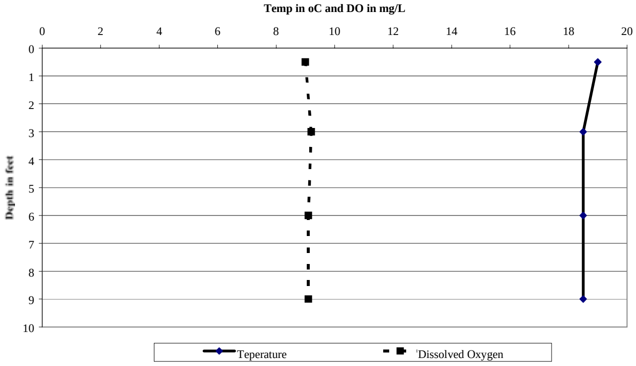
Dissolved Oxygen Profiles for Blue Dog Lake
April 29, 1998 -- Site BDL-1



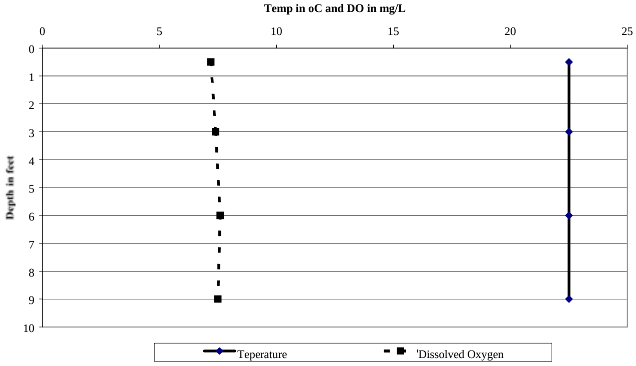
Dissolved Oxygen Profiles for Blue Dog Lake
April 29, 1998 -- Site BDL-2



Dissolved Oxygen Profiles for Blue Dog Lake
May 27, 1998 -- Site BDL-1



Dissolved Oxygen Profiles for Blue Dog Lake
July 30, 1998 -- Site BDL-1



Appendix F

Blue Dog Lake Phytoplankton Tables

Table 1 Biological Monitoring of Algae in Blue Dog Lake (1997)

Blue Dog Lake		27-Mar-97		29-Apr-97		05-Jun-97		08-Jul-97		13-Aug-97		17-Sep-97		22-Oct-97	
		BDL-1	BDL-2	BDL-1	BDL-2	BDL-1	BDL-2	BDL-1	BDL-2	BDL-1	BDL-2	BDL-1	BDL-2	BDL-1	BDL-2
Algae Type		cells/ml	cells/ml	cells/ml	cells/ml	cells/ml	cells/ml	cells/ml	cells/ml	cells/ml	cells/ml	cells/ml	cells/ml	cells/ml	cells/ml
Blue-Green Algae	Anabaena spp.	-	-	-	30	15	-	210	140	30	-	25	35	15	-
Blue-Green Algae	Aphanizomenon flos-aquae	-	-	-	-	368	-	2,070	1,470	1,022	40	1,209	1,319	292	6,494
Blue-Green Algae	Aphanocapsa spp.	-	-	-	-	-	50	270	160	17,938	38,540	44,075	246,000	10,370	9,600
Blue-Green Algae	Aphanothece spp.	-	-	-	-	-	-	150	90	-	-	-	-	-	-
Blue-Green Algae	Coelosphaerium spp.	-	-	-	-	-	-	-	-	-	-	-	70	-	-
Blue-Green Algae	Merismopedia spp.	-	-	-	-	-	-	60	-	-	237	-	-	-	-
Blue-Green Algae	Merismopedia tenuissima	-	-	-	-	-	-	-	-	-	-	547	200	80	140
Blue-Green Algae	Microcystis aeruginosa	-	-	-	-	-	-	-	-	30	-	474	560	-	-
Blue-Green Algae	Microcystis incerta	-	-	-	-	-	-	-	-	-	-	230	-	2,500	2,350
Blue-Green Algae	Oscillatoria spp.	-	-	-	40	-	-	-	-	-	-	-	35	-	130
Blue-Green Algae	**Total Blue-Green Algae**	**-**	**-**	**-**	**70**	**383**	**50**	**-**	**-**	**19,480**	**38,817**	**46,560**	**248,219**	**13,257**	**18,714**
Diatoms	Asterionella formosa	-	-	48	59	16	19	-	-	-	-	1	-	-	-
Diatoms	Cyclotella meneghiniana	-	-	-	-	-	-	-	-	-	-	-	-	10	15
Diatoms	Fragilaria crotonensis	-	-	-	-	25	-	180	120	-	-	-	-	-	-
Diatoms	Gyrosigma spp.	-	-	-	-	-	-	-	30						
Diatoms	Melosira granulata	-	-	12	-	-	11	650	1,170	28	4	127	153	24	42
Diatoms	Melosira granulata v. angustissima	-	-	-	-	-	-	-	-	66	85	17	4	46	39
Diatoms	Nitzschia holsatica	-	-	-	-	-	-	-	-	-	-	20	-	-	-
Diatoms	Nitzschia acicularis	-	-	30	17	1	3	10	60	5	3	25	17	1	3
Diatoms	Nitzschia spp.	-	-	30	15	-	-	-	-	8	10	15	26	30	20
Diatoms	Stephanodiscus spp.	-	-	-	-	-	-	30	90	-	-	-	-	-	-
Diatoms	Stephanodiscus hantzschii	-	-	15,670	19,500	110	60	-	-	90	65	160	120	1,080	1,495
Diatoms	Stephanodiscus niagarae	-	-	11	-	9	11	-	-	1	-	70	62	629	756
Diatoms	Surirella ovalis	-	-	-	-	-	-	-	-	-	-	-	-	1	1
Diatoms	Unidentified centric diatoms	-	-	-	-	-	-	60	100	-	-	-	-	-	-
Diatoms	Unidentified pennate diatoms	-	-	4	5	2	7	10	-	30	-	20	6	2	1
Diatoms	**Total Diatoms**	**-**	**-**	**15,805**	**19,596**	**163**	**111**	**940**	**1,570**	**228**	**167**	**455**	**388**	**1,823**	**2,372**
Flagellated Algae	Ceratium hirundinella	-	-	-	-	-	-	-	-	2	2	1	-	-	-
Flagellated Algae	Chlamydomonas spp.	10	350	540	560	-	30	840	720	40	55	85	135	80	80
Flagellated Algae	Chlamydomonas pseudopertyi	-	-	-	-	-	-	-	-	-	-	100	110	-	-
Flagellated Algae	Chroomonas spp.	10	-	1,160	1,000	350	270	-	-	235	313	320	230	920	1,250
Flagellated Algae	Chrysochromulina parva	-	-	110	80	650	450	-	-	1,435	1,230	3,792	410	270	80
Flagellated Algae	Cryptomonas spp.	2	3	630	760	65	64	90	110	80	117	140	120	160	115
Flagellated Algae	Dinobryon sertularia	-	-	470	420	-	-	50	60	-	-	1	-	-	1
Flagellated Algae	Eudorina spp.	-	-	20	50	-	-	-	-	-	-	-	-	8	-
Flagellated Algae	Euglena oxyuris	-	-	-	-	-	-	-	-	-	-	-	2	-	-
Flagellated Algae	Euglena tripteris	-	-	-	-	-	-	-	-	2	2	2	-	-	-
Flagellated Algae	Euglena spp.	-	-	3	1	-	-	-	-	1	2	6	10	-	2

Table 1 Biological Monitoring of Algae in Blue Dog Lake (1997) Continued

Blue Dog Lake		27-Mar-97		29-Apr-97		05-Jun-97		08-Jul-97		13-Aug-97		17-Sep-97		22-Oct-97	
		BDL-1	BDL-2	BDL-1	BDL-2	BDL-1	BDL-2	BDL-1	BDL-2	BDL-1	BDL-2	BDL-1	BDL-2	BDL-1	BDL-2
Algae Type		cells/ml	cells/ml	cells/ml	cells/ml	cells/ml	cells/ml	cells/ml	cells/ml	cells/ml	cells/ml	cells/ml	cells/ml	cells/ml	cells/ml
Flagellated Algae	Hymenomonas spp.	-	-	-	-	-	-	-	-	-	-	130	20	-	-
Flagellated Algae	Mallomonas acaroides	-	-	-	-	-	-	-	-	-	-	-	-	7	8
Flagellated Algae	Mallomonas akrokomos	-	-	10	-	-	-	-	-	-	-	-	-	-	-
Flagellated Algae	Mallomonas caudata	-	-	-	-	-	-	-	-	-	-	-	-	1	4
Flagellated Algae	Mallomonas pseudocoronata	-	-	-	-	-	-	-	-	-	-	-	-	2	1
Flagellated Algae	Mallomonas spp.	-	-	10	-	1	-	-	-	-	-	4	5	-	-
Flagellated Algae	Ochromonas spp.	-	-	-	40	20	30	-	-	-	-	-	-	-	-
Flagellated Algae	Pagastiella tetras	-	-	-	4	-	-	-	-	-	-	-	-	-	-
Flagellated Algae	Pandorina morum	-	-	-	-	-	-	-	-	6	8	78	122	36	45
Flagellated Algae	Pandorina unicocca	-	-	-	-	-	-	-	-	-	-	16	48	-	-
Flagellated Algae	Peridinium spp.	-	1	18	11	-	-	-	-	2	-	1	1	-	-
Flagellated Algae	Phacus spp.	-	-	-	-	-	-	-	-	-	3	3	10	1	-
Flagellated Algae	Spermatozoopsis spp.	-	-	20	-	-	-	-	-	-	-	-	-	-	-
Flagellated Algae	Synura uvella	-	-	23	15	-	-	-	-	-	-	-	-	-	-
Flagellated Algae	Trachelomonas spp.	-	-	5	4	-	-	-	-	20	25	10	15	-	-
Flagellated Algae	Uroglenopsis spp.	-	-	120	-	-	-	-	-	-	-	-	-	-	-
Flagellated Algae	Unidentified flagellates	290	200	4,370	4,240	4,280	3,390	250	100	7,030	4,975	4,620	2,868	721	641
Flagellated Algae	**Total Flagellates**	**312**	**556**	**7,509**	**7,185**	**5,366**	**4,234**	**1,230**	**990**	**8,853**	**6,732**	**9,309**	**4,286**	**2,206**	**2,227**
Non-Motile GreenAlga	Ankistrodesmus spp.	70	7	920	1,440	10	18	-	-	-	20	-	-	1	10
Non-Motile GreenAlga	Ankistrodesmus convolutus	-	-	-	-	-	-	80	120	-	-	-	-	-	-
Non-Motile GreenAlga	Binuclearia spp.	-	-	-	-	-	-	-	-	40	74	6	24	16	23
Non-Motile GreenAlga	Characium limneticum	-	-	-	-	-	-	-	-	120	120	60	39	60	40
Non-Motile GreenAlga	Chodatella (Lagerheimia) spp.	-	-	-	-	-	-	-	-	-	-	-	2	-	30
Non-Motile GreenAlga	Closteriopsis longissima	-	-	-	-	-	-	-	-	2	3	5	3	1	2
Non-Motile GreenAlga	Closterium aciculare	-	-	-	-	-	-	-	-	12	5	1	1	-	-
Non-Motile GreenAlga	Coelastrum spp.	-	-	-	-	-	-	-	-	-	-	-	-	-	12
Non-Motile GreenAlga	Cosmarium spp.	-	-	-	-	-	-	-	-	-	-	-	1	-	-
Non-Motile GreenAlga	Crucigenia quadrata	-	-	-	-	-	-	-	-	-	-	58	160	56	92
Non-Motile GreenAlga	Crucigenia spp	-	-	-	-	-	-	-	-	-	-	5	-	-	-
Non-Motile GreenAlga	Crucigenia tetrapedia	-	-	-	-	-	-	-	-	-	-	58	160	56	92
Non-Motile GreenAlga	Dictyosphaerium pulchellum	-	-	-	-	-	-	-	-	40	200	-	10	1,935	2,060
Non-Motile GreenAlga	Elakatothrix viridis	-	-	-	-	-	-	-	-	30	17	11	18	4	11
Non-Motile GreenAlga	Golenkinia radiata	-	-	-	-	-	-	-	-	-	-	2	-	-	-
Non-Motile GreenAlga	Micractinium pusillum	-	-	-	-	-	-	-	-	-	180	590	112	12	-
Non-Motile GreenAlga	Oocystis spp.	-	-	-	-	10	1	40	70	170	100	210	320	450	400
Non-Motile GreenAlga	Pediastrum boryanum	-	-	-	-	-	-	-	-	18	-	6	-	-	-
Non-Motile GreenAlga	Pediastrum duplex	-	1	-	-	-	-	-	-	36	18	60	131	63	58
Non-Motile GreenAlga	Pediastrum simplex	-	-	-	-	-	-	-	-	4	-	7	6	-	16
Non-Motile GreenAlga	Scenedesmus bijuga	-	-	-	-	-	-	-	40	-	-	-	-	-	-
Non-Motile GreenAlga	Scenedesmus quadricauda	-	-	-	-	-	-	20	50	-	-	-	-	-	-

Table 1 Biological Monitoring of Algae in Blue Dog Lake (1997) Continued

~~Blue Dog Lake~~		27-Mar-97		29-Apr-97		05-Jun-97		08-Jul-97		13-Aug-97		17-Sep-97		22-Oct-97	
		BDL-1	BDL-2	BDL-1	BDL-2	BDL-1	BDL-2	BDL-1	BDL-2	BDL-1	BDL-2	BDL-1	BDL-2	BDL-1	BDL-2
Algae Type		cells/ml	cells/ml	cells/ml	cells/ml	cells/ml	cells/ml	cells/ml	cells/ml	cells/ml	cells/ml	cells/ml	cells/ml	cells/ml	cells/ml
Non-Motile GreenAlga	Scenedesmus spp.	-	-	-	4	-	8	-	-	60	70	135	33	270	270
Non-Motile GreenAlga	Schroederia spp.	-	-	-	-	-	-	-	-	-	-	7	4	-	-
Non-Motile GreenAlga	Schroederia judayi	1	-	1	-	2	2	-	-	-	-	-	-	-	-
Non-Motile GreenAlga	Schroederia setigera	-	-	-	-	3	7	10	20	60	45	30	60	10	-
Non-Motile GreenAlga	Selenastrum minutum	-	-	-	-	-	-	-	-	20	40	-	-	40	50
Non-Motile GreenAlga	Sphaerocytis schroeteri	-	-	-	-	15	-	-	-	-	-	-	-	26	-
Non-Motile GreenAlga	Tetrastrum elegans	-	-	-	-	-	-	-	-	-	-	-	-	-	4
Non-Motile GreenAlga	Tetrastrum staurogeniaeforme	-	-	-	-	-	-	-	-	40	75	40	23	40	120
Non-Motile GreenAlga	Unidentified green algae	-	-	-	-	-	-	-	-	-	-	70	33	-	-
Non-Motile GreenAlga	**Total non-motile Green Algae**	**71**	**8**	**921**	**1,444**	**40**	**36**	**150**	**300**	**668**	**967**	**1,303**	**1,340**	**2,984**	**3,202**
Unidentified Misc. Algae		490	310	3,650	6,060	19,840	16,050	-	-	24,805	12,710	17,466	5,658	13,417	11,470
Total Algae		**873**	**874**	**27,885**	**34,355**	**25,792**	**20,481**	**5,080**	**4,720**	**54,034**	**59,393**	**75,093**	**259,891**	**33,687**	**37,985**

Table 2 Biological Monitoring of Algae in Blue Dog Lake (1998)

Blue Dog Lake		29-Apr-98		27-May-98	24-Jun-98	30-Jul-98
Algae Type		BDL-1 cells/ml	BDL-2 cells/ml	BDL-1 cells/ml	BDL-1 cells/ml	BDL-1 cells/ml
Blue-Green Algae	Anabaena flos-aquae	-	-	1,020	1,398	-
Blue-Green Algae	Anabaena spiroides	-	-	-	3,111	-
Blue-Green Algae	Aphanizomenon flos-aquae	-	-	2,750	222,800	17,890
Blue-Green Algae	Aphanocapsa spp.	-	-	500	72,000	22,000
Blue-Green Algae	Coelosphaerium naegelianum	-	-	-	53	-
Blue-Green Algae	Dactylococcopsis spp.	-	-	-	20	-
Blue-Green Algae	Merismopedia tenuissima	-	-	-	560	320
Blue-Green Algae	Microcystis aeruginosa	50	-	-	-	-
Blue-Green Algae	Microcystis spp.	-	-	-	1,720	910
Blue-Green Algae	Oscillatoria spp.	-	-	-	-	190
Blue-Green Algae	**Total Blue-Green Algae**	**50**	**-**	**4,270**	**301,662**	**41,310**
Diatoms	Asterionella formosa	198	330	68	8	-
Diatoms	Cyclotella meneghiniana	60	100	1	2	-
Diatoms	Cymbella spp.	1	-	-	-	-
Diatoms	Fragilaria crotonensis	16	-	371	-	-
Diatoms	Gomphonema spp.	-	4	-	-	-
Diatoms	Melosira granulata	6	6	48	2	12
Diatoms	Nitzschia acicularis	94	154	-	5	-
Diatoms	Nitzschia spp.	24	20	3	3	10
Diatoms	Stephanodiscus hantzschii	3,220	4,020	21	320	170
Diatoms	Stephanodiscus niagarae	25	36	98	4	3
Diatoms	Synedra acus	-	4	-	-	-
Diatoms	Synedra spp.	-	3	-	-	-
Diatoms	Synedra ulna	1	5	-	-	1
Diatoms	Unidentified pennate diatoms	1	3	-	-	12
Diatoms	**Total Diatoms**	**3,646**	**4,685**	**610**	**344**	**208**
Flagellated Algae	Ceratium hirundinella	-	-	5	-	-
Flagellated Algae	Chlamydomonas spp.	-	40	-	290	70
Flagellated Algae	Chroomonas spp.	800	1,060	160	330	540
Flagellated Algae	Chrysochromulina parva	120	140	50	820	50
Flagellated Algae	Chrysococcus amphora	40	80	-	-	-
Flagellated Algae	Cryptomonas spp.	74	93	8	4	98
Flagellated Algae	Dinobryon sertularia	8	12	1	24	-
Flagellated Algae	Euglena gracilis	-	-	-	19	3
Flagellated Algae	Euglena spp.	-	-	-	-	2

Table 2 Biological Monitoring of Algae in Blue Dog Lake (1998) Continued

Blue Dog Lake		29-Apr-98		27-May-98	24-Jun-98	30-Jul-98
Algae Type		BDL-1 cells/ml	BDL-2 cells/ml	BDL-1 cells/ml	BDL-1 cells/ml	BDL-1 cells/ml
Flagellated Algae	Mallomonas acaroides	-	4	-	-	-
Flagellated Algae	Mallomonas akrokomos	2	1	-	-	-
Flagellated Algae	Mallomonas producta	5	4	-	-	-
Flagellated Algae	Mallomonas pseudocoronata	2	-	-	1	-
Flagellated Algae	Mallomonas spp.	2	-	-	1	-
Flagellated Algae	Pandorina morum	-	-	41	-	-
Flagellated Algae	Phacotus lenticularis	-	-	-	-	20
Flagellated Algae	Strombomonas spp.	-	-	-	8	2
Flagellated Algae	Trachelomonas spp.	2	2	-	-	-
Flagellated Algae	Unidentified flagellates	3,480	5,420	720	1,090	310
Flagellated Algae	**Total Flagellates**	**4,535**	**6,856**	**985**	**2,587**	**1,095**
Non-Motile GreenAlgae	Ankistrodesmus spp.	20	60	-	-	4
Non-Motile GreenAlgae	Botryococcus braunii	-	-	-	15	-
Non-Motile GreenAlgae	Characium limneticum	10	19	7	40	60
Non-Motile GreenAlgae	Closteriopsis spp.	-	-	-	-	3
Non-Motile GreenAlgae	Closterium aciculare	-	-	1	-	-
Non-Motile GreenAlgae	Crucigenia tetrapedia	-	-	-	9	-
Non-Motile GreenAlgae	Elakatothrix viridis	-	-	-	8	-
Non-Motile GreenAlgae	Kirchneriella spp.	-	-	-	30	50
Non-Motile GreenAlgae	Oocystis spp.	5	4	22	170	250
Non-Motile GreenAlgae	Pediastrum duplex	-	-	-	-	36
Non-Motile GreenAlgae	Scenedesmus spp.	13	44	19	100	70
Non-Motile GreenAlgae	Schroederia spp.	-	-	-	-	6
Non-Motile GreenAlgae	Schroederia judayi	-	-	-	10	70
Non-Motile GreenAlgae	Schroederia setigera	-	2	-	-	-
Non-Motile GreenAlgae	Sphaerocytis schroeteri	-	-	-	-	28
Non-Motile GreenAlgae	Tetraedron mininum	-	-	1	-	-
Non-Motile GreenAlgae	Tetrastrum elegans	-	4	-	-	-
Non-Motile GreenAlgae	**Total non-motile Green Algae**	**50**	**138**	**50**	**542**	**747**
Unidentified Misc. Algae		10,520	11,980	1,940	49,500	23,410
Total Algae		**18,801**	**23,659**	**7,855**	**354,635**	**66,770**

Appendix G

Blue Dog Lake QA/QC Data

Field Duplicate Blanks

Site:	Time	Date:	Alkalinity-M mg/L	Solids, Total mg/L	Solids, Suspended mg/L	Ammonia mg/L	Nitrate mg/L	TKN mg/L	Total Phosphorus mg/L	Total Diss. Phosphorus mg/L	Fecal Coliform Counts/100ml	pH su	Tot. Volatile Susp. Solids mg/L
BDL 12	1250	9/3/96	3.00	3.0	2.0	0.06	0.10	0.10	0.007	0.007	<10	7.86	
BDL 12	1315	10/16/96	3.00	5.0	<1.0	0.05	<0.10	<0.10	<0.008	<0.008	<10	8.70	
BDL 12	1200	2/20/97	3.00	21.0	<1.0	0.06	0.10	<0.10	<0.002	0.002	<10	7.58	
BDL 12	1400	4/17/97	3.00	<22.34	<1.0	<0.02	<0.10	<0.10	<0.002	<0.002	<10	6.37	
BDL 12	1300	6/5/97	2.30	<22.0	<1.0	<0.02	<0.10	<0.10	<0.002	<0.002	<10	6.07	
BDL 12	1430	7/8/97	<31.42	<22.34	4.0	<0.02	<0.10	<0.10	0.006	0.003	<10	6.38	<1.0
BDL 12	1330	8/13/97	<31.42	3.0	1.0	<0.02	<0.10	<0.10	0.003	<0.002	<10	7.53	1.00
BDL 12	1000	9/16/97	<31.42	<22.34	<1.0	<0.02	0.10	<0.10	0.005	0.004	<10	7.01	<1.0
BDL 12	1230	9/17/97	<31.42	<22.34	<1.0	<0.02	<0.10	<0.10	<0.002	0.006	<10	6.69	<1.0
BDL 12	1020	9/24/97	3.00	<22.34	<1.0	<0.02	<0.10	<0.10	0.008	0.008	<10		
BDL 12	1030	9/30/97	3.00	<22.34	1.0	<0.02	0.10	<0.10	0.002	<0.002	<10	6.11	<1.0
BDL 12	1045	10/9/97	<31.42	7.0	1.0	<0.02	<0.10	<0.10	0.004	0.006	<10	6.35	<1.0
BDL 12	1600	10/13/97	2.00	1.0	1.0	<0.02	<0.10	<0.10	0.006	<0.002		6.47	<1.0
BDL 12	1135	10/22/97	<31.42	<22.34	1.0	<0.02	<0.10	<0.10	0.003	<0.002	<10	6.35	
BDL 12	1400	2/24/98	3.00	<22.34	<1.0	<0.02	<0.10	<0.10	<0.002	<0.002	<10	7.75	
BDL 12	1100	3/18/98	<31.42	3.0	<1.0	<0.02	<0.10	0.12	0.009	0.002	<10	6.52	
BDL 12	1300	4/21/98				0.03	0.10	<0.10	0.006	0.004	<10	7.01	
BDL 12	1215	4/29/98	0.19	2.0	<1.0	<0.02	<0.10	0.10	0.011	0.011	<10	7.15	
BDL 12	1330	5/5/98	0.43	4.0	<1.0	<0.02	<0.10	0.10	<0.002	0.004	<10	7.00	
BDL 12	1400	5/13/98	<0.17	17.0	0.0	<0.02	<0.10	0.34	0.006	<0.002	<10	7.85	
BDL 12		5/27/98	<0.17	2.0	4.0	<0.02	<0.10	<0.10	0.005	0.005	<10	8.01	
BDL 12	1300	6/22/98	<5.8	2.0	<1.0	<0.02	0.10	<0.10	<0.002	<0.002	<10	6.47	
BDL 12	1030	7/30/98	0.00	0.5	<1.0	<0.02	1.00	0.13	<0.002	<0.002	<10	7.47	

Field Duplicate Samples

Site:	Time	Date:	Depth:	Alkalinity-M mg/L	Total Solids mg/L	Susp. Solids mg/L	Ammonia mg/L	Nitrate mg/L	TKN mg/L	Total Phosphorus mg/L	Tot .Diss. Phosphorus mg/L	Fecal Coliform Counts/100ml	VTSS mg/L	BOD
BDL-11	1145	9/3/96	surface	308.0	419.0	17.0	0.61	0.10	2.32	0.502	0.251	930		
BDL-7	1145	9/3/96	surface	305.0	410.0	16.0	0.65	0.10	2.61	0.506	0.258	1000		
	Industrial Statistic			**0.5%**	**1.1%**	**3.0%**	**3.2%**	**0.0%**	**5.9%**	**0.4%**	**1.4%**	**3.6%**		
BDL-11	1105	10/16/96	surface	224.0	349.0	31.0	0.02	0.30	0.70	0.114	0.044	<10		
BDL-3	1105	10/16/96	surface	221.0	351.0	31.0	0.02	0.30	0.99	0.121	0.047	<10		
	Industrial Statistic			**0.7%**	**0.3%**	**0.0%**	**0.0%**	**0.0%**	**17.2%**	**3.0%**	**3.3%**	**0.0%**		
BDL-11	1040	2/20/97	surface	283.0	443.0	3.0	0.04	0.60	0.61	0.076	0.081	<10		
BDL-2	1040	2/20/97	surface	296.0	471.0	2.0	0.05	0.60	0.91	0.086	0.085	<10		
	Industrial Statistic			**2.2%**	**3.1%**	**20.0%**	**11.1%**	**0.0%**	**19.7%**	**6.2%**	**2.4%**	**0.0%**		
BDL-11	1300	4/17/97	surface	194.0	291.0	35.0	0.13	0.20	1.15	0.099	0.028	<10		
BDL-4A	1300	4/17/97	surface	195.0	291.0	37.0	0.12	0.20	1.18	0.091	0.027	20		
	Industrial Statistic			**0.3%**	**0.0%**	**2.8%**	**4.0%**	**0.0%**	**1.3%**	**4.2%**	**1.8%**	**33.0%**		
BDL-11	1045	5/27/97	surface	236.0	281.0	7.0	<0.02	0.10	0.75	0.038	0.017	20		
BDL-9	1045	5/27/97	surface	236.0	283.0	9.0	<0.02	0.10	0.68	0.037	0.019	10		
	Industrial Statistic			**0.0%**	**0.4%**	**12.5%**	**0.0%**	**0.0%**	**4.9%**	**1.3%**	**5.6%**	**33.3%**		
BDL-11	1430	7/8/97	surface	232.0	327.0	55.0	<0.02	<0.10	1.20	0.130	0.014	10	10.00	5.00
BDL-3	1430	7/8/97	surface	233.0	334.0	56.0	<0.02	<0.10	1.59	0.126	0.015	10	10.00	5.00
	Industrial Statistic			**0.2%**	**1.1%**	**0.9%**	**0.0%**	**0.0%**	**14.0%**	**1.6%**	**3.4%**	**0.0%**	**0.0%**	**0.0%**
BDL-11	1040	8/13/97	surface	206.0	313.0	18.0	<0.02	0.10	0.77	0.087	0.035	<10	6.00	
BDL-2	1040	8/13/97	surface	205.0	308.0	19.0	<0.02	0.10	0.74	0.088	0.033	<10	6.00	
	Industrial Statistic			**0.2%**	**0.8%**	**2.7%**	**0.0%**	**0.0%**	**2.0%**	**0.6%**	**2.9%**	**0.0%**	**0.0%**	
BDL-11	1430	9/15/97	surface	263.0	395.0	62.0	<0.02	0.70	0.48	0.185	0.076	3700	15.00	
BDL-6	1430	9/15/97	surface	268.0	401.0	64.0	<0.02	0.60	0.40	0.186	0.081	4200	14.00	
	Industrial Statistic			**0.94%**	**0.75%**	**1.59%**	**0.00%**	**7.69%**	**9.09%**	**0.27%**	**3.18%**	**6.33%**	**3.45%**	
BDL-11	1030	9/16/97	surface	256.0	335.0	2.0	<0.02	0.10	0.86	0.059	0.044	30	<1	
BDL-9	1030	9/16/97	surface	259.0	328.0	1.0	<0.02	0.10	0.78	0.067	0.043	310	1.00	
	Industrial Statistic			**0.58%**	**1.06%**	**33.33%**	**0.00%**	**0.00%**	**4.88%**	**6.35%**	**1.15%**	**82.35%**		
BDL-11	1015	9/17/97	surface	227.0	355.0	59.0	<0.02	0.10	0.80	0.124	0.048	360	11.00	
BDL-2	1015	9/17/97	surface	227.0	356.0	57.0	<0.02	0.10	0.60	0.124	0.040	360	9.00	
	Industrial Statistic			**0.0%**	**0.1%**	**1.7%**	**0.0%**	**0.0%**	**14.3%**	**0.0%**	**9.1%**	**0.0%**	**10.0%**	
BDL-11	950	9/24/97	surface	249.0	367.0	40.0	0.08	0.20	1.10	0.166	0.058	820		
BDL-4A	950	9/24/97	surface	244.0	361.0	44.0	0.09	0.20	0.98	0.169	0.051	930		
	Industrial Statistic			**1.0%**	**0.8%**	**4.8%**	**5.9%**	**0.0%**	**5.8%**	**0.9%**	**6.4%**	**6.3%**		

Field Duplicate Samples -page 2

Site:	Time	Date:	Depth:	Alkalinity-M mg/L	Solids, Total mg/L	Solids, Suspended mg/L	Ammonia mg/L	Nitrate mg/L	TKN mg/L	Total Phosphorus mg/L	Total Diss. Phosphorus mg/L	Fecal Coliform Counts/100ml	VTSS: mg/L	BOD
BDL-11	1010	9/30/97	surface	225.0	323.0	7.0	<0.02	6.00	0.32	0.024	0.017	100		
BDL-10	1010	9/30/97	surface	228.0	326.0	5.0	<0.02	6.00	0.38	0.025	0.016	40		
		Industrial Statistic		**0.7%**	**0.5%**	**16.7%**	**0.0%**	**0.0%**	**8.6%**	**2.0%**	**3.0%**	**42.9%**		
BDL-11	1130	10/8/97	surface	279.0	438.0	116.0	<0.02	0.50	1.19	0.262	0.068	2300	24.00	
BDL-6	1130	10/8/97	surface	277.0	446.0	162.0	<0.02	0.50	0.89	0.252	0.073	1700	36.00	
		Industrial Statistic		**0.4%**	**0.9%**	**16.5%**	**0.0%**	**0.0%**	**14.4%**	**1.9%**	**3.5%**	**15.0%**	**20.0%**	
BDL-11	1310	10/13/97	surface	244.0	353.0	10.0	<0.02	0.20	1.01	0.143	0.096		4.00	
BDL-5	1310	10/13/97	surface	242.0	353.0	11.0	<0.02	0.20	0.90	0.132	0.099		6.00	
		Industrial Statistic		**0.4%**	**0.0%**	**4.8%**	**0.0%**	**0.0%**	**5.8%**	**4.0%**	**1.5%**		**20.0%**	
BDL-11	910	10/22/97	surface	234.0	351.0	34.0	<0.02	0.20	0.51	0.115	0.054	<10		
BDL-2	910	10/22/97	Surface	233.0	343.0	36.0	<0.02	0.20	0.54	0.112	0.047	10		
		Industrial Statistic		**0.2%**	**1.2%**	**2.9%**	**0.0%**	**0.0%**	**2.9%**	**1.3%**	**6.9%**			
BDL-11	1315	2/24/98	surface	219.0	308.0	6.0	0.10	0.60	1.07	0.124	0.082	<10		
BDL-5	1315	2/24/98	surface	219.0	305.0	6.0	0.10	0.60	1.10	0.123	0.082	40		
		Industrial Statistic		**0.0%**	**0.5%**	**0.0%**	**0.0%**	**0.0%**	**1.4%**	**0.4%**	**0.0%**			
BDL-11	945	3/18/98	surface	204.0	262.0	<1	<0.02	0.10	0.68	0.015	0.006	<10		
ESL-2	945	3/18/99	surface	204.0	272.0	1.0	<0.02	0.10	0.71	0.011	0.006	<10		
		Industrial Statistic		**0.0%**	**1.9%**		**0.0%**	**0.0%**	**2.2%**	**15.4%**	**0.0%**			
BDL-11	1200	4/21/98	surface	188.0	270.0	20.0	<0.02	<0.10	0.79	0.045	0.012	<10		
BDL-4B	1200	4/21/98	surface	187.0	265.0	18.0	<0.02	<0.10	0.82	0.047	0.011	<10		
		Industrial Statistic		**0.3%**	**0.9%**	**5.3%**	**0.0%**	**0.0%**	**1.9%**	**2.2%**	**4.3%**			
BDL-11	1010	4/29/98	surface	202.0	295.0	13.0	<0.02	<0.10	0.63	0.040	0.019	<10		
BDL-2	1010	4/29/98	surface	201.0	293.0	8.0	<0.02	<0.10	0.59	0.045	0.021	<10		
		Industrial Statistic		**0.2%**	**0.3%**	**23.8%**	**0.0%**	**0.0%**	**3.3%**	**5.9%**	**5.0%**			
BDL-11	1145	5/5/98	surface	270.0	350.0	30.0	<0.02	0.20	0.75	0.080	0.024	<10		
BDL-5	1145	5/5/98	surface	268.00	343.00	16.00	<0.02	0.20	0.70	0.090	0.023	20		
		Industrial Statistic		**0.4%**	**1.0%**	**30.4%**	**0.0%**	**0.0%**	**3.4%**	**5.9%**	**2.1%**			
BDL-11	1210	5/13/98	surface	188.0	297.0	24.0	<0.02	<0.10	1.06	0.069	0.014	30		
BDL-4A	1210	5/13/98	surface	191.0	306.0	25.0	<0.02	<0.10	1.01	0.062	0.008	20		
		Industrial Statistic		**0.8%**	**1.5%**	**2.0%**	**0.0%**	**0.0%**	**2.4%**	**5.3%**	**27.3%**	**20.0%**		
BDL-11	1030	5/27/98	surface	213.0	309.0	14.0	<0.02	<0.10	1.01	0.043	0.014	10		
BDL-1	1100	5/27/98	Surface	214.0	312.0	11.0	0.02	0.10	0.71	0.038	0.016	10		
		Industrial Statistic		**0.2%**	**0.5%**	**12.0%**	**0.0%**	**0.0%**	**17.4%**	**6.2%**	**6.7%**	**0.0%**		

Field Duplicate Samples -page 3

Site:	Time	Date:	Depth:	Alkalinity-M mg/L	Solids, Total mg/L	Solids, Suspended mg/L	Ammonia mg/L	Nitrate mg/L	TKN mg/L	Total Phosphorus mg/L	Total Diss. Phosphorus mg/L	Fecal Coliform Counts/100ml	VTSS: mg/L	BOD
BDL-11	945	6/22/98	surface	203.0	294.0	23.0	<0.02	0.10	1.24	0.074	0.029	70		
BDL-4A	945	6/22/98	surface	206.0	295.0	22.0	<0.02	0.10	1.32	0.078	0.018	90		
	Industrial Statistic			**0.7%**	**0.2%**	**2.2%**	**0.0%**	**0.0%**	**3.1%**	**2.6%**	**23.4%**	**12.5%**		
BDL-11	1000	7/30/98	surface	242.00	354.00	23.00	<0.02	0.10	1.12	0.071	0.024	<10		
BDL-1	1000	7/30/98	Surface	235.0	355.0	24.0	<0.02	0.10	1.00	0.075	0.033	<10		
	Industrial Statistic			**1.5%**	**0.1%**	**2.1%**	**0.0%**	**0.0%**	**5.7%**	**2.7%**	**15.8%**			

Appendix H

Blue Dog Lake Tributary Data

Site	Time	Date	pH	Water Temp	DO	Fecal Coliform	Alkalinity-M	Total Solids	Suspended Solids	VTSS
			su	°C	mg/L	Counts/100ml	mg/L	mg/L	mg/L	mg/L
BDL-10	1320	8/14/96	8.55	20.0	9.40	60	240.0	341.0	4.0	
BDL-4B	1130	8/14/96	8.58	20.0	7.60	360	214.0	334.0	46.0	
BDL-5	1645	8/14/96	8.72	24.0	13.80	280	253.0	370.0	28.0	
BDL-6	1600	8/14/96	8.32	21.0	10.20	1,800	264.0	359.0	9.0	
BDL-7	1415	8/14/96	7.62	23.0	3.60	550	256.0	364.0	9.0	
BDL-8	1500	8/14/96	8.03	18.4	7.80	10	259.0	363.0	10.0	
BDL-10	1250	9/3/96	7.86	21.6	7.50	40	256.0	346.0	7.0	
BDL-7	1145	9/3/96	7.73	24.0	3.20	1,000	305.0	410.0	16.0	
BDL-4B	1150	9/4/96	8.12	26.8	6.00	1,400	217.0	331.0	26.0	
BDL-5	1115	9/4/96	8.17	22.8	9.20	880	257.0	370.0	24.0	
BDL-6	1020	9/4/96	8.06	18.2	8.80	5,600	275.0	375.0	23.0	
BDL-8	925	9/4/96	7.95	15.6	7.40	80	262.0	358.0	40.0	
BDL-10	950	9/24/96	8.05	8.5	8.20	30	272.0	360.0	7.0	
BDL-4B	1305	9/24/96	8.11	17.8	9.60	780	226.0	340.0	22.0	
BDL-5	1215	9/24/96	8.12	12.4	9.70	320	274.0	397.0	25.0	
BDL-6	1120	9/24/96	8.02	10.5	10.60	390	274.0	378.0	16.0	
BDL-7	850	9/24/96	7.83	8.5	6.60	2,500	276.0	402.0	7.0	
BDL-8	1040	9/24/96	7.78	9.2	9.40	10	259.0	346.0	6.0	
BDL-9	1430	10/18/96	8.12	3.0	11.60		223.0	328.0	5.0	
BDL-10	1015	10/23/96	8.27	2.6	12.60	220	267.0	390.0	11.0	
BDL-4A	1430	10/23/96	8.86	13.6	12.40	20	232.0	342.0	20.0	
BDL-5	1355	10/23/96	7.87	6.0	11.40	90	262.0	412.0	15.0	
BDL-6	1250	10/23/96	8.02	5.9	11.80	460	261.0	386.0	31.0	
BDL-7	1100	10/23/96	8.06	2.9	10.80	820	266.0	389.0	13.0	
BDL-8	1400	10/23/96	8.01	5.5	10.40	10	249.0	341.0	6.0	
BDL-10	1030	10/30/96	8.04	1.0	12.20	360	258.0	398.0	10.0	
BDL-5	1430	10/30/96	7.94	1.0	11.80	10,000	213.0	401.0	15.0	
BDL-6	1020	10/30/96	8.12	1.0	12.00	42,000	211.0	340.0	15.0	
BDL-7	1055	10/30/96	7.98	0.0	10.30	830	204.0	325.0	30.0	
BDL-8	1145	10/30/96	8.02	1.5	11.60	70	230.0	317.0	6.0	
BDL-9	945	10/30/96	8.06	0.0	13.40	1,700	199.0	301.0	4.0	
BDL-6	1430	3/27/97	7.82	2.0	10.30	370	224.0	348.0	67.0	
BDL-5	1045	3/31/97	7.74	0.5	5.20	150	206.0	297.0	8.0	
BDL-6	1200	4/1/97	7.88	11.0	10.20	30	149.0	242.0	47.0	
BDL-10	1540	4/2/97	8.08	0.0	11.80	10	64.0	101.0	13.0	
BDL-9	1450	4/2/97	8.01	0.0	11.20	<10	62.0	89.0	4.0	
BDL-5	1410	4/3/97	7.68	1.0	9.10	<10	124.0	181.0	21.0	
BDL-6	1130	4/3/97	7.97	0.5	10.20	<10	115.0	163.0	20.0	
BDL-7	1015	4/3/97	7.93	0.5	9.80	<10	86.0	166.0	65.0	
BDL-10	1040	4/5/97	7.66	1.0	11.50		69.0	145.0	49.0	
BDL-7	1130	4/5/97	7.81	1.0	10.90		88.0	144.0	22.0	
BDL-9	1015	4/5/97	7.58	1.0	11.40		66.0	100.0	4.0	
BDL-4A		4/15/97	8.09	0.0	10.80	<10	148.0	248.0	44.0	
BDL-5	1345	4/15/97	7.89	1.0	6.80	<10	198.0	280.0	13.0	
BDL-7	1440	4/15/97	7.84	2.0	8.60	<10	163.0	230.0	10.0	
BDL-10	1220	4/16/97	7.63	1.5	7.80	<10	171.0	235.0	4.0	
BDL-6	1110	4/16/97	7.86	0.3	8.00	10	174.0	234.0	2.0	
BDL-4A	1300	4/17/97	8.02	8.0	9.20	20	195.0	291.0	37.0	
BDL-9	1040	4/17/97	7.72	2.5	9.40	<10	160.0	213.0	8.0	
BDL-10	1215	5/5/97	8.47	12.5	14.40	10	249.0	318.0	6.0	
BDL-7	1330	5/5/97	8.43	13.5	13.50	<10	227.0	286.0	10.0	
BDL-8	1415	5/5/97	8.22	13.2	11.60	80	270.0	264.0	5.0	
BDL-9	1120	5/5/97	8.33	12.0	10.60	<10	197.0	253.0	8.0	

Site	Time	Date	pH	Water Temp	DO	Fecal Coliform	Alkalinity-M	Total Solids	Suspended Solids	VTSS
			su	°C	mg/L	Counts/100ml	mg/L	mg/L	mg/L	mg/L
BDL-5	1415	5/7/97	8.17	13.0	8.10	20	240.0	308.0	8.0	
BDL-6	1330	5/7/97	8.07	11.5	9.40	<10	228.0	889.0	5.0	
BDL-10	1000	5/27/97	8.26	10.0	11.70	110	274.0	332.0	7.0	
BDL-5	1420	5/27/97	8.25	12.2	11.40	50	262.0	326.0	26.0	
BDL-6	1330	5/27/97	8.09	11.0	9.90	1,400	258.0	359.0	68.0	
BDL-7	1245	5/27/97	8.24	12.2	11.80	20	269.0	287.0	6.0	
BDL-8	1200	5/27/97	8.03	10.2	10.10	30	246.0	304.0	13.0	
BDL-9	1045	5/27/97	8.16	11.0	10.40	10	236.0	283.0	9.0	
BDL-4A	1230	6/10/97	8.63	23.0	8.90	80	198.0	288.0	35.0	
BDL-4B	1315	6/10/97	8.68	22.5	10.20	20	207.0	281.0	14.0	
BDL-10	1030	6/17/97	7.92	14.8	9.80	1,400	209.0	305.0	5.0	
BDL-5		6/17/97	8.19	23.0	8.60	320	269.0	361.0	34.0	
BDL-6		6/17/97	8.07	19.3	8.30	1,200	279.0	391.0	78.0	
BDL-7	1230	6/17/97	7.95	23.0	7.10	540	244.0	305.0	13.0	
BDL-8	1145	6/17/97	7.91	15.5	8.40	150	259.0	336.0	22.0	
BDL-9	1115	6/17/97	7.84	16.0	10.40	100	271.0	328.0	4.0	
BDL-10	845	7/16/97	7.76	18.2	6.80	280	209.0	312.0	3.0	
BDL-4A	1240	7/16/97	8.52	29.0	10.20	310	206.0	302.0	20.0	
BDL-4B	1310	7/16/97	8.65	28.8	10.80	100	213.0	292.0	10.0	
BDL-4C	1400	7/16/97	7.91	29.0	5.30	190	218.0	303.0	4.0	
BDL-5	1110	7/16/97	8.14	25.2	7.30	530	270.0	388.0	39.0	
BDL-6	1030	7/16/97	8.03	19.5	8.40	20,000	277.0	394.0	40.0	
BDL-7	1000	7/16/97	7.83	24.0	6.10	550	242.0	308.0	4.0	
BDL-8	930	7/16/97	7.64	16.0	8.20	100	261.0	337.0	6.0	
BDL-7	1530	7/17/97	7.92	28.0	6.50	2,700	151.0	235.0	6.0	1
BDL-5	1515	7/21/97	8.35	25.0	12.00	1,600	267.0	382.0	27.0	6
BDL-9	1500	7/21/97	8.19	25.5	10.40	710	237.0	307.0	2.0	1
BDL-10	1230	8/4/97	8.24	21.3	13.10	120	214.0	315.0	4.0	4
BDL-4A	1345	8/4/97	8.82	27.0	9.70	400	202.0	311.0	50.0	15
BDL-4B	1315	8/4/97	8.63	27.0	8.80	100	218.0	309.0	19.0	9
BDL-4C	1425	8/4/97	7.97	27.0	5.20	420	222.0	309.0	9.0	7
BDL-5	930	8/4/97	8.10	21.5	5.20	1,500	284.0	403.0	62.0	15
BDL-6	1015	8/4/97	8.21	18.0	8.30	1,800	275.0	365.0	11.0	7
BDL-7		8/4/97	7.65	23.0	6.60	3,400	226.0	308.0	8.0	6
BDL-8	1130	8/4/97	7.98	17.0	7.60	110	262.0	353.0	5.0	3
BDL-5	1200	8/14/97	8.16	14.2	8.30	2,800	235.0	335.0	29.0	7
BDL-6	1245	8/14/97	7.92	13.8	7.00	11,000	212.0	424.0	90.0	22
BDL-8	1330	8/14/97	7.88	13.8	6.40	2,000	210.0	333.0	24.0	7
BDL-9	1415	8/14/97		15.5	7.20	4,400	167.0	254.0	4.0	1
BDL-4A	1130	8/26/97	8.62	23.5	7.90	500	218.0	334.0	46.0	11
BDL-4B	1205	8/26/97	8.62	26.0	9.30	170	226.0	320.0	16.0	6
BDL-4C	1245	8/26/97	7.84	23.0	5.90	290	240.0	332.0	7.0	1
BDL-5	1400	8/26/97	8.34	24.5	14.70	430	265.0	368.0	20.0	3
BDL-10	945	8/27/97	7.81	18.0	8.00	160	224.0	314.0	2.0	
BDL-6	1150	8/27/97	8.00	19.0	8.70	24,600	282.0	395.0	56.0	
BDL-7	1110	8/27/97	7.80	23.0	6.00	1,800	235.0	299.0	2.0	
BDL-8	1025	8/27/97	7.71	15.2	7.60	90	267.0	327.0	3.0	
BDL-6	2100	8/29/97	8.27	17.5	10.20	650	153.0	365.0	178.0	
BDL-10	1015	9/2/97	8.34	15.0	9.00	250	260.0	331.0	9.0	
BDL-5	1200	9/2/97	8.27	17.5	10.20	650	240.0	351.0	14.0	5
BDL-7	1115	9/2/97	7.70	17.5	4.80	160	193.0	279.0	9.0	
BDL-6	1430	9/15/97	8.08	17.5	7.80	4,200	268.0	401.0	64.0	14
BDL-5	1315	9/16/97	9.31	19.5	9.50	310	270.0	384.0	15.0	

Site	Time	Date	pH	Water Temp	DO	Fecal Coliform	Alkalinity-M	Total Solids	Suspended Solids	VTSS
			su	°C	mg/L	Counts/100ml	mg/L	mg/L	mg/L	mg/L
BDL-9	1030	9/16/97	8.08	20.0	6.40	310	259.0	328.0	1.0	1
BDL-4A	950	9/24/97	7.99	13.0	10.30	930	244.0	361.0	44.0	
BDL-4B	1115	9/24/97	8.09	14.0	10.60	110	252.0	369.0	18.0	
BDL-4C	1130	9/24/97	7.70	12.0	6.00	100	272.0	378.0	10.0	
BDL-10	1010	9/30/97	7.92	10.0	11.10	40	228.0	326.0	5.0	1
BDL-5	1310	9/30/97	8.08	13.0	13.00	60	89.0	357.0	11.0	2
BDL-6	1230	9/30/97	8.06	11.5	10.70	50	267.0	347.0	8.0	1
BDL-7	1155	9/30/97	7.00	11.7	8.60	230	259.0	322.0	8.0	3
BDL-8	1115	9/30/97	7.65	9.5	9.20	20	262.0	335.0	4.0	<0.01
BDL-6	1130	10/8/97	8.08	10.0	8.90	1,700	277.0	446.0	162.0	36
BDL-4A	1200	10/9/97	8.10	11.0	10.70	7,300	248.0	377.0	42.0	8
BDL-4B	1210	10/9/97	8.05	11.0	10.80	570	254.0	395.0	25.0	5
BDL-4C	1245	10/9/97	7.66	10.0	7.00	800	275.0	418.0	14.0	4
BDL-5	1145	10/9/97	8.24	10.0	11.60	740	273.0	383.0	17.0	5
BDL-5	1310	10/13/97	7.93	6.5	9.60		242.0	353.0	11.0	6
BDL-6	1225	10/13/97	7.91	6.8	8.80		232.0	343.0	19.0	4
BDL-7	1200	10/13/97	7.99	6.8	10.30		237.0	315.0	9.0	2
BDL-9	1110	10/13/97	7.97	4.5	10.80		231.0	313.0	3.0	2
BDL-10	1030	2/24/98	7.95	2.0	12.40	<10	183.0	279.0	2.0	
BDL-5	1315	2/24/98	7.74	2.5	11.80	40	219.0	305.0	6.0	
BDL-6	1215	2/24/98	7.77	2.5	10.40	70	230.0	308.0	11.0	
BDL-7	1115	2/24/98	7.55	1.0	8.40	880	195.0	260.0	9.0	
BDL-10	1030	2/26/98	7.95	0.0	12.10	10	93.0	153.0	8.0	
BDL-5	1430	2/26/98	7.95	1.0	11.50	130	161.0	245.0	9.0	
BDL-6	1310	2/26/98	7.92	0.0	11.70	160	117.0	179.0	6.0	
BDL-7	1120	2/26/98	7.84	0.0	10.70	30	144.0	212.0	19.0	
BDL-9	930	2/26/98	7.82	0.0	11.90	80	89.0	141.0	5.0	
BDL-10	1000	3/27/98	7.69	1.0	11.60		101.0	152.0	4.0	
BDL-4A	1400	3/27/98	8.09	8.0	11.40		230.0	310.0	33.0	
BDL-5	1230	3/27/98	7.79	2.0	11.40		146.0	203.0	11.0	
BDL-6	1110	3/27/98	7.73	2.0	11.60		120.0	173.0	4.0	
BDL-7	1030	3/27/98	7.71	1.0	11.20		90.0	141.0	13.0	
BDL-9	915	3/27/98	7.69	0.0	11.00		107.0	146.0	7.0	
BDL-10	940	4/6/98	7.61	1.0	12.00	<10	153.0	212.0	2.0	
BDL-5	1130	4/6/98	7.73	4.0	10.20	<10	208.0	275.0	2.0	
BDL-6	1050	4/6/98	7.72	3.0	11.40	<10	186.0	251.0	6.0	
BDL-7	1015	4/6/98	7.71	2.5	11.90	<10	164.0	224.0	4.0	
BDL-9	900	4/6/98	7.58	2.0	11.20	<10	170.0	221.0	5.0	
BDL-4A	1030	4/21/98	8.47	12.0	10.30	<10	186.0	263.0	20.0	
BDL-4B	1200	4/21/98	8.33	11.5	10.60	<10	187.0	265.0	18.0	
BDL-10	1000	5/5/98	7.87	11.0	10.60	10	268.0	334.0	2.0	
BDL-5	1145	5/5/98	7.99	14.0	9.40	20	268.0	343.0	16.0	
BDL-6	1115	5/5/98	7.90	11.5	9.60	50	262.0	346.0	36.0	
BDL-7	1030	5/5/98	7.76	14.0	6.80	200	242.0	293.0	1.0	
BDL-8	1100	5/5/98	7.82	11.0	9.60	<10	247.0	301.0	16.0	
BDL-9	925	5/5/98	7.64	11.0	7.20	30	229.0	272.0	3.0	
BDL-10	1115	5/12/98	7.89	12.0	7.70	240	141.0	224.0	12.0	
BDL-5	1230	5/12/98	7.90	12.0	7.10	2,900	202.0	268.0	16.0	
BDL-6	1215	5/12/98	7.76	12.0	6.80	38,000	190.0	259.0	5.0	
BDl-7	1145	5/12/98	7.80	13.0	6.00	1,100	199.0	237.0	6.0	
BDL-9	1035	5/12/98	7.86	12.2	7.00	2,200	169.0	223.0	4.0	
BDL-4A	1210	5/13/98	8.63	16.0	9.40	20	191.0	306.0	25.0	
BDL-4B	1235	5/13/98	8.31	15.5	9.10	210	188.0	333.0	17.0	

Site	Time	Date	pH	Water Temp	DO	Fecal Coliform	Alkalinity-M	Total Solids	Suspended Solids	VTSS
			su	**°C**	**mg/L**	**Counts/100ml**	**mg/L**	**mg/L**	**mg/L**	**mg/L**
BDL-10	930	6/16/98	7.95	14.0	8.80	60	266.0	339.0	2.0	
BDL-5	1110	6/16/98	8.02	17.0	9.80	430	284.0	371.0	21.0	
BDL-6	1030	6/16/98	7.91	15.0	8.10	1,000	275.0	360.0	24.0	
BDL-7	1000	6/16/98	7.74	17.0	5.40	720	264.0	330.0	7.0	
BDL-9	900	6/16/98	7.82	16.5	6.40	250	236.0	276.0	3.0	
BDL-4A	945	6/22/98	8.40	20.0	8.50	90	206.0	295.0	22.0	
BDL-4B	1030	6/22/98	8.29	19.5	8.00	170	206.0	301.0	27.0	
BDL-6	736	8/3/98	8.08	17.0	6.80	59,000	257.0	449.0	81.0	
BDL-6	759	8/22/98	7.76	17.0	6.80	37,000	256.0	403.0	51.0	
BDL-10	1000	10/5/98	7.72	10.5	8.90	240	228.0	361.0	6.0	
BDL-5	1200	10/5/98	8.16	11.0	9.40	7,200	228.0	448.0	22.0	
BDL-6	1115	10/5/98	8.04	10.5	7.60	46,000	245.0	462.0	118.0	
BDL-7	1045	10/5/98	7.79	10.5	7.40	6,000	208.0	442.0	30.0	
BDL-9	930	10/5/98	7.69	10.0	7.00	12,000	196.0	358.0	4.0	

Site	Time	Date	Ammonia mg/L	Unionized Ammonia mg/L	Nitrate mg/L	TKN mg/L	Total Phosphate mg/L	Tot. Diss. Phosphate mg/L	BOD mg/L
BDL-10	1320	8/14/96	<0.02	0.00124	2.40	0.53	0.047	0.044	
BDL-4B	1130	8/14/96	<0.02	0.00131	0.10	1.82	0.181	0.030	
BDL-5	1645	8/14/96	<0.02	0.00218	0.20	0.57	0.124	0.034	
BDL-6	1600	8/14/96	<0.02	0.00082	0.40	0.83	0.077	0.040	
BDL-7	1415	8/14/96	0.28	0.00564	0.10	1.52	0.355	0.355	
BDL-8	1500	8/14/96	<0.02	0.00036	0.50	0.25	0.060	0.057	
BDL-10	1250	9/3/96	<0.02	0.00031	1.50	0.60	0.064	0.064	
BDL-7	1145	9/3/96	0.65	0.01799	0.10	2.61	0.506	0.258	
BDL-4B	1150	9/4/96	0.24	0.01883	0.20	2.97	0.184	0.037	
BDL-5	1115	9/4/96	0.07	0.00470	0.50	0.92	0.144	0.044	
BDL-6	1020	9/4/96	<0.02	0.00038	0.70	0.50	0.111	0.050	
BDL-8	925	9/4/96	<0.02	0.00025	0.80	0.31	0.077	0.027	
BDL-10	950	9/24/96	0.03	0.00055	2.70	0.78	0.057	0.030	
BDL-4B	1305	9/24/96	0.2	0.00834	0.20	1.80	0.164	0.023	
BDL-5	1215	9/24/96	<0.02	0.00029	0.60	0.59	0.100	0.037	
BDL-6	1120	9/24/96	<0.02	0.00020	0.70	0.40	0.080	0.070	
BDL-7	850	9/24/96	0.21	0.00232	0.20	1.59	0.100	0.064	
BDL-8	1040	9/24/96	<0.02	0.00010	0.80	0.42	0.054	0.020	
BDL-9	1430	10/18/96	<0.02	0.00014	0.10	0.98	0.087	0.064	
BDL-10	1015	10/23/96	0.03	0.00056	4.80	0.46	0.044	0.027	
BDL-4A	1430	10/23/96	<0.02	0.00151	0.10	0.63	0.141	0.044	
BDL-5	1355	10/23/96	0.03	0.00030	0.70	0.66	0.100	0.027	
BDL-6	1250	10/23/96	<0.02	0.00014	0.80	0.58	0.104	0.030	
BDL-7	1100	10/23/96	0.15	0.00179	0.30	1.23	0.107	0.044	
BDL-8	1400	10/23/96	0.03	0.00039	1.10	0.33	0.047	0.027	
BDL-10	1030	10/30/96	0.05	0.00049	4.20	0.48	0.047	0.027	
BDL-5	1430	10/30/96	<0.02	0.00008	0.20	0.76	0.151	0.111	
BDL-6	1020	10/30/96	<0.02	0.00012	0.30	0.74	0.194	0.144	
BDL-7	1055	10/30/96	0.05	0.00039	0.20	1.13	0.181	0.137	
BDL-8	1145	10/30/96	<0.02	0.00010	0.70	0.35	0.064	0.030	
BDL-9	945	10/30/96	<0.02	0.00009	<0.10	0.51	0.074	0.084	
BDL-6	1430	3/27/97	0.59	0.00379	0.60	1.74	0.230	0.067	
BDL-5	1045	3/31/97	0.13	0.00061	0.30	1.11	0.155	0.094	
BDL-6	1200	4/1/97	0.11	0.00166	0.30	0.97	0.270	0.168	
BDL-10	1540	4/2/97	0.05	0.00049	0.90	1.09	0.193	0.147	
BDL-9	1450	4/2/97	<0.02	0.00008	0.60	0.59	0.129	0.121	
BDL-5	1410	4/3/97	<0.02	0.00004	0.40	0.84	0.160	0.093	
BDL-6	1130	4/3/97	<0.02	0.00008	0.60	0.56	0.169	0.102	
BDL-7	1015	4/3/97	<0.02	0.00007	0.70	1.35	0.218	0.112	
BDL-10	1040	4/5/97	<0.02	0.00004	0.50	0.41	0.185	0.092	
BDL-7	1130	4/5/97	0.02	0.00012	0.50	0.70	0.160	0.078	
BDL-9	1015	4/5/97	<0.02	0.00003	0.20	0.45	0.084	0.059	
BDL-4A		4/15/97	0.18	0.00181	0.30	0.81	0.145	0.051	
BDL-5	1345	4/15/97	<0.02	0.00007	0.30	0.36	0.068	0.036	
BDL-7	1440	4/15/97	<0.02	0.00007	0.30	0.18	0.066	0.035	
BDL-10	1220	4/16/97	<0.02	0.00004	0.50	0.28	0.069	0.044	
BDL-6	1110	4/16/97	<0.02	0.00006	0.30	0.31	0.061	0.039	
BDL-4A	1300	4/17/97	0.12	0.00197	0.20	1.18	0.091	0.027	
BDL-9	1040	4/17/97	<0.02	0.00005	0.20	0.54	0.082	0.037	
BDL-10	1215	5/5/97	0.08	0.00501	0.70	0.14	0.023	0.011	
BDL-7	1330	5/5/97	<0.02	0.00062	<0.10	0.21	0.036	0.013	
BDL-8	1415	5/5/97	<0.02	0.00038	0.20	<0.10	0.042	0.014	
BDL-9	1120	5/5/97	<0.02	0.00044	<0.10	0.39	0.040	0.008	

Site	Time	Date	Ammonia	Unionized Ammonia	Nitrate	TKN	Total Phosphate	Tot. Diss. Phosphate	BOD
			mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
BDL-5	1415	5/7/97	<0.02	0.00034	0.10	0.20	0.040	0.028	
BDL-6	1330	5/7/97	<0.02	0.00024	0.20	<0.10	0.046	0.021	
BDL-10	1000	5/27/97	<0.02	0.00033	1.50	0.54	0.016	0.013	
BDL-5	1420	5/27/97	<0.02	0.00038	0.20	0.67	0.048	0.024	
BDL-6	1330	5/27/97	<0.02	0.00024	0.40	0.68	0.153	0.036	
BDL-7	1245	5/27/97	<0.02	0.00037	<0.10	0.59	0.028	0.015	
BDL-8	1200	5/27/97	<0.02	0.00020	0.60	0.43	0.053	0.015	
BDL-9	1045	5/27/97	<0.02	0.00028	0.10	0.68	0.037	0.019	
BDL-4A	1230	6/10/97	<0.02	0.00174	<0.10	0.80	0.057	0.014	
BDL-4B	1315	6/10/97	<0.02	0.00186	<0.10	0.69	0.032	0.014	
BDL-10	1030	6/17/97	<0.02	0.00022	5.10	0.45	0.034	0.026	
BDL-5		6/17/97	0.07	0.00497	0.50	0.59	0.123	0.030	
BDL-6		6/17/97	<0.02	0.00042	0.60	0.63	0.182	0.043	
BDL-7	1230	6/17/97	<0.02	0.00042	<0.10	0.73	0.106	0.059	
BDL-8	1145	6/17/97	<0.02	0.00023	0.80	0.55	0.072	0.020	
BDL-9	1115	6/17/97	<0.02	0.00020	0.10	0.36	0.049	0.022	
BDL-10	845	7/16/97	<0.02	0.00020	4.20	0.58	0.028	0.017	
BDL-4A	1240	7/16/97	<0.02	0.00199	<0.10	1.13	0.101	0.032	
BDL-4B	1310	7/16/97	<0.02	0.00249	<0.10	0.94	0.076	0.035	
BDL-4C	1400	7/16/97	<0.02	0.00058	0.10	1.02	0.109	0.062	
BDL-5	1110	7/16/97	<0.02	0.00074	0.40	0.85	0.146	0.036	
BDL-6	1030	7/16/97	<0.02	0.00039	0.70	1.29	0.211	0.087	
BDL-7	1000	7/16/97	<0.02	0.00035	<0.10	1.00	0.147	0.114	
BDL-8	930	7/16/97	<0.02	0.00013	0.80	0.52	0.056	0.027	
BDL-7	1530	7/17/97	<0.02	0.00055	0.10	1.15	0.166	0.117	
BDL-5	1515	7/21/97	<0.02	0.00113	0.10	1.06	0.144	0.058	
BDL-9	1500	7/21/97	<0.02	0.00084	<0.10	1.02	0.091	0.061	
BDL-10	1230	8/4/97	<0.02	0.00071	4.20	<0.10	0.034	0.019	
BDL-4A	1345	8/4/97	<0.02	0.00302	<0.10	0.58	0.126	0.027	
BDL-4B	1315	8/4/97	<0.02	0.00218	<0.10	0.47	0.119	0.061	
BDL-4C	1425	8/4/97	<0.02	0.00058	0.10	0.63	0.127	0.065	3
BDL-5	930	8/4/97	<0.02	0.00053	0.30	0.45	0.177	0.038	
BDL-6	1015	8/4/97	<0.02	0.00053	0.60	<0.10	0.119	0.070	
BDL-7		8/4/97	<0.02	0.00022	<0.10	0.24	0.127	0.089	
BDL-8	1130	8/4/97	<0.02	0.00029	0.80	<0.10	0.073	0.027	
BDL-5	1200	8/14/97	<0.02	0.00036	0.30	0.58	0.106	0.031	
BDL-6	1245	8/14/97	<0.02	0.00020	0.30	0.79	0.249	0.088	
BDL-8	1330	8/14/97	<0.02	0.00019	0.30	0.89	0.126	0.055	
BDL-9	1415	8/14/97	<0.02	0.00000	0.10	1.04	0.154	0.109	
BDL-4A	1130	8/26/97	<0.02	0.00176	0.10	1.29	0.136	0.033	
BDL-4B	1205	8/26/97	<0.02	0.00203	<0.10	1.22	0.108	0.071	
BDL-4C	1245	8/26/97	<0.02	0.00033	0.10	1.13	0.122	0.076	<0.01
BDL-5	1400	8/26/97	<0.02	0.00107	0.40	0.56	0.091	0.029	
BDL-10	945	8/27/97	<0.02	0.00022	4.80	0.54	0.034	0.023	
BDL-6	1150	8/27/97	<0.02	0.00036	0.60	1.10	0.224	0.076	
BDL-7	1110	8/27/97	<0.02	0.00030	0.10	0.92	0.139	0.106	
BDL-8	1025	8/27/97	<0.02	0.00014	0.80	0.27	0.048	0.023	
BDL-6	2100	8/29/97	<0.02	0.00058	0.50	1.00	0.512	0.161	
BDL-10	1015	9/2/97	<0.02	0.00057	0.01	0.60	0.099	0.051	
BDL-5	1200	9/2/97	<0.02	0.00058	0.20	0.88	0.140	0.085	
BDL-7	1115	9/2/97	<0.02	0.00016	<0.10	1.02	0.130	0.082	<0.01
BDL-6	1430	9/15/97	<0.02	0.00038	0.60	0.40	0.186	0.081	
BDL-5	1315	9/16/97	<0.02	0.00439	0.30	0.52	0.106	0.054	

Site	Time	Date	Ammonia	Unionized Ammonia	Nitrate	TKN	Total Phosphate	Tot. Diss. Phosphate	BOD
			mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
BDL-9	1030	9/16/97	<0.02	0.00046	0.10	0.78	0.067	0.043	
BDL-4A	950	9/24/97	0.09	0.00202	0.20	0.98	0.169	0.051	
BDL-4B	1115	9/24/97	0.11	0.00333	0.20	1.27	0.115	0.050	
BDL-4C	1130	9/24/97	0.09	0.00097	0.20	1.26	0.108	0.054	
BDL-10	1010	9/30/97	<0.02	0.00015	6.00	0.38	0.025	0.016	
BDL-5	1310	9/30/97	<0.02	0.00027	0.60	0.42	0.061	0.027	
BDL-6	1230	9/30/97	<0.02	0.00023	0.80	0.25	0.053	0.039	
BDL-7	1155	9/30/97	<0.02	0.00002	0.30	0.87	0.079	0.037	
BDL-8	1115	9/30/97	<0.02	0.00008	1.00	0.21	0.040	0.022	
BDL-6	1130	10/8/97	<0.02	0.00022	0.50	0.89	0.252	0.073	
BDL-4A	1200	10/9/97	0.05	0.00124	0.30	0.92	0.210	0.082	
BDL-4B	1210	10/9/97	0.09	0.00199	0.30	1.54	0.135	0.062	
BDL-4C	1245	10/9/97	0.1	0.00084	0.20	1.13	0.136	0.068	
BDL-5	1145	10/9/97	<0.02	0.00031	0.30	0.48	0.085	0.046	
BDL-5	1310	10/13/97	<0.02	0.00012	0.20	0.90	0.132	0.099	
BDL-6	1225	10/13/97	<0.02	0.00012	0.20	0.88	0.201	0.170	
BDL-7	1200	10/13/97	<0.02	0.00014	0.10	0.84	0.135	0.095	
BDL-9	1110	10/13/97	<0.02	0.00011	0.10	0.95	0.119	0.095	
BDL-10	1030	2/24/98	<0.02	0.00009	5.40	0.57	0.070	0.055	
BDL-5	1315	2/24/98	0.10	0.00056	0.60	1.10	0.123	0.082	
BDL-6	1215	2/24/98	0.15	0.00089	0.60	1.10	0.140	0.084	
BDL-7	1115	2/24/98	<0.02	0.00003	0.10	0.69	0.137	0.085	
BDL-10	1030	2/26/98	0.11	0.00080	0.50	1.43	0.240	0.189	
BDL-5	1430	2/26/98	0.09	0.00072	0.50	1.26	0.221	0.158	
BDL-6	1310	2/26/98	0.16	0.00109	0.70	1.59	0.294	0.229	
BDL-7	1120	2/26/98	0.03	0.00017	0.60	1.11	0.159	0.089	
BDL-9	930	2/26/98	<0.02	0.00005	0.30	1.05	0.145	0.123	
BDL-10	1000	3/27/98	<0.02	0.00004	0.40	1.00	0.168	0.007	
BDL-4A	1400	3/27/98	0.03	0.00058	0.20	1.13	0.069	0.016	
BDL-5	1230	3/27/98	<0.02	0.00006	0.40	0.90	0.143	0.076	
BDL-6	1110	3/27/98	<0.02	0.00005	0.30	0.96	0.177	0.107	
BDL-7	1030	3/27/98	<0.02	0.00005	0.30	1.04	0.150	0.079	
BDL-9	915	3/27/98	<0.02	0.00004	0.10	0.72	0.112	0.069	
BDL-10	940	4/6/98	<0.02	0.00004	0.80	0.68	0.094	0.068	
BDL-5	1130	4/6/98	<0.02	0.00006	0.20	0.49	0.056	0.048	
BDL-6	1050	4/6/98	<0.02	0.00006	0.40	0.69	0.081	0.055	
BDL-7	1015	4/6/98	<0.02	0.00005	0.70	0.74	0.054	0.031	
BDL-9	900	4/6/98	<0.02	0.00004	0.20	0.76	0.072	0.026	
BDL-4A	1030	4/21/98	<0.02	0.00060	<0.10	0.83	0.040	0.007	
BDL-4B	1200	4/21/98	<0.02	0.00043	<0.10	0.82	0.047	0.011	
BDL-10	1000	5/5/98	<0.02	0.00015	2.00	0.46	0.035	0.019	
BDL-5	1145	5/5/98	<0.02	0.00024	0.20	0.70	0.090	0.023	
BDL-6	1115	5/5/98	<0.02	0.00016	0.40	0.67	0.104	0.025	
BDL-7	1030	5/5/98	<0.02	0.00014	<0.10	0.71	0.057	0.036	
BDL-8	1100	5/5/98	<0.02	0.00013	0.50	0.46	0.046	0.016	
BDL-9	925	5/5/98	<0.02	0.00009	0.50	0.64	0.044	0.018	
BDL-10	1115	5/12/98	<0.02	0.00017	0.90	1.37	0.144	0.077	
BDL-5	1230	5/12/98	<0.02	0.00017	0.10	0.42	0.111	0.050	
BDL-6	1215	5/12/98	<0.02	0.00012	0.20	0.60	0.166	0.122	
BDl-7	1145	5/12/98	<0.02	0.00015	0.10	0.38	0.079	0.056	
BDL-9	1035	5/12/98	<0.02	0.00016	0.50	1.19	0.082	0.044	
BDL-4A	1210	5/13/98	<0.02	0.00112	<0.10	1.01	0.062	0.008	
BDL-4B	1235	5/13/98	<0.02	0.00055	<0.10	1.12	0.072	0.015	

Site	**Time**	**Date**	**Ammonia**	**Unionized Ammonia**	**Nitrate**	**TKN**	**Total Phosphate**	**Tot. Diss. Phosphate**	**BOD**
			mg/L	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**
BDL-10	930	6/16/98	<0.02	0.00022	2.10	0.31	0.045	0.038	
BDL-5	1110	6/16/98	<0.02	0.00032	0.20	0.56	0.104	0.056	
BDL-6	1030	6/16/98	<0.02	0.00022	0.40	0.36	0.134	0.056	
BDL-7	1000	6/16/98	<0.02	0.00017	0.10	0.49	0.076	0.072	
BDL-9	900	6/16/98	<0.02	0.00020	0.50	0.51	0.066	0.035	
BDL-4A	945	6/22/98	<0.02	0.00091	0.10	1.32	0.078	0.018	
BDL-4B	1030	6/22/98	<0.02	0.00069	<0.10	1.59	0.090	0.025	
BDL-6	736	8/3/98	<0.02	0.00037	0.50	0.97	0.242	0.090	
BDL-6	759	8/22/98	<0.02	0.00018	0.70	0.36	0.198	0.114	
BDL-10	1000	10/5/98	<0.02	0.00010	5.80	0.64	0.140	0.049	
BDL-5	1200	10/5/98	<0.02	0.00028	0.50	1.29	0.202	0.117	
BDL-6	1115	10/5/98	<0.02	0.00021	0.80	0.87	0.340	0.134	
BDL-7	1045	10/5/98	<0.02	0.00012	0.50	1.58	0.231	0.152	
BDL-9	930	10/5/98	<0.02	0.00009	0.10	1.64	0.231	0.175	

Appendix I

Blue Dog Lake Inlake Water Quality

Site	Time	Date	pH	Water Temp	DO	Secchi Depth	Fecal Coliform	Alkalinity-M	Total Solids	Suspended Solids	Volatile Susp. Sol.	Ammonia	Unionized Ammonia	Nitrate
			su	**^{o}C**	**mg/L**	**m**	**Counts/100ml**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**
BDL-1	1330	8/27/96	8.67	21.50	7.80	0.30	<10	205.0	347.0	29.0		<0.02	0.00172	0.10
BDL-2	1430	8/27/96	8.77	21.50	9.90	0.30	10	196.0	334.0	30.0		<0.02	0.00207	0.10
BDL-1	1050	9/23/96	8.61	14.00	8.60	0.37	20	214.0	322.0	19.0		0.02	0.00187	0.40
BDL-2	1120	9/23/96	8.55	14.00	9.20	0.30	110	220.0	327.0	19.0		0.04	0.00330	0.40
BDL-1	1010	10/16/96	8.68	11.50	9.20	0.27	10	221.0	350.0	26.0		0.03	0.00273	0.30
BDL-2	945	10/16/96	8.72	11.50	9.00	0.27	50	224.0	348.0	29.0		0.03	0.00297	0.30
BDL-1	1220	2/20/97	8.12	1.00	8.60		<10	297.0	486.0	1.0		0.03	0.00035	0.70
BDL-2	1040	2/20/97	7.80	0.50	7.40		<10	296.0	471.0	2.0		0.05	0.00027	0.60
BDL-1	1230	3/26/97	8.23	0.50	11.60		<10	230.0	408.0	5.0		0.52	0.00751	2.20
BDL-2	1000	3/27/97	7.79	1.00	7.20		<10	288.0	421.0	6.0		0.03	0.00017	0.70
BDL-1	1130	4/29/97	8.38	7.50	12.80	0.40	<10	176.0	270.0	24.0		<0.02	0.00035	0.10
BDL-2	1100	4/29/97	8.44	7.00	13.40	1.01	<10	177.0	250.0	9.0		<0.02	0.00039	<0.10
BDL-1	1055	6/5/97	8.25	19.20	8.50	1.01	20	203.0	273.0	4.0		<0.02	0.00062	<0.10
BDL-2	1030	6/5/97	8.15	19.50	8.60	1.07	<10	207.0	272.0	3.0		<0.02	0.00051	0.10
BDL-1	1500	7/8/97	8.43	22.00	9.10	0.21	50	231.0	330.0	46.0	4.0	<0.02	0.00110	0.10
BDL-2	1510	7/8/97	8.29	21.00	9.00	0.21	20	229.0	315.0	38.0		<0.02	0.00077	0.10
BDL-1	1015	8/13/97	8.49	19.80	7.00	0.27	<10	211.0	318.0	30.0	6.0	<0.02	0.00108	0.10
BDL-2	1040	8/13/97	8.50	20.00	7.10	0.43	<10	205.0	308.0	19.0	6.0	<0.02	0.00112	0.10
BDL-1	1030	9/17/97	8.44	19.00	8.00	0.21	<10	218.0	345.0	37.0	8.0	<0.02	0.00092	0.10
BDL-2	1015	9/17/97	8.46	19.00	7.90	0.18	360	227.0	356.0	57.0	9.0	<0.02	0.00096	0.10
BDL-2	910	10/22/97	8.41	6.00	10.80	0.24	10	233.0	343.0	36.0		<0.02	0.00034	0.20
BDL-1	930	10/22/97	8.42	6.50	10.60	0.24	<10	224.0	342.0	32.0		<0.02	0.00036	0.20
BDL-1	940	2/23/98	8.02	1.00	9.00		<10	205.0	286.0	6.0		0.05	0.00047	0.30
BDL-1	1000	3/5/98	7.78	1.00	12.60		<10	<31.0	37.0	5.0		0.21	0.00113	0.30
BDL-2	1030	3/5/98	7.71	0.50	12.40		<10	144.0	207.0	2.0		0.50	0.00220	0.50
BDL-1	950	4/28/98	8.43	15.00	9.00	0.70	10	203.0	295.0	6.0		<0.02	0.00069	0.10
BDL-2	1010	4/28/98	8.43	15.00	9.40	0.58	<10	201.0	293.0	8.0		<0.02	0.00069	<0.10
BDL-1	1100	5/27/98	8.29	19.00	9.00	0.82	<10	214.0	312.0	11.0		<0.02	0.00067	0.10
BDL-1	1230	6/24/98	8.57	25.00	8.80	0.64	50	221.0	318.0	10.0		<0.02	0.00175	<0.10
BDL-1	1000	7/30/98	8.47	22.50	7.20	0.30	<10	235.0	355.0	24.0		<0.02	0.00123	0.10
		Mean	**8.34**	**12.75**	**9.29**	**0.45**	**27**	**212.4**	**321.3**	**19.1**	**6.6**	**0.06**	**0.0013**	**0.29**
		Minimum	**7.71**	**0.50**	**7.00**	**0.18**	**<10**	**15.5**	**37.0**	**1.0**	**4.0**	**<0.02**	**0.0002**	**<0.10**
		Maximum	**8.77**	**25.00**	**13.40**	**1.07**	**360**	**297.0**	**486.0**	**57.0**	**9.0**	**0.52**	**0.0075**	**2.20**
		Median	**8.43**	**14.50**	**9.00**	**0.30**	**<10**	**216.0**	**324.5**	**19.0**	**6.0**	**<0.02**	**0.0009**	**0.10**
		Standard Deviation	**0.29**	**8.35**	**1.77**	**0.28**	**98.9**	**32.3**	**79.4**	**15.0**	**1.9**	**0.19**	**0.00144**	**0.43**

Site	Time	Date	TKN	Total Phosphate	Tot. Diss. Phosphate	BOD	Uncorrected Chlorophyll	Corrected Chlorophyll	TSI Secchi	TSI Phosphorus	TSI Chlorophyll	Average TSI
			mg/L	mg/L	mg/L	mg/L	mg/m^3	mg/m^3				
BDL-1	1330	8/27/96	1.04	0.087	0.013		35.51	31.07	77.14	68.58	65.59	70.44
BDL-2	1430	8/27/96	2.23	0.090	0.037		79.06	81.64	77.14	69.07	73.44	73.22
BDL-1	1050	9/23/96	0.89	0.074	0.040		3.69	2.17	74.51	66.24	43.36	61.37
BDL-2	1120	9/23/96	0.81	0.097	0.034		13.07	10.12	77.14	70.15	55.78	67.69
BDL-1	1010	10/16/96	0.74	0.104	0.047		2.68	3.61	78.66	71.15	40.24	63.35
BDL-2	945	10/16/96	0.89	0.104	0.054		2.01	3.61	78.66	71.15	37.42	62.41
BDL-1	1220	2/20/97	0.80	0.112	0.106		1.34	2.17		72.22	33.44	52.83
BDL-2	1040	2/20/97	0.91	0.086	0.085					68.41		68.41
BDL-1	1230	3/26/97	1.22	0.131	0.123		0.10	0.10		74.48	7.98	41.23
BDL-2	1000	3/27/97	0.50	0.060	0.049		0.67	5.06		63.22	26.64	44.93
BDL-1	1130	4/29/97	0.12	0.072	0.013		1.68	1.45	73.36	65.85	35.66	58.29
BDL-2	1100	4/29/97	0.44	0.054	0.012		12.73	15.17	59.92	61.70	55.53	59.05
BDL-1	1055	6/5/97	0.67	0.032	0.012		0.67	1.45	59.92	54.15	26.64	46.90
BDL-2	1030	6/5/97	0.73	0.032	0.016		1.34	2.89	59.07	54.15	33.44	48.89
BDL-1	1500	7/8/97	0.91	0.105	0.026	1	20.77	24.57	82.29	71.29	60.33	71.30
BDL-2	1510	7/8/97	0.82	0.093	0.031		16.08	18.79	82.29	69.54	57.82	69.88
BDL-1	1015	8/13/97	0.78	0.090	0.035		7.37	7.23	78.66	69.07	50.16	65.96
BDL-2	1040	8/13/97	0.74	0.088	0.033		7.04	7.23	72.29	68.74	49.71	63.58
BDL-1	1030	9/17/97	0.84	0.107	0.042		12.06	10.84	82.29	71.57	55.00	69.62
BDL-2	1015	9/17/97	0.60	0.124	0.040		15.41	15.90	84.51	73.69	57.40	71.87
BDL-2	910	10/22/97	0.54	0.112	0.047		20.10	20.23	80.36	72.22	60.01	70.86
BDL-1	930	10/22/97	0.46	0.128	0.053		17.09	16.62	80.36	74.15	58.42	70.98
BDL-1	940	2/23/98	0.73	0.045	0.029		1.34	0.10		59.07	33.44	46.25
BDL-1	1000	3/5/98	0.46	0.015	0.005		1.01	1.45		43.22	30.67	36.94
BDL-2	1030	3/5/98	0.80	0.088	0.051		9.05	5.06		68.74	52.18	60.46
BDL-1	950	4/28/98	0.59	0.054	0.019		3.02	2.17	65.12	61.70	41.41	56.08
BDL-2	1010	4/28/98	0.59	0.045	0.021		4.69	2.17	67.88	59.07	45.73	57.56
BDL-1	1100	5/27/98	0.71	0.038	0.016		4.36	3.61	62.81	56.63	45.01	54.82
BDL-1	1230	6/24/98	1.00	0.048	0.036		62.98	65.75	66.44	60.00	71.21	65.88
BDL-1	1000	7/30/98	1.00	0.075	0.033		11.39	10.12	77.14	66.44	54.43	66.00
		Mean	**0.79**	**0.080**	**0.039**	**1**	**12.70**	**12.84**	**73.82**	**65.86**	**46.83**	**60.57**
		Minimum	**0.12**	**0.015**	**0.005**	**1**	**0.10**	**0.10**	**59.07**	**43.22**	**7.98**	**36.94**
		Maximum	**2.23**	**0.131**	**0.123**	**1**	**79.06**	**81.64**	**84.51**	**74.48**	**73.44**	**73.22**
		Median	**0.76**	**0.088**	**0.035**	**1**	**7.04**	**5.06**	**77.14**	**68.66**	**49.71**	**62.88**
		Standard Deviation	**0.35**	**0.031**	**0.027**		**18.23**	**18.75**	**8.04**	**7.26**	**14.80**	**10.06**

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