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WATER QUALITY ASSESSMENTS FOR SELECTED NEW MEXICO LAKES

2007

MONITORING AND ASSESSMENT SECTION

SURFACE WATER QUALITY BUREAU

NEW MEXICO ENVIRONMENT DEPARTMENT

1190 St. Francis Drive - P.O. Box 5469

Santa Fe, New Mexico USA 87502

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LAKE WATER QUALITY MONITORING, TROPHIC STATE EVALUATION, AND STANDARDS ASSESSMENTS FOR:

Abiquiu Reservoir, El Vado Reservoir, Heron Reservoir, Bill Evans Lake, Lake Van, Lea Lake, Figure Eight Lake, Bitter Lake, Bitter Lake Sink Hole #19, Tres Lagunas N.E., Perch Lake, Serpent Lake, Middle Fork Lake, Canjilon Lake, Williams Lake, Ned Houk Lake, Bosque Redondo Lake, Santa Fe Lake and Nambe Lake, New Mexico USA

2007

EXECUTIVE SUMMARY

During 2007, the Monitoring and Assessment Section of the Surface Water Quality Bureau of the New Mexico Environment Department conducted water quality and biological assessment surveys of nineteen lacustrine systems throughout New Mexico. These surveys were partially funded by EPA grants and were completed as the survey component of an Environmental Protection Agency funded §104(b)(3) lakes nutrient criteria development grant, and in fulfillment of work-plan commitments of the *FY 2007 §106 Work Program for Water Quality Management.*

Four of the lake surveys occurred concurrently with intensive Total Maximum Daily Load (TMDL) stream studies conducted within the Chama and Gila River watersheds. These joint lake and stream surveys help to ensure a timely return to the lake systems as watersheds are revisited and add to the understanding of surface waters within the overall watershed. The remainder of the nineteen lakes were randomly chosen from subsets of lake types and sizes to further contribute to a lake nutrient criteria development study funded by the Environmental Protection Agency under the Clean Water Act §104(b)(3). All lake studies received a full sampling effort for all applicable water quality criteria except that some smaller waterbodies were visited on only one occasion. Water quality sampling methods used during these surveys were in accordance with the "Quality Assurance Project Plan for Water Quality Management Programs" (NMED 2007).

Lakes surveyed ranged from three large mainstem reservoirs to relatively small impoundments, high elevation cirque lakes, sinkholes and ponds. Specific sites included:

- Abiquiu, El Vado and Heron Reservoirs all large impoundments located on the Chama River, a primary tributary to the Rio Grande in north central NM
- Bill Evans Lake, an off channel impoundment where source water is pumped from the Gila River near Silver City, NM
- Figure Eight Lake (sinkhole) and Lea Lake (large sinkhole derived lake) were studied within the Bottomless Lakes State Park in Southeastern NM
- Bitter Lake (saline playa lake) and Bitter Lakes Sinkhole #19 within the Bitter Lakes National Wildlife Refuge near Roswell, NM
- Tres Lagunas NE (small impoundment) and Perch Lake (large sinkhole) were studied near Santa Rosa, NM
- Santa Fe and Nambe Lakes, cirque lakes located within the Santa Fe National Forest, NM
- Serpent, Middle Fork and Williams Lakes, cirque lakes located within the Carson National Forest, NM
- Bosque Redondo Lake (oxbow lake), Ned Houk Lake and Lake Van (municipal park lakes) in east-central and southeast NM.

The following lake assessments provide information pertaining to water quality, biological integrity, trophic state, limiting nutrients, water quality criteria exceedence and water quality standards specific to designated and existing uses in the State of New Mexico Standards for Interstate and Intrastate Surface Waters (NMAC 2007).


Serpent Lake, Carson National Forest, New Mexico, 2007.

Physical, chemical and biological sampling at lake stations include total and dissolved nutrients, total and dissolved metals, major ions including total dissolved solids, total suspended solids, hardness and alkalinity, radionuclides, volatile and semi-volatile organic compounds, cyanide, and microbiological collections. Samples were also collected for chlorophyll, phytoplankton and benthic diatom analysis.

Because of the large amount of data collected, only a pertinent subset of these data is included in this report. All data are available upon request. The following summaries detail those results specifically related to the general physical nature, trophic state, limiting nutrient or criteria exceedence and consequent attainment status for designated or existing uses specific to the particular lake system.

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WATER QUALITY ASSESSMENT SURVEYS OF NINETEEN NEW MEXICO LAKES APRIL THROUGH NOVEMBER, 2007

Danny R. Davis, Principal Investigator

1.0 Abiquiu Reservoir Rio Arriba County, April 11, July 24, and November 6, 2007

Background

The U.S. Army Corp of Engineers (USACE) completed construction of Abiquiu Dam in February of 1963. As the largest earthfill dam in New Mexico, it boasts a 550-meter (1,800 ft) long, 104-meter (340 ft) high structure (USACE 2000). Abiquiu Reservoir captures water from a 5,558 square kilometer (2,146 mi^2) watershed, which includes waters from Rio Chama, Cañones Creek, Rio Puerco de Chama, and Canjilon Creek. Maximum storage capacity is 1,478 x 10^6 $meters^3$ (1,198,500 acre-feet) but lacks any form of conservation or dead storage pool in its design purpose (USGS 2003). The reservoir is located within the Arizona/New Mexico Plateau of the Xeric West aggregate ecoregion (Omernik 2006) with a mean elevation of 1,890 meters (6,200 ft.) above sea level. Precipitation over a fifty year history averages 24.7 cm (9.88 in.) per year with pan evaporation averaging 180 cm (72.1 in) per year resulting in a 155 cm (62.22 in) water deficit per year (WRCC – DRI 2009).

The reservoir was originally designed for flood and sediment control, but following a 1986 contract with the City of Albuquerque, which agreed to store up to 200,000 acre-feet of water, the reservoir now supports other functions such as irrigation storage, camping, boating, and fishing. Common fish species found in the lake include catfish, crappie, largemouth bass, smallmouth bass, rainbow trout, and brown trout. The USACE also manages two six-megawatt hydroelectric turbines within the dam that supply power to the city of Los Alamos, New Mexico. Current plans are to install a low-flow turbine within a year that will continue to supply electricity even during low flow conditions and will also meet federal government definitions as a renewable energy (David Dutton, pers. Com.).

In 2007, SWQB successfully completed three seasonal visits to two lake stations. These stations included a deep station (Abiquiu Reservoir at the dam) and a shallow station (Abiquiu Reservoir near the Rio Chama inlet).

Abiquiu Reservoir, 2007.

Physical / Chemical Data

Physical measurements collected at Abiquiu Reservoir included Secchi depth, Forel-Ule color, pH, conductivity, turbidity, dissolved oxygen, and temperature (Table 1.1). Lake chemistry sampling consisted of total, dissolved and calculated nutrients, anions and cations, total and dissolved heavy metals, volatile and semi-volatile organics, radionuclides, bacteria, and cyanide, which cover all water quality criteria pertinent to the protection of all designated or existing uses (Table 1.0).

Table 1.0. Chemical analyses performed seasonally by station.

Samples Collected	Abiquiu Reservoir Deep			Abiquiu Reservoir Shallow		
	Spring	Summer	Fall	Spring	Summer	Fall
Major Anions and Cations	X	X	X	MDP	X	X
Total Nutrients	X	X	X	MDP	X	X
Dissolved Nutrients	X	X	X	MDP	X	X
Total Mercury and Selenium	X	X	X	MDP	X	X
Dissolved Metals	X	X	X	MDP	X	X
Radionuclides		X	X	MDP		
Volatile Organics		X	X	MDP		
Semi-Volatile Organics		X	X	MDP		
Cyanide		X	X	MDP		
E. coli	X	X	X			

MDP = Missing Data Point.

Table 1.1. Physical Characteristics for Abiquiu Reservoir, 2007

Physical Characteristics		Deep Station	Shallow Station
Secchi (m)	Sp	1.5	MDP
	Su	5.0	1.5
	Fall	0.6	1.3
Forel Ule Color	Sp	11	MDP
	Su	10	11
	Fall	10	10
Maximum Depth (m)	Sp	Est. ~40	MDP
	Su	39	9.5
	Fall	35.5	4.8
Euphotic Zone (m)	Sp	~5	MDP
	Su	7.25	6.0
	Fall	2.0	4.5
Surface Area km^2 (Acres)	Sp	15.74 (3,886)	
	Su	15.74 (3,884)	
	Fall	16.16 (3,990)	
Storage Capacity m^3 (Ac. Ft.)	Sp	212×10^6 (172,108)	
	Su	212×10^6 (171,915)	
	Fall	223×10^6 (181,475)	
Anoxic Hypolimnion * (Y/N)	Sp	MDP	MDP
	Su	No	No
	Fall	No	No
Stratified (Y/N) @ depth (m)	Sp	MDP	MDP
	Su	Yes (6-7)	Yes (6-7)
	Fall	No	No
pH (s.u.)	Sp	7.4	MDP
	Su	6.82	8.05
	Fall	7.33	8.02
Conductivity (µS)	Sp	324	MDP
	Su	325	322
	Fall	314	313
Turbidity (NTUs)	Sp	5.10	MDP
	Su	1.25	9.0
	Fall	15.6	7.8
Integrated Sample surface to (m)	Sp	5.0	MDP
	Su	25	8.0
	Fall	2.0	0.5
Dissolved Oxygen ** (mg/L)	Sp	9.93	MDP
	Su	5.89	5.76
	Fall	5.82	6.52

Physical Characteristics		Deep Station	Shallow Station
Dissolved Oxygen Bottom (mg/L)	Sp	11.66	MDP
	Su	2.98	2.79
	Fall	6.12	6.50
Temperature ** (°C)	Sp	8.69	MDP
	Su	23.04	23.23
	Fall	12.80	12.53
Temperature Bottom (°C)	Sp	MDP	MDP
	Su	13.61	17.21
	Fall	12.66	12.46

NOTES: * Anoxia exists when DO < 0.5 mg/L
** Dissolved oxygen and temperature are mean values from the epilimnion or upper 1/3 of water column
Sp = Spring; Su = Summer; MDP = missing data point.

All physical and chemical parameters were well below levels of concern except for dissolved oxygen (D.O.). Dissolved oxygen is assessed following sampling procedures outlined in segment 20.6.4.14 (NMAC 2007), where "water quality measurements taken at intervals in the entire water column at a sampling station shall be averaged for the epilimnion, or in the absence of an epilimnion, for the upper one-third of the water column of the lake to determine attainment of criteria." Three of five D.O. results were slightly below the 6.0 mg/L criterion for coldwater aquatic life. However, D.O. results fully supported the warmwater aquatic life use (5.0 mg/L). Only criteria exceedence are discussed below, however all data are available upon request.

Nutrient Data

Abiquiu Reservoir upper lake area.

Currently, lake and reservoir criteria specific to this ecoregion are being developed for total nitrogen and total phosphorous for use as a multiparametric nutrient assessment tool. Until this assessment tool is complete, nutrient assessments are provided using methods and indicators consistent with past assessment.

Water quality studies have been performed prior to this investigation. In 1978, Abiquiu Reservoir was classified as mesotrophic in a study conducted by investigators from the University of New Mexico, which was later updated to a mesoeutrophic condition in 1980 (Johnson and Barton 1980). In 1988, the Surface Water Quality Bureau (SWQB) conducted a water quality study on Abiquiu Reservoir, which resulted in an overall Oligotrophic condition, probably as a function of dilution due to high reservoir storage volume during that survey year (Potter and Davis 1989). In 1999, the SWQB conducted another water quality study on Abiquiu Reservoir, which resulted in an overall oligomesotrophic determination (Davis and Joseph 1999).

Table 1.2. Trophic State (Carlson 1977)

		Deep Station	Shallow Station
Secchi Depth	Sp	Eutrophic	MDP
	Su	Oligomeso	Eutrophic
	Fall	Eutrophic	Eutrophic
Chlorophyll *a*	Sp	Oligotrophic	MDP
	Su	Oligomeso	Oligomeso
	Fall	Oligomeso	Mesotrophic
Total Phosphorous	Sp	Oligotrophic	MDP
	Su	Oligotrophic	Oligotrophic
	Fall	Oligotrophic	Oligotrophic
Total Nitrogen	Sp	Oligomeso	MDP
	Su	Oligotrophic	Oligomeso
	Fall	Mesotrophic	Oligomeso
Overall Trophic Condition		**Oligomesotrophic**	

Data collected during the 2007 study indicate that Abiquiu Reservoir be classified as oligomesotrophic according to Carlson's (1977) indices for Secchi depth, chlorophyll *a*, total phosphorus, total nitrogen, and algal community composition (Likens 1975) (Table 1.2). These results are consistent with earlier assessments by Potter and Davis (1989) and Davis and Joseph (1999). Nitrogen and phosphorus were co-limiting nutrients for algal productivity during the spring visit whereas nitrogen was limiting in the summer. During the fall sampling effort, the deep station at the dam showed phosphorous as the limiting nutrient whereas the shallow station was nitrogen limited (Table 1.3). The 1988 and 1999 studies both showed phosphorus as the limiting nutrient for algal development.

Table 1.3. Nutrient Variables

		Deep Station	Shallow Station
Chlorophyll *a* (μg/L)	Sp	0.28	MDP
	Su	1.07	1.87
	Fall	1.34	3.46
Limiting Nutrient	Sp	N/P	MDP
	Su	N	N
	Fall	P	N
Total Phosphorus (mg/L)	Sp	< 0.03	MDP
	Su	0.017	0.024
	Fall	0.022	0.024
Total Nitrogen (mg/L)	Sp	0.199	MDP
	Su	0.162	0.189
	Fall	0.480	0.189

Biological Data

Phytoplankton

Seasonal succession of the phytoplankton community was represented by high abundance of Cryptophyta and Chrysophyta in spring, increasing abundance of Bacillariophyta, Cyanophyta, and Chlorophyta through summer, and a secondary bloom of cryptophytes and chrysophytes in fall. Species of *Komma*, *Cryptomonas,* and small nano-flagellates were among the first colonizers in the early growing season, whereas species of *Fragilaria*, *Aulacoseira*, and a coccoid, blue-green algae were dominant during the summer visit. Fall phytoplankton composition had returned to a Cryptophyta dominated community represented by *Komma sp.* and *Cryptomonas,* which was followed by the blue-green *Microcystis.* Small, non-described nano-flagellates were also significant members within this fall sample. It is important to note that blue-green algae were observed during both the summer and fall sampling visits; however they represented less than sixteen percent of the community during the summer and less than nine percent of the total phytoplankton community during the fall visit. The predominance of Cryptophytes and diatoms during all sample visits is supportive of the overall oligo-mesotrophic conditions found during this study period (Likens 1975).

Diatom Community Composition

A single multiple substrate sample was collected during the summer visit to determine the diatom community composition. From this sample, 509 frustules were counted and 25 species of diatoms from 14 genera were identified. The dominant species, which comprised about sixty-one percent of the community, was *Achnanthidium minutissimum* (Kützing) Czarnecki, a ubiquitous and abundant diatom. *Fragilaria capucina* var. *gracilis* (Østrup) Hustedt, another common diatom, was the second most abundant species comprising twelve percent of the community. Diversity according to Shannon and Weaver (1949) was high, with an equitability value of 0.68.

Abiquiu Reservoir, 2007.

Water Quality Status Assessment

Abiquiu Reservoir is classified under water quality segment 20.6.4.117 in the *New Mexico Water Quality Standards for Interstate and Intrastate Surface Waters* with designated uses of irrigation, livestock watering, wildlife habitat, primary contact, coldwater aquatic life, and warmwater aquatic life (NMAC 2007). Because of the large amount of data collected, only pertinent subsets of these data have been included in this report. All data are available upon request. Assessment of chemical data collected during 2007 indicated that irrigation, primary contact, wildlife habitat, and livestock watering are fully supported (Table 1.4). Both the coldwater and warmwater aquatic life uses remain impaired due to continued fish consumption advisory for mercury in fish tissue. Finally, dissolved oxygen (D.O.) was added as a cause of non-support for the coldwater aquatic life use because of the low D.O. values observed during this study. This type of D.O. exceedence has never been observed at Abiquiu Reservoir, so it presents some questions and uncertainties as to the cause and nature of these lower D.O. values. This is especially curious considering the fact that measured nutrient concentrations did not appear sufficiently high to significantly increase oxygen demand; chlorophyll *a*, and water color, or decrease Secchi depth, which were indicative of moderate to low nutrient concentrations. In addition, trophic state determinations according to Carlson fell within the overall oligomesotrophic range. The consistent lower dissolved oxygen results from Abiquiu Reservoir as well as El Vado and Heron Reservoirs, which were sampled the day immediately following Abiquiu, suggests possible inconsistencies in equipment function; however equipment calibration sheets used in preparation of the sampling trips showed acceptable calibration values. As such, these data must be taken at face value with future D.O. data collection needed to either confirm or remove this impairment listing for dissolved oxygen concentration.

Table 1.4. Summary of attainment status for all designated uses

Designated or Existing Use	Criteria Exceedence	Attainment Status
Coldwater Aquatic Life	Mercury in Fish Tissue* and Dissolved Oxygen	Not Supporting
Warmwater Aquatic Life	Mercury in Fish Tissue*	Not Supporting
Irrigation	None	Fully Supporting
Primary Contact	None	Fully Supporting
Livestock Watering	None	Fully Supporting
Wildlife Habitat	None	Fully Supporting

* "Mercury in Fish Tissue" is a historic listing and a fish advisory remains for Abiquiu Reservoir. Mercury will continue to be a cause of non-support until new findings show that this cause no longer exists.

2.0 El Vado Reservoir
Rio Arriba County, April 11, September 25, and November 6, 2007

Background

During 2007, an intensive water quality survey was conducted on El Vado Reservoir during spring, summer and fall seasons, and at two established monitoring stations, El Vado Deep near the dam and El Vado Shallow near shale point. El Vado Reservoir is formed by a steel faced, rock fill dam which impounds the Rio Chama with about 2,260 km^2 (873 mi^2) of upstream watershed area (USGS 2003). Maximum storage capacity is 229 x 10^6 $meters^3$ (186,250 acre-feet), with a surface area of 12.96 km^2 (3,200 acres). The reservoir is located within the Southern Rockies of the Xeric West aggregate ecoregion (Omernik 2006) with a mean elevation of 2,104 meters (6,902 ft.) above sea level. Precipitation over an eighty year history of record averages 36.8 cm (14.50 in.) per year (WRCC – DRI 2009) with pan evaporation averaging 71.6 cm (28.18 in) per year resulting in a 42 cm (16.6 in) water deficit per year (Gabin and Lesperance 1977).


El Vado Reservoir, courtesy of New Mexico State Parks

El Vado Lake is located in north-central New Mexico approximately 170 km (106 mi) northwest of Santa Fe, 45 km (27 mi) southwest of Chama and 25 km (15 mi) west of Tierra Amarilla, New Mexico. El Vado dam began impounding Rio Chama water in January of 1935 originally for irrigation use by the Middle Rio Grande Conservancy District, but since December of 1972, contract water from the San Juan-Chama project has also been stored at the reservoir. This increase in storage has added to the recreational opportunities that now include camping, boating, and fishing. These activities are managed by the El Vado Lake State Park, which provides and maintains camping facilities, boat ramp and other recreational activities. Common fish species taken from the lake include rainbow trout (*Oncorhynchus mykiss*) Kokanee salmon (*Oncorhynchus nerka*), and brown trout (*Salmo trutta*). Many species of migratory waterfowl and shore birds are common. Nesting Osprey and wintering Bald and Golden Eagles are common.

Water quality studies have been performed prior to this investigation. In 1978, El Vado Reservoir was classified as early eutrophic to mesotrophic in a national eutrophication study conducted by the U.S. Environmental Protection Agency (USEPA). In 1989, the Surface Water Quality Bureau (SWQB) conducted a water quality study on El Vado Reservoir, which resulted in an overall mesotrophic condition (Davis and Potter 1990), and again in 1998, El Vado again displayed mesotrophic lake conditions over a multi-seasonal, two station sampling study (Davis and Joseph 1998).

Physical / Chemical Data

Lake chemistry sampling consisted of total, dissolved and calculated nutrients, anions and cations, total and dissolved heavy metals, volatile and semi-volatile organics, radionuclides, bacteria, and cyanide, which cover all water quality criteria pertinent to the protection of all designated or existing uses (Table 2.0). Physical measurements collected at El Vado Reservoir included Secchi depth, Forel-Ule color, pH, specific conductance, turbidity, dissolved oxygen, and temperature (Table 2.1).

Table 2.0. Chemical analyses performed seasonally by station.

Samples Collected	El Vado Deep			El Vado Shallow		
	Spring	Summer	Fall	Spring	Summer	Fall
Major Anions and Cations	X	X	X	MDP	X	X
Total Nutrients	X	X	X	MDP	X	X
Dissolved Nutrients	X	X	X	MDP	X	X
Total Mercury and Selenium	X	X	X	MDP	X	X
Dissolved Metals	X	X	X	MDP	X	X
Radionuclides	X	X		MDP		
Volatile Organics	X	X		MDP		
Semi-Volatile Organics	X	X		MDP		
Cyanide	X	X		MDP		
E. coli	X	X	X			

MDP = Missing Data Point.

El Vado Reservoir at Dam Station

Table 2.1. Physical Characteristics for El Vado Reservoir, 2007

Physical Characteristics		Deep Station	Shallow Station
Secchi (m)	Sp	1.0	MDP
	Su	1.4	1.4
	Fall	0.5	0.65
Forel-Ule Color	Sp	10	MDP
	Su	11	11
	Fall	12	12
Maximum Depth (m)	Sp	30	MDP
	Su	31	4.5
	Fall	31.3	4.5
Euphotic Zone (m)	Sp	4	MDP
	Su	4.1	4.1
	Fall	2.0	2.5
Surface Area km^2 (Acres)	Sp	10.66 (2,634)	
	Su	10.08 (2,489)	
	Fall	10.03 (2,479)	
Storage Capacity m^3 (Ac. Ft.)	Sp	162 x 10^6 (172,108)	
	Su	151 x 10^6 (171,915)	
	Fall	150 x 10^6 (181,475)	
Anoxic Hypolimnion * (Y/N)	Sp	No	MDP
	Su	No	No
	Fall	No	No
Stratified (Y/N) @ depth (m)	Sp	MDP	MDP
	Su	Yes (10)	No
	Fall	No	No
pH (s.u.)	Sp	7.42	MDP
	Su	6.97	7.83
	Fall	7.95	7.94
Conductivity (µS)	Sp	201	MDP
	Su	203	203
	Fall	211	211
Turbidity (NTUs)	Sp	14.2	MDP
	Su	10.4	6.0
	Fall	24.8	16.6
Integrated Sample surface to (m)	Sp	4.0	MDP
	Su	27	0.25
	Fall	2.0	0.5
Dissolved Oxygen **(mg/L)	Sp	9.96	MDP
	Su	4.81	6.04
	Fall	5.65	5.84

Physical Characteristics		Deep Station	Shallow Station
Dissolved Oxygen Bottom (mg/L)	Sp	8.77	MDP
	Su	3.02	6.02
	Fall	5.35	5.86
Temperature ** (°C)	Sp	7.76	MDP
	Su	17.93	19.51
	Fall	11.42	12.52
Temperature Bottom (°C)	Sp	5.6	MDP
	Su	11.65	18.17
	Fall	11.27	11.68

NOTES: ***** Anoxia exists when DO < 0.5 mg/L
** Dissolved oxygen and temperature are mean values from the epilimnion or upper 1/3 of water column
Sp = Spring; Su = Summer; MDP = missing data point.

All physical and chemical parameters were well below levels of concern except for dissolved oxygen (D.O.). Dissolved oxygen is assessed following sampling procedures outlined in segment 20.6.4.14 (NMAC), where "water quality measurements taken at intervals in the entire water column at a sampling station shall be averaged for the epilimnion, or in the absence of an epilimnion, for the upper one-third of the water column of the lake to determine attainment of criteria." Three of five D.O. results were below the 6.0 mg/L criterion for coldwater aquatic life (Table 2.1). Both El Vado and Abiquiu dissolved oxygen exceedences occurred during the same seasonal trips and using the same field equipment. Pre-survey sonde calibration worksheets showed equipment tolerances were within acceptable ranges, so until further D.O. profiles can be collected these results will stand with the corresponding impairment listing for coldwater aquatic life.

Table 2.2. Nutrient Variables

		Deep Station	Shallow Station
Chlorophyll *a* (µg/L)	Sp	6.18	MDP
	Su	MDP	1.78
	Fall	0.56	0.75
Limiting Nutrient	Sp	N	MDP
	Su	N	N
	Fall	N	N
Total Phosphorus (mg/L)	Sp	0.052	MDP
	Su	0.020	0.012
	Fall	4.36 *	0.015
Total Nitrogen (mg/L)	Sp	0.271	MDP
	Su	<0.15	<0.15
	Fall	37.8 *	0.34

*** Results are suspect and these values far exceed historical values.**

Nutrient Data

Currently, lake and reservoir criteria specific to this ecoregion are being developed for total nitrogen and total phosphorous for use as a multiparametric nutrient assessment tool. Until this assessment tool is complete, nutrient assessments are provided using methods and indicators consistent with past assessment. Table 2.2 shows results for common nutrient variables.

Data collected during the 2007 study indicate that El Vado Reservoir may be classified as mesotrophic according to Carlson's (1977) indices for Secchi depth, chlorophyll *a*, total phosphorus, total nitrogen, and algal community composition (Likens 1975) (Table 2.3). Though Secchi depth results indicate eutrophic conditions, the reduced water transparency was due to sediment load, not nutrient driven productivity. Chlorophyll, nitrogen and phosphorous results were, for the most part, indicative of oligomesotrophic conditions.

Nitrogen and phosphorous results during the fall sampling visit indicated dystrophic conditions, however, these results seem suspect and are in disagreement with overall trophic indicators. Upon reviewing Total Kjeldahl Nitrogen (TKN) and Total Phosphorus (TP) from surveys conducted in 1989 and 1998, the highest TKN result from either study was 0.730 mg/L compared to the fall 2007 value of 37.8 mg/L. The highest value for TP from previous surveys was 0.294 mg/L compared to the fall 2007 sample result of 4.36 mg/L. These two exceedingly high results are more than an order of magnitude greater than any previous result and push what is a more oligomesotrophic condition to the more mesotrophic range. Furthermore, if TN and TP concentrations were actually this high one might also expect to observe variation in other parameters such as dissolved oxygen and chlorophyll *a*, however these parameters are consistent with previous measurements. Finally, although the analytical lab that conducted the analyses cannot find a reason to reject these results, they too find these results to be extremely questionable. In summary, while there is no reason to reject these values, they must be considered suspect.

Table 2.3. Trophic State (Carlson 1977)

		Deep Station	**Shallow Station**
Secchi Depth	Sp	Eutrophic	MDP
	Su	Eutrophic	Eutrophic
	Fall	Eutrophic	Eutrophic
Chlorophyll *a*	Sp	Mesotrophic	MDP
	Su	Oligotrophic	Oligomesotrophic
	Fall	Oligotrophic	Oligotrophic
Total Phosphorous	Sp	Eutrophic	MDP
	Su	Mesotrophic	Oligomesotrophic
	Fall	Dystrophic ?	Oligotrophic
Total Nitrogen	Sp	Oligomesotrophic	MDP
	Su	Oligotrophic	Oligotrophic
	Fall	Dystrophic ?	Oligomesotrophic
Overall Trophic Condition		**Oligomesotrophic**	

As such, the data are presented in this report but were not used in making the overall conclusion on the conditions of El Vado Reservoir. Results are consistent with earlier assessments by the U.S. Environmental Protection Agency National Eutrophication Survey (1977), Potter and Davis (1989) and Davis and Joseph (1999). Nitrogen was the limiting nutrient for algal productivity during all seasonal visits (Table 2.2). This is in general agreement with past study results except for the 1989 study where nitrogen and phosphorus were found to be co-limiting.

Biological Data

Phytoplankton

Cryptomonas and *Komma* species are both members of the Cryptophyta, and were, by far, the most common groups of phytoplankton observed during all seasonal visits. The second most abundant group of phytoplankton was the Bacillariophyceae (diatoms) and small nano-flagellates. No members of the Cyanophyta or blue-green algae were observed in any of the samples submitted for examination, which further supports an overall mesotrophic classification determined during this sampling study.

Diatom Community Composition

A single multiple substrate sample was collected during the summer visit to determine the diatom community composition. From this sample, 505 cells were counted and 29 species of diatoms from 13 genera were identified. The dominant species, which comprised about sixty-one percent of the community, was *Achnanthidium minutissimum* (Kützing) Czarnecki, a ubiquitous and abundant benthic diatom. *Cocconeis pediculus* Ehrenburg was the second most common diatom representing about eight percent of the community. Diversity according to Shannon and Weaver (1949) was high, with an equitability value of about 0.72.

Water Quality Status Assessment

El Vado Reservoir is classified under water quality segment 20.6.4.120 in the *New Mexico Water Quality Standards for Interstate and Intrastate Surface Waters* with designated uses of irrigation, livestock watering, wildlife habitat, primary contact, and coldwater aquatic life (NMAC 2007). Because of the large amount of data collected, only pertinent subsets of these data have been included in this report. All data are available upon request. Assessment of chemical data

collected during 2007 indicated that irrigation, primary contact, wildlife habitat, and livestock watering are fully supported (Table 2.4). The coldwater aquatic life use has now become a cause of non-support for the coldwater aquatic life use because of the low D.O. values observed during this study. This type of D.O. exceedence has never been observed at El Vado Reservoir, so it presents some questions and uncertainties as to the cause and nature of these lower D.O. values. This is especially curious considering that measured nutrients concentrations, except for the suspiciously high TKN and Total Phosphorous, did not appear sufficiently high to significantly increase oxygen demand, Secchi depth, chlorophyll *a*, and water color. These were indicative of moderate nutrient concentrations and trophic state determinations according to Carlson were well within the mesotrophic range. Without the two dystrophic results encountered during the fall sampling visit, the overall trophic state would have reflected more oligomesotrophic conditions.
The consistent lower dissolved oxygen results from Abiquiu Reservoir as well as El Vado and Heron Reservoirs, which were sampled the day immediately following Abiquiu, suggests possible inconsistencies in equipment function however equipment calibration sheets used in preparation for the sampling trips showed acceptable calibration values. As such, these data must be taken at face value with future D.O. data collection needed to either confirm or remove this impairment listing for dissolved oxygen concentration.

Table 2.4. Summary of attainment status of designated uses for El Vado Reservoir.

Designated or Existing Use	Criteria Exceedence	Attainment Status
Coldwater Aquatic Life	Dissolved Oxygen	Not Supporting
Irrigation	None	Fully Supporting
Primary Contact	None	Fully Supporting
Livestock Watering	None	Fully Supporting
Wildlife Habitat	None	Fully Supporting

3.0 Heron Reservoir
Rio Arriba County, May 16, September 26, and November 7, 2007

Background

SWQB conducted a multi-seasonal water quality survey on Heron Reservoir during spring, summer and fall of 2007, at two established monitoring stations, Heron Deep near the dam and Heron Shallow near the narrows outlet. Heron Reservoir is formed by an earth fill dam which impounds San Juan/Chama diversion water through three Colorado Compact tunnels; the Blanco, Oso and Azotea tunnels. Willow Creek and, to a smaller extent, Horse Creek also flow into the reservoir, representing about 500 km^2 (193 mi^2) of watershed, not including the diverted water source (USGS 2003). Maximum storage capacity is 494 x 10^6 m^3 (401,300 acre-feet), with a surface area of 23.9 km^2 (5,900 acres). The reservoir is located within the Southern Rockies of the Xeric West aggregate ecoregion (Omernik 2006) with a mean elevation of 2,194 meters (7,200 ft.) above sea level. Precipitation recorded from nearby El Vado Reservoir, representing over eighty years of record, averages 36.8 cm (14.50 in.) per year (WRCC – DRI 2009) with pan evaporation averaging 71.6 cm (28.18 in) per year resulting in a 42 cm (16.6 in) water deficit per year (Gabin and Lesperance 1977).

Heron Reservoir, May 2007

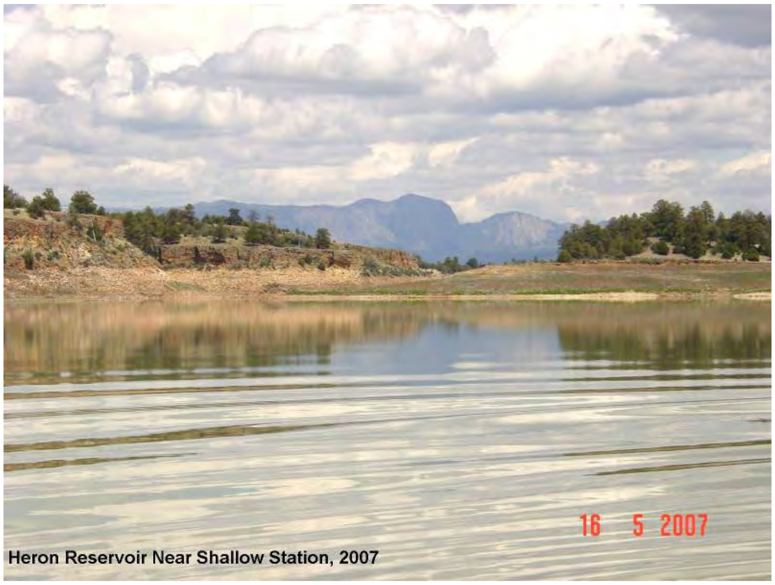
Heron Reservoir is located in north-central New Mexico approximately 167 kilometers (104 miles) northwest of Santa Fe, 34 km (21 mi) southwest of Chama and 20 km (12.5 mi) west of Tierra Amarilla, New Mexico. Heron dam was completed in 1971 and began impounding San Juan–Chama project water upon completion of the diversion project. The project is managed by the Bureau of Reclamation, who controls water delivery to downstream users such as the Middle Rio Grande Conservancy District, Cities of Albuquerque and Santa Fe, and the U.S. Department of Energy.

Recreational activities are provided and managed by the Heron Lake State Park where camping, fishing and boating are primary activities enjoyed by the public. The park has been designated a “quiet lake” such that boats are required to travel at “no-wake” speeds. Common fish species taken from the lake include rainbow trout (*Oncorhynchus mykiss*) and Kokanee salmon (*Oncorhynchus nerka*). Many species of migratory waterfowl and shore birds are common. Nesting Osprey and wintering Bald and Golden Eagles are common.

Water quality studies have been performed prior to this investigation. In 1987, Heron Reservoir was sampled by Potter and Davis during August of that year and at two stations. A formal report of that single visit was not produced, however, examination of those data suggest a low nutrient, clear, oligotrophic condition on that day. One other multi-seasonal water quality survey was conducted on Heron Reservoir by Davis and Hopkins (1991) of the SWQB. This three-season, two station study resulted in an overall mesotrophic determination using both nutrient and response variables plus phytoplankton community composition.

Physical / Chemical Data

Lake chemistry sampling consisted of total, dissolved and calculated nutrients, anions and cations, total and dissolved heavy metals, volatile and semi-volatile organics, radionuclides, bacteria, and cyanide, which cover all water quality criteria pertinent to the protection of all designated or existing uses (Table 3.0). Physical measurements collected at Heron Reservoir included Secchi depth, Forel-Ule color, pH, specific conductance, turbidity, dissolved oxygen, and temperature (Table 3.1).



Heron Reservoir Near Shallow Station, 2007

Table 3.0. Chemical analyses performed seasonally by station.

Samples Collected	Heron Deep			Heron Shallow		
	Spring	Summer	Fall	Spring	Summer	Fall
Major Anions and Cations	X	X	X	X	X	X
Total Nutrients	X	X	X	X	X	X
Dissolved Nutrients	X	X	X	X	X	X
Total Mercury and Selenium	X	X	X	X	X	X
Dissolved Metals	X	X	X	X	X	X
Radionuclides	X	X				
Volatile Organics	X	X				
Semi-Volatile Organics	X	X				
Cyanide	X	X				
E. coli	X	X	X			

Table 3.1. Physical Characteristics for Heron Reservoir, 2007

Physical Characteristics		Deep Station	Shallow Station
Secchi (m)	Sp	0.8	0.5
	Su	3.9	1.8
	Fall	1.0	1.7
Forel Ule Color	Sp	11	12
	Su	9	10
	Fall	11	11
Maximum Depth (m)	Sp	49	4.25
	Su	45.5	4.5
	Fall	42.2	8.0
Euphotic Zone (m)	Sp	3	1.5
	Su	7.0	>4.5
	Fall	3.5	6.0
Surface Area km^2 (Acres)	Sp	15.95 (3,939)	
	Su	17.45 (4,310)	
	Fall	17.16 (4,239)	
Storage Capacity m^3 (Ac. Ft.)	Sp	245×10^6 (199,004)	
	Su	284×10^6 (231,009)	
	Fall	277×10^6 (224,682)	
Anoxic Hypolimnion * (Y/N)	Sp	No	No
	Su	No	No
	Fall	No	No
Stratified (Y/N) @ depth (m)	Sp	Yes (6)	No
	Su	Yes (10)	No
	Fall	No	No
pH (s.u.)	Sp	7.05	7.08
	Su	8.07	8.20
	Fall	7.95	8.07
Conductivity (µS)	Sp	213	187
	Su	212	213
	Fall	214	216
Turbidity (NTUs)	Sp	13	20.6
	Su	7.6	5.2
	Fall	9.6	7.7
Integrated Sample surface to (m)	Sp	48	2.0
	Su	30	4.0
	Fall	3.0	6.0
Dissolved Oxygen ** (mg/L)	Sp	7.72	7.95
	Su	6.72	6.93
	Fall	5.91	6.78

Physical Characteristics		Deep Station	Shallow Station
Dissolved Oxygen Bottom (mg/L)	Sp	1.88	7.68
	Su	4.83	6.92
	Fall	3.24	6.81
Temperature ** (°C)	Sp	13.21	13.3
	Su	17.5	18.31
	Fall	10.52	10.53
Temperature Bottom (°C)	Sp	7.15	10.79
	Su	9.77	18.31
	Fall	9.97	10.28

NOTES: * Anoxia exists when DO < 0.5 mg/L
** Dissolved oxygen and temperature are mean values from the epilimnion (upper 1/3 of water column)
Sp = Spring; Su = Summer; MDP = missing data point.

All physical and chemical parameters were well below levels of concern except for one occasion where dissolved oxygen was slightly below the 6.0 mg/L criterion. Dissolved oxygen is assessed following sampling procedures outlined in segment 20.6.4.14 (NMAC), where "water quality measurements taken at intervals in the entire water column at a sampling station shall be averaged for the epilimnion, or in the absence of an epilimnion, for the upper one-third of the water column of the lake to determine attainment of criteria." As per assessment protocols, this single exceedence does not constitute an aquatic life use impairment, however, mercury in fish tissue remains a cause for non-support of the aquatic life use and will remain until fish tissue concentrations for mercury are below levels of concern.

Nutrient Data

Currently, lake and reservoir criteria specific to this ecoregion are being developed for total nitrogen and total phosphorous for use as a multiparametric nutrient assessment tool. Until this assessment tool is complete, nutrient assessments are provided using methods and indicators consistent with past assessment practices. Table 3.2 shows results for common nutrient variables.

Table 3.2. Nutrient Variables

		Deep Station	Shallow Station
Chlorophyll *a* (µg/L)	Sp	2.34	4.30
	Su	0.37	0.90
	Fall	0.37	3.36
Limiting Nutrient	Sp	N	N
	Su	N	N
	Fall	N	N
Total Phosphorus (mg/L)	Sp	0.018	0.031
	Su	0.015	0.031
	Fall	0.024	0.025
Total Nitrogen (mg/L)	Sp	0.291	0.249
	Su	0.050	0.100
	Fall	0.310	0.360

Data collected during the 2007 study indicate that Heron Reservoir may be classified as mesotrophic according to Carlson's (1977) indices for Secchi depth, chlorophyll *a*, total phosphorus, total nitrogen, and algal community composition (Likens 1975) (Table 3.3). Chlorophyll, nitrogen and phosphorous results were, for the most part, indicative of mesotrophic conditions. These results are consistent with earlier assessment results by Davis (1991), where mesotrophic conditions were also observed. Nitrogen was the limiting nutrient for algal productivity during all seasonal visits (Table 3.2). During the earlier study, nitrogen and phosphorus were determined to be co-limiting overall.

Table 3.3. Trophic State (Carlson 1977)

		Deep Station	**Shallow Station**
Secchi Depth	Sp	Eutrophic	Eutrophic
	Su	Mesotrophic	Eutrophic
	Fall	Eutrophic	Eutrophic
Chlorophyll *a*	Sp	Oligomesotrophic	Mesotrophic
	Su	Oligotrophic	Oligotrophic
	Fall	Oligotrophic	Mesotrophic
Total Phosphorous	Sp	Oligotrophic	Eutrophic
	Su	Mesotrophic	Eutrophic
	Fall	Mesotrophic	Eutrophic
Total Nitrogen	Sp	Oligomesotrophic	Oligomesotrophic
	Su	Oligotrophic	Oligomesotrophic
	Fall	Oligomesotrophic	Mesotrophic
Overall Trophic Condition		**Mesotrophic**	

<u>Biological Data</u>

Phytoplankton

Spring phytoplankton community members consisted primarily of *Cryptomonas* and *Komma* species of the Cryptomonadaceae and Chroomonadaceae respectively, followed by lesser numbers of the diatoms *Nitzschia*, *Aulacoseira* and *Cymbella*. Summer and fall phytoplankton community composition consisted primarily of small nano-flagellates and Komma species, with smaller numbers of diatom genera, *Mallomonas* and the Euglenoid *Trachelomonas* in the fall. The community composition was consistent with those members preferring moderate to low nutrient concentrations in agreement with the overall mesotrophic conditions observed during this survey (Likens 1975). No members of the Cyanophyta or blue-green algae were observed in any of the samples submitted for examination, further supporting the mesotrophic determination.

Fishing near Heron Dam, 2007

Diatom Community Composition

A single multiple substrate diatom sample was collected during the summer visit to determine community composition. From this sample, 511 cells were counted and 23 species of diatoms from 13 genera were identified. The dominant species, which comprised about thirty-four percent of the community, was *Achnanthidium minutissimum* (Kützing) Czarnecki, a ubiquitous and abundant benthic diatom. *Diatoma moniliformis* Kützing was the second most common diatom representing about eighteen percent of the community. Diversity according to Shannon and Weaver (1949) was very high, with an equitability value of about 0.94.

Water Quality Status Assessment

Heron Reservoir is classified under water quality segment 20.6.4.120 in the *New Mexico Water Quality Standards for Interstate and Intrastate Surface Waters* with designated uses of irrigation, livestock watering, wildlife habitat, primary contact, and coldwater aquatic life (NMAC 2007). Because of the large amount of data collected, only pertinent subsets of these data have been included in this report. All data are available upon request. Assessment of chemical data collected during 2007 indicated that irrigation, primary contact, wildlife habitat, and livestock watering are fully supported (Table 3.4). The coldwater aquatic life use remains unsupported due to mercury in fish tissue. Secchi depth, chlorophyll *a*, and water color were indicative of moderate nutrient concentrations and trophic state determinations according to Carlson fell within the overall mesotrophic range.

Table 3.4. Summary of attainment status of designated uses for El Vado Reservoir.

Designated or Existing Use	Criteria Exceedence	Attainment Status
Coldwater Aquatic Life	Mercury in fish tissue	Not Supporting
Irrigation	None	Fully Supporting
Primary Contact	None	Fully Supporting
Livestock Watering	None	Fully Supporting
Wildlife Habitat	None	Fully Supporting

4.0 Bill Evans Lake
Grant County, May 1 and August 28, 2007

Background

During 2007, a multi-seasonal water quality survey was conducted on Bill Evans Lake during spring and summer seasons, at two established monitoring stations, Bill Evans Deep near the dam and Bill Evans Shallow near the northern shore across from the dam. Bill Evans Lake is a 0.251 km^2 (62 acre) impoundment originally built by the Phelps-Dodge Mining Company who constructed the earthfill dam to provide water for their Tyrone copper refining facility. The lake was constructed in 1969 at an elevation of 1,426 meters (4,680 ft) above sea level and sits perched

91.4 meters (300 ft) above the Gila River from where its water is pumped. Estimates from Tyrone Mine records show average storage capacity of 2.6 x 10^6 m^3 (2,100 acre-feet). Starting in 1972, the lake and surrounding adjacent land were leased to the State Game Commission from Phelps Dodge, to manage the recreational activities where fishing, boating, picnicking, primitive camping and access to hiking trails are provided. Bill Evans Lake is located approximately 47 km (29 mi) from Silver City via US 180 and Forest Road 809. The reservoir is generally characterized within the Arizona – New Mexico Mountains of the Xeric West aggregate ecoregion (Omernik 2006). Precipitation recorded from nearby Cliff and Red Rock gauges show precipitation averages 35.6 cm (14.0 in.) per year (WRCC – DRI 2009) and pan evaporation averages 113 cm (44.6 in) per year resulting in an approximate 79 cm (31 in) water deficit per year (Gabin and Lesperance 1977).

One previous water quality study was conducted on Bill Evans Lake prior to this investigation. In 1990, a three season, two station water quality study was conducted by SWQB (Davis 1991). Examination of those data indicated an overall mesoeutrophic condition existed at that time with nitrogen and phosphorus being co-limiting nutrients overall.

Physical / Chemical Data

Lake chemistry sampling consisted of total and dissolved nutrients, anions and cations, total and dissolved heavy metals, volatile and semi-volatile organics, radionuclides, bacteria, and cyanide, which cover all water quality criteria pertinent to the protection of designated or existing uses (Table 4.0). Physical measurements collected at Bill Evans Lake included Secchi depth, Forel-Ule color, pH, specific conductance, turbidity, dissolved oxygen, and temperature (Table 4.1).

Table 4.0. Chemical analyses performed seasonally by station.

Samples Collected	Bill Evans Deep		Bill Evans Shallow	
	Spring	Summer	Spring	Summer
Major Anions and Cations	X	X	X	X
Total Nutrients	X	X	X	X
Dissolved Nutrients	X	X	X	X
Total Mercury and Selenium	X	X	X	X
Dissolved Metals	X	X	X	X
Radionuclides	X	X		
Volatile Organics	X	X		
Semi-Volatile Organics	X	X		
Cyanide	X	X		
E. coli	X	X		

Table 4.1. Physical Characteristics for Bill Evans Lake, 2007

Physical Characteristics		Deep Station	Shallow Station
Secchi (m)	Sp	2.5	2.5
	Su	3.65	3.0
Forel Ule Color	Sp	7	8
	Su	7	7
Maximum Depth (m)	Sp	8.0	4.0
	Su	8.1	5.9
Euphotic Zone (m)	Sp	8.0	8.0
	Su	>8.1	>5.9
Surface Area km^2 (Acres)	Sp	0.25 Km^2 (62 ac)	
	Su		
Storage Capacity m^3 (Ac. Ft.)	Sp	2.6 x 10^6 M^3 (2,100 AF)	
	Su		
Anoxic Hypolimnion * (Y/N)	Sp	No	No
	Su	No	No
Stratified (Y/N) @ depth (m)	Sp	Yes (1-2)	Yes (2-3)
	Su	Yes (0-1)	MDP
pH (s.u.)	Sp	7.94	8.78
	Su	7.81	8.16
Conductivity (µS)	Sp	398	394
	Su	391	396
Turbidity (NTUs)	Sp	3.91	4.76
	Su	2.26	2.56
Integrated Sample surface to (m)	Sp	8.0	3.5
	Su	8.0	0.25
Dissolved Oxygen ** (mg/L)	Sp	8.1	8.4
	Su	6.24	6.01
Dissolved Oxygen Bottom (mg/L)	Sp	6.88	8.82
	Su	0.78	MDP
Temperature ** (°C)	Sp	19.98	20.3
	Su	27.2	28.2
Temperature Bottom (°C)	Sp	10.11	17.24
	Su	20.17	MDP

NOTES: * Anoxia exists when DO < 0.5 mg/L
** Dissolved oxygen and temperature are mean values from the epilimnion (upper 1/3 of water column)
Sp = Spring; Su = Summer; MDP = missing data point.

All physical and chemical parameters were below levels of concern under the current aquatic life use designation, however, this lake is not afforded proper protection of all uses under the current 20.6.4.99 use classification as both warmwater and marginal coldwater uses exist in Bill Evans Lake. If the marginal coldwater aquatic life use was reclassified for this waterbody, two of four temperature exceedences could result in classifying this use as impaired. Lake profiles showed much cooler water temperatures just a meter or two below the surface with acceptable dissolved oxygen concentration. This may indicate that seasonal lake specific temperature criteria may be required if reclassification is considered. Physical conditions are assessed following sampling procedures outlined in segment 20.6.4.14 (NMAC), where "water quality measurements taken at intervals in the entire water column at a sampling station shall be averaged for the epilimnion, or in the absence of an epilimnion, for the upper one-third of the water column of the lake to determine attainment of criteria." As per assessment protocols, the absence of any exceedences of the 34º C aquatic life criteria does not constitute an aquatic life use impairment.

Nutrient Data

Currently, lake and reservoir criteria specific to this ecoregion are being developed for total nitrogen and total phosphorous for use as a multiparametric nutrient assessment tool. Until this assessment tool is complete, nutrient assessments are provided using methods and indicators consistent with past assessment practices. However, the draft nutrient assessment protocol for lakes and reservoirs was reviewed and compared against the August sampling run to Bill Evans as this is considered within the growing season for the respective ecoregion. Nitrogen, phosphorus, chlorophyll and cyanobacterial targets for this assessment protocol were below levels of concern further supporting the determination that nutrients were not a significant concern at Bill Evans Lake during this study. Table 4.2 shows results for common nutrient variables.

Table 4.2. Nutrient Variables

		Deep Station	Shallow Station
Chlorophyll *a* (µg/L)	Spring	6.07	2.96
	Summer	0.84	0.53
Total Phosphorus (mg/L)	Spring	<0.03	<0.03
	Summer	0.031	0.037
Total Nitrogen (mg/L)	Spring	0.276	0.456
	Summer	0.370	0.390
Limiting Nutrient	Spring	N	N
	Summer	N	N

Data collected during the 2007 study indicate that Bill Evans Lake may be classified as oligomesotrophic according to Carlson's (1977) indices for Secchi depth, chlorophyll *a*, total phosphorus, total nitrogen, and algal community composition (Likens 1975) (Table 4.3). Chlorophyll, nitrogen and phosphorous results were overall indicative of oligomesotrophic conditions. These results appear to be an improvement from the earlier assessment results by Davis (1990), where mesoeutrophic conditions were observed. The earlier study also showed significant concentrations of blue-green algae specifically *Anabaena* and *Aphanizomenon*; however samples analyzed for the current study showed no blue-green presence what-so-ever. Nitrogen was the limiting nutrient for algal productivity during both spring and summer visits (Table 4.2).

Table 4.3. Trophic State (Carlson 1977)

		Deep Station	Shallow Station
Secchi Depth	Sp	Mesotrophic	Mesotrophic
	Su	Mesotrophic	Mesotrophic
Chlorophyll *a*	Sp	Mesotrophic	Mesotrophic
	Su	Oligotrophic	Oligotrophic
Total Phosphorous	Sp	Oligotrophic	Oligotrophic
	Su	Oligotrophic	Oligotrophic
Total Nitrogen	Sp	Oligomesotrophic	Mesotrophic
	Su	Oligotrophic	Mesotrophic
Overall Trophic Condition		**Oligomesotrophic**	

Biological Data

Phytoplankton

Spring phytoplankton community members were dominated by the diatom genera *Puncticulata* and *Fragilaria,* which together comprised over 41 percent of the community. *Komma* and the common planktonic diatom species *Asterionella* added another 25 percent to the total. Small nano-flagellates were the fifth most common phytoplankton present of the twenty total genera identified. The summer phytoplankton sample was dominated by the small nano-flagellates followed by Komma species which together comprised about 40 percent of the total community. *Dinobryon sp., Peridinium sp.* and *Peridiniopsis sp.* completed the list of five most common phytoplankton species that totaled about 58 percent of the community composition of twenty-six species. The phytoplankton community compositions for both spring and summer visits were dominated by those members generally associated with lower nutrient concentrations, which is in agreement with Likens (1975). No members of the Cyanophyta (blue-green algae) were observed in any of the samples submitted for examination, further supporting the oligomesotrophic determination.

Diatom Community Composition

A single multiple substrate diatom sample was collected during the summer visit to determine community composition. From this sample, 501 cells were counted and 42 species of diatoms from 22 genera were identified. The dominant species, which comprised about thirty-seven percent of the community, was *Achnanthidium minutissimum* (Kützing) Czarnecki, a ubiquitous and abundant benthic diatom. *Mastogloia smithii* Thwaites and *Staurosira construens* var. *binodis* (Ehrenberg) Hamilton, followed adding another fourteen percent to this total community composition. Diversity according to Shannon and Weaver (1949) was high, with an equitability value of about 0.69.

Water Quality Status Assessment

Bill Evans Lake is classified under water quality segment 20.6.4.99 in the *New Mexico Water Quality Standards for Interstate and Intrastate Surface Waters* with designated uses of aquatic life, livestock watering, wildlife habitat and secondary contact and presumed 101(a)(2) uses of primary contact and warmwater aquatic life (NMAC 2007). Specific criteria applicable to protect these uses fall short of the actual uses that exist at Bill Evans Lake (Table 4.4). Assessment of physical and chemical data collected during 2007 indicated that secondary contact, wildlife habitat, and livestock watering are fully supported. The existing use of warmwater aquatic life was also fully supported during the study year; however, the marginal coldwater aquatic life use, which exists in the form of a trout fishery, showed two out of four exceedences of the 25º C marginal coldwater aquatic life criteria. This temperature criterion is not always attainable at Bill Evans Lake due to the nature of the lake and the water supply source. A segment specific temperature criterion should be discussed and adopted for this lake that first, protects the marginal cold water use, and second, is more characteristic of this unique lake environment.

Table 4.4. Summary of attainment status of designated uses for Bill Evans Lake.

Designated or Existing Use	Criteria Exceedence	Attainment Status
Marginal Coldwater Aquatic Life (existing use)	2/4	Not Supporting
Warmwater Aquatic Life(existing use)	None	Fully Supporting
Primary Contact (presumed use)	None	Fully Supporting
Secondary Contact	None	Fully Supporting
Livestock Watering	None	Fully Supporting
Wildlife Habitat	None	Fully Supporting

5.0 Lea Lake and Figure Eight Lake at Bottomless Lakes State Park Chaves County, June 12, 2007

Background

During 2007, a single-day water quality survey was conducted on two waterbodies located within the Bottomless Lakes State Park east of Roswell, New Mexico. Numerous sinkhole lakes were created by the underground dissolution of minerals causing the surface to sink below ambient groundwater levels. In the case of **Lea Lake**, a series of sinkholes resulted in the largest, deepest and clearest of the park's lakes. Lea Lake has a maximum depth of 27.5 meters (90 ft) and is the only lake where swimming and paddle boating is allowed. The surface area of Lea Lake is .06 km^2 (15 ac) and is at an elevation of 1,054 meters (3,460 ft) above sea level. The daily spring-supplied flow results in almost 2.5 million gallons of water per day, which flows from the lake, through wetland areas and eventually to the Pecos River. Due to the high water clarity, Lea Lake is a popular scuba diving destination as well.

Figure Eight Lake is comprised of two adjacent sinkhole basins separated by an earthen berm nestled within a small forest of salt cedar. Combined surface area for the two pools is 0.008 Km^2 (2.22 ac). The deeper of these two sinkholes is 11.2 meters (37 ft) deep. Unlike some sinkholes that support a winter trout fishery, excessive salinity and low dissolved oxygen in Figure Eight Lake limit aquatic life.

An earlier SWQB study was conducted on five of the sinkhole lakes including Lea Lake (Davis and Joseph 1998). The 2007 sampling effort was the first for Figure Eight Lake, but between the two studies, baseline water quality data has been collected for six of the waterbodies within Bottomless Lakes State Park.

Bottomless Lakes State Park is in the Chihuahuan Desert of the Xeric West aggregate ecoregion (Omernik 2006). Precipitation recorded from nearby Bitter Lakes National Wildlife Refuge, Hagerman and the State Park averages 31 cm (12.2 in) per year (WRCC – DRI 2009) with pan evaporation averaging 126 cm (49.5 in) per year resulting in an approximate 96 cm (38 in) water deficit per year (Gabin and Lesperance 1977).

These two sinkhole lakes represent two of nineteen waterbodies of varying types studied during this sampling season with the principal goal of increasing understanding of nutrient conditions in varying lake types throughout New Mexico. As these two lakes received only a single visit, a formal water quality assessment (which requires a sample size of at least 2) was not possible. However, the breadth of information and data collected from these single sampling events will allow for a classification of these waterbodies affording these unique systems greater protection of existing and future use designations.

Bottomless Lakes State Park is included as critical habitat for the Pecos Pupfish (*Cyprinodon pecosensis*) in a conservation agreement between U.S. Fish and Wildlife, New Mexico Department of Game and Fish and other agencies. This agreement recognizes that the sinkholes and springs associated with the park provide a special haven for the threatened Pupfish. "In New Mexico, it currently occurs mainly in habitats on Bitter Lake National Wildlife Refuge and Bottomless Lakes State Park" (NMDG&F 2006). Other fish likely to occur within both Lea Lake and Figure Eight Lake are the Mexican tetra (*Astyanax mexicanas*) listed as threatened, Plains Killifish (*Fundulus zebrinus*), green sunfish (*Lepomis cyanellis*) Pecos Gambusia (*Gambusia nobilis*) listed as endangered, and mosquito fish (*Gambusia affinis*) (Shawn Denny, personal communication).

<u>Physical / Chemical Data</u>

Lake chemistry sampling consisted of total and dissolved nutrients, anions and cations, total and dissolved heavy metals, volatile and semi-volatile organics, radionuclides, bacteria, and cyanide, which cover all water quality criteria pertinent to the protection of designated or existing uses (Table 5.0). Physical measurements collected at both Lea and Figure Eight Lakes included Secchi depth, Forel-Ule color, pH, specific conductance, turbidity, dissolved oxygen, and temperature (Table 5.1).

All physical and chemical parameters were below levels of concern under both the designated and existing aquatic life use designations for Lea Lake and Figure Eight Lake. **Lea Lake** is not only the largest, clearest and possibly the home to the largest community of vertebrates and invertebrates occupying sinkholes within the park, it also provides a well established swimming beach with lifeguards on duty in summer months. The lake has become a popular scuba diving destination as well suggesting that this lake, or series of lakes, be reclassified to a more suitable and protective standards segment.

Warmwater aquatic life is an existing use in **Figure Eight Lake** and would be an appropriate use designation to support the fish community that inhabits this sinkhole; however, marginal coldwater aquatic life, which may exist in neighboring sinkholes during certain years, does not exist for this particular waterbody due to its naturally high salinity.

Table 5.0. Chemical analyses performed at each waterbody.

	Lea Lake	Figure Eight Lake
Major Anions and Cations	X	X
Total Nutrients	X	X
Dissolved Nutrients	X	X
Total Mercury and Selenium	X	X
Dissolved Metals	X	X
Radionuclides	X	X
Volatile Organics	X	X
Semi-Volatile Organics	X	X
Cyanide	X	X
E. coli	X	X

Table 5.1. Physical Characteristics for Lea Lake and Figure Eight Lake, 2007.

Characteristic	Lea Lake	Figure Eight Lake
Secchi (m)	4.5	2.7
Forel Ule Color	7	10
Maximum Depth (m)	22.0	8.5
Euphotic Zone (m)	14.5	8.0
Surface Area km^2 (Acres)	0.06 (15)	0.008 (2.2)
Storage Capacity m^3 (Ac. Ft.)	MDP	MDP
Anoxic Hypolimnion* (Y/N)	No	No

Characteristic	Lea Lake	Figure Eight Lake
Stratified (Y/N) @ depth (m)	Yes (9-10)	Yes (2-3)
pH (s.u.)	7.65	7.98
Conductivity (µS)	10,901	34,860
Turbidity (NTUs)	3.69	3.6
Integrated Sample surface to (m)	22	8.0
Dissolved Oxygen ** (mg/L)	5.76	8.03
Dissolved Oxygen Bottom (mg/L)	2.32	1.99
Temperature ** (°C)	22.37	26.78
Temperature Bottom (°C)	14.92	19.0

NOTES: ***** Anoxia exists when DO < 0.5 mg/L
** Dissolved oxygen and temperature are mean values from the epilimnion (upper 1/3 of water column)
MDP = missing data point

Nutrient Data

Currently, lake and reservoir criteria specific to this ecoregion are being developed for total nitrogen and total phosphorous for use as a multiparametric nutrient assessment tool. Until this assessment tool is complete, nutrient assessments are provided using methods and indicators consistent with past assessment practices. However, the draft nutrient assessment protocol for lakes and reservoirs was reviewed and compared against the June sampling runs for both Lea Lake and Figure Eight Lake. This weighted nutrient assessment approach suggests that nutrient enrichment is not a concern within either of these study basins. Table 5.2 shows results for common nutrient variables.

Table 5.2. Nutrient Variables

	Season	Lea Lake	Figure Eight Lake
Chlorophyll *a* (µg/L)	Summer	0.51	3.8
Total Phosphorus (mg/L)	Summer	0.015	0.036
Total Nitrogen (mg/L)	Summer	0.91	2.06
Limiting Nutrient	Summer	P	N

Data collected during the 2007 study indicate that **Lea Lake** may be classified as mesotrophic and **Figure Eight Lake** as Mesoeutrophic according to Carlson's (1977) indices for Secchi depth, chlorophyll *a,* total phosphorus, total nitrogen, and algal community composition (Likens 1975) (Table 5.3). Chlorophyll, nitrogen and phosphorous results were overall indicative of oligomesotrophic conditions. During the summer visit, nitrogen was the limiting nutrient for **Figure Eight Lake,** whereas phosphorus limited algal productivity in **Lea Lake** (Table 5.2).

Table 5.3. Trophic State (Carlson 1977)

	Lea Lake	Figure Eight Lake
Secchi Depth	Oligomesotrophic	Mesotrophic
Chlorophyll *a*	Oligotrophic	Mesotrophic
Total Phosphorous	Mesotrophic	Eutrophic
Total Nitrogen	Eutrophic	Eutrophic
Overall Trophic Classification	**Mesotrophic**	**Mesoeutrophic**

Biological Data

Phytoplankton

Phytoplankton community members for **Lea Lake** were dominated by the diatom genera *Cyclotella* and *Cymbella* with *Komma* and *Surirella* filling out the top four genera identified. **Figure Eight Lake** phytoplankton analysis resulted in a predominance of small, non-described dinoflagellates ("small *Peridinium*") with *Cyclotella*, *Peridiniopsis* and *Botryococcus* being other dominant members identified. Cyanobacteria were not detected in the samples from either lake. For both lakes, seventeen species were identified resulting in a high diversity with a resulting equitability of 0.69 for each lake according to Shannon and Weaver (1949).

Diatom Community Composition

A single multiple substrate diatom sample was collected from both Lea Lake and Figure Eight Lake during the single sampling visit to determine community composition. Of the 505 cells counted from the **Lea Lake** sample, 31 species of diatoms from 18 genera were identified. The dominant species, which comprised about twenty-six percent of the community, was *Fragilaria famelica* (Kützing) Lange-Bertalot. The second most abundant diatom community member was *Navicula salinicola* Hustedt which comprised about twenty-two percent of the Lea Lake diatom community. **Figure Eight Lake** had a total of 27 species representing thirteen genera. The most abundant member was *Brachysira aponina* Kützing comprising thirty-seven percent of the community followed by *Fragilaria famelica* (Kützing) Lange-Bertalot and *Amphora coffeaeformis* (Agardh) Kützing, which each represented about eleven percent of the total diatom community. Diversity according to Shannon and Weaver (1949) was high for both Lea and Figure Eight Lakes with an equitability of 0.66 and 0.69 respectively.

Water Quality Status Assessment

Lea Lake and Figure Eight Lake are classified under water quality segment 20.6.4.99 in the *New Mexico Water Quality Standards for Interstate and Intrastate Surface Waters* (NMAC 2007), with designated uses of aquatic life, livestock watering, wildlife habitat and secondary contact and presumed 101(a)(2) uses of primary contact and warmwater aquatic life. Current assessment protocols require a minimum of two separate sampling events for a waterbody, however only one visit was included as part of this study design. Additional water quality data and information collected by New Mexico State Parks, New Mexico Department of Game and Fish, and past water quality sampling efforts provide the necessary information for a better analysis of existing uses in order to adopt more appropriate uses that are specific to these sinkhole lakes. Current existing and designated uses listed in the 2010 – 2012 303(d) / 305(b) Integrated List for Lea Lake and Figure Eight Lake are listed in Table 5.4a and Table 5.4b.

Physical and chemical data collected during 2007 indicated that secondary contact, wildlife habitat, and livestock watering are fully supported for both Lea Lake and Figure Eight Lake. **Lea Lake** has long supported swimming and other forms of primary contact recreation, which showed full support from the single sample collected during this survey, and with data collected in 1998 when this lake was studied by this agency for the first time. All other uses were fully supported as well.

According to the Integrated Report, **Figure Eight Lake** has an existing use of marginal coldwater aquatic life with other designated uses applied under segment 20.6.4.99; however, marginal coldwater aquatic life is not applicable to this highly saline sinkhole even though, during prolonged wet periods, four neighboring sinkholes (Inkwell, Cottonwood, Pasture Lake, and Mirror Lake) provide a winter game fishery where the seasonal marginal coldwater aquatic life designation would apply.

A single exceedence of the primary contact criteria for *E. coli* was observed. The sample result was 920.8 cfu/100 mL, more than twice the single sample criterion of 410 cfu/100 mL. This closed basin sinkhole does not and likely cannot support a primary contact use due to the nature of this confined waterbody and the fact that this use is prohibited by the State Park at this and all other sinkhole lakes within the park except for Lea Lake. As no privies, waste water lines, or camping areas are in close proximity to Figure Eight Lake, natural sources of *E. coli* such as migratory waterfowl and terrestrial organisms are the most likely sources.

In the interest of more specific and protective standards designations for lakes located within the Bottomless Lakes State Park, it is suggested that a specific standards segment designation be established that includes waterbodies within the park such that appropriate uses and criterion can be applied to recognize the unique nature of these lake types.

Table 5.4a. Summary of attainment status of designated uses for Lea Lake.

Designated or Existing Use	Criteria Exceedence	Attainment Status
Warmwater Aquatic Life (existing use)	None	Partially Evaluated *
Primary Contact (existing use)	None	Partially Evaluated *
Secondary Contact	None	Partially Evaluated *
Livestock Watering	None	Partially Evaluated *
Wildlife Habitat	None	Partially Evaluated *

*** Lacking two sampling events necessary to assess, but adequate data to establish and verify existing uses.**

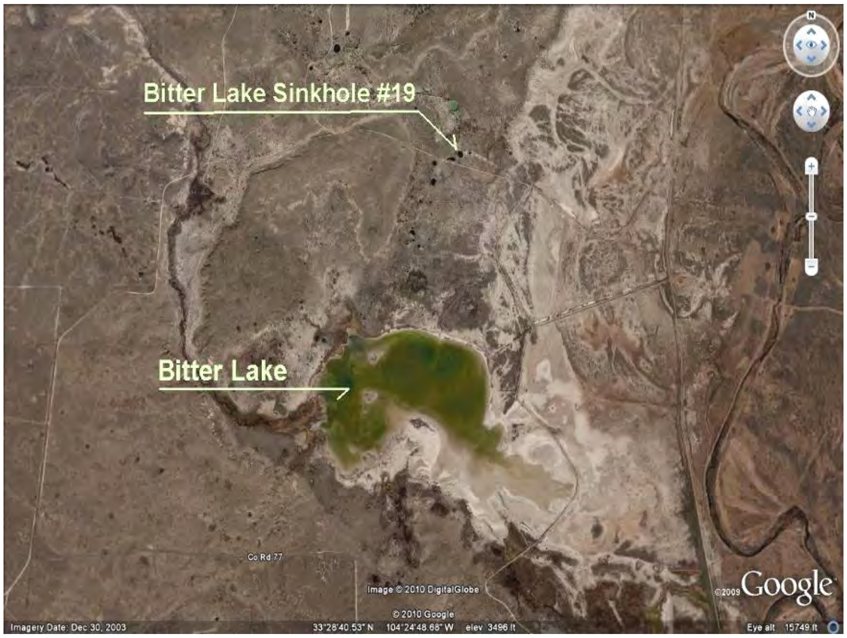
Table 5.4b. Summary of attainment status of designated uses for Figure Eight Lake.

Designated or Existing Use	Criteria Exceedence	Attainment Status
Marginal Coldwater Aquatic Life (25ºC)	1/1	Inappropriate Use Designation
Warmwater (existing use)	None	Partially Evaluated *
Primary Contact (presumed use)	1/1	Prohibited by Park
Livestock Watering	None	Partially Evaluated *
Wildlife Habitat	None	Partially Evaluated *

*** Lacking two sampling events necessary to assess, but adequate data to establish and verify existing uses.**

6.0 Bitter Lake and Bitter Lake Sinkhole # 19 at Bitter Lakes National Wildlife Refuge, Chaves County, June 13, 2007

Background



During 2007, a single-visit water quality survey was conducted on two waterbodies located within the Bitter Lakes National Wildlife Refuge (BLNWR) east of Roswell, New Mexico. This 99.3 km^2 (24,536 ac) refuge was established in 1937 to provide habitat for thousands of migrating sandhill cranes and waterfowl. More than 70 sinkholes dot the landscape within the refuge supporting unique wildlife such as the endangered Pecos pupfish and Pecos gambusia, Roswell spring snail, green throat darter, Noel's amphipod, and more than 80 species of dragonflies.

BLNWR is a cooperator in the Pecos Pupfish (*Cyprinodon pecosensis*) conservation agreement between U.S. Fish and Wildlife, New Mexico Department of Game and Fish and other agencies. This agreement recognizes that the sinkholes and springs within the refuge are unique habitats that provide a special haven for the threatened pupfish. "In New Mexico, [the Pecos pupfish] currently occurs mainly in habitats on Bitter Lake National Wildlife Refuge and Bottomless Lakes State Park" (NMDG&F 2006). In fact, Pecos pupfish (*Cyprinodon pecosensis*) occur in 21 sinkholes within the refuge including Bitter Lake and Sinkhole #19. Pecos gambusia (*Gambusia nobilis*) occur in eight sinkholes (Brooks and Wood 1988). Other fish known to occur within BLNWR sinkholes are the Plains Killifish (*Fundulus zebrinus*) and the mosquito fish (*Gambusia affinis*) (Swaim and Boeing 2008).

In 2007, **Bitter Lake** and **Bitter Lake Sinkhole #19** were studied for the first time by this agency. BLNWR is located where the Chihuahuan Desert meets the Southern Plains (Omernik 2006) with Bitter Lake and Bitter Lake Sinkhole #19 sitting at an elevation of 1,064 meters (3,493 ft) and 1,068 meters (3,505 ft) above sea level, respectively. Precipitation recorded from Bitter Lakes Refuge, Hagerman, and Bottomless Lake State Park averages 31 cm (12.2 in.) per year (WRCC – DRI 2009) with pan evaporation averaging 126 cm (49.5 in) per year resulting in an approximate 96 cm (38 in) water deficit per year (Gabin and Lesperance 1977).

Bitter Lake and Sinkhole #19 represent two of nineteen lentic waterbodies of varying shapes, sizes, and characteristics studied throughout New Mexico during the 2007 sampling year. The goal of this intensive study was to increase understanding of nutrient conditions in different lake types throughout the state to further SWQB's nutrient criteria development. However, full chemical, physical and some biological sampling was included to increase the overall understanding of each lake system. Due to the single visit each of these two lakes received, a formal assessment was not possible. However, the breadth of information resulting from the data collected during these single sampling events will allow for proper classification of these waterbodies such that appropriate criteria are assigned to protect existing and future use designations.

Physical / Chemical Data

Lake chemistry sampling consisted of total and dissolved nutrients, anions and cations, total and dissolved heavy metals, volatile and semi-volatile organics, radionuclides, bacteria, and cyanide, which cover all water quality criteria pertinent to the protection of designated or existing uses (Table 6.0). Physical measurements collected at both Bitter Lake and Bitter Lakes Sinkhole #19 included Secchi depth, Forel-Ule color, pH, specific conductance, turbidity, dissolved oxygen, and temperature (Table 6.1).

All physical and chemical parameters were below levels of concern under the current aquatic life use designation for both **Bitter Lake** and **Bitter Lake Sinkhole #19**, however, each of these lakes, and the majority of other sinkholes and playas are by their very nature, too saline to support the livestock watering use that is applicable within the 20.6.4.99 NMAC segment designation. Both lakes examined during this study clearly support a warmwater aquatic life use based upon the temperatures and dissolved oxygen values measured. In addition, the wildlife habitat use was fully supported in both of these lakes. The general public has little to no access to many areas within the refuge and special scientific studies require access permits. For this reason, any form of contact recreation including fishing is absolutely forbidden within the Bitter Lakes NWR.

Table 6.0. Chemical analyses performed at each waterbody.

	Bitter Lake	Bitter Lake Sinkhole #19
Major Anions and Cations	X	X
Total Nutrients	X	X
Dissolved Nutrients	X	X
Total Mercury and Selenium	X	X
Dissolved Metals	X	X
Radionuclides	X	X
Volatile Organics	X	X
Semi-Volatile Organics	X	X
Cyanide	X	X
E. coli	X	X

Table 6.1. Physical Characteristics for Bitter Lake and Sinkhole #19, 2007.

Characteristic	Bitter Lake	Bitter Lake Sinkhole #19
Secchi (m)	>0.5	2.0
Forel Ule Color	4.5	16
Maximum Depth (m)	0.5	3.0
Euphotic Zone (m)	>0.5	>3.0
Surface Area km^2 (Acres)	0.61 (150)	0.00004 (0.1)
Storage Capacity m^3 (Ac. Ft.)	MDP	MDP
Anoxic Hypolimnion * (Y/N)	No	No
Stratified (Y/N) @ depth (m)	No	No
pH (s.u.)	8.13	7.98
Conductivity (µS)	32,900	34,710
Turbidity (NTUs)	13.4	4.31
Integrated Sample surface to (m)	0.5	0.5
Dissolved Oxygen ** (mg/L)	8.41	10.0

Characteristic	Bitter Lake	Bitter Lake Sinkhole #19
Dissolved Oxygen Bottom (mg/L)	8.41	5.95
Temperature ** (°C)	23.67	26.7
Temperature Bottom (°C)	23.67	28.9

NOTES: * Anoxia exists when DO < 0.5 mg/L
** Dissolved oxygen and temperature are mean values from the epilimnion (upper 1/3 of water column)
MDP = missing data point

Nutrient Data

Currently, lake and reservoir criteria specific to this ecoregion are being developed for total nitrogen and total phosphorous for use as a multiparametric nutrient assessment tool. Until this assessment tool is complete, nutrient assessments are provided using methods and indicators consistent with past assessment practices. However, the draft nutrient assessment protocol for lakes and reservoirs was reviewed and compared against the summer sampling data for both Bitter Lake and Sinkhole # 19. The weight-of-evidence assessment approach suggested that nutrient enrichment is not a concern within either of these waterbodies. Table 6.2 shows results for common nutrient variables.

Table 6.2. Nutrient Variables

	Season	Bitter Lake	B.L. Sinkhole #19
Chlorophyll *a* (µg/L)	Summer	5.57	3.8
Total Phosphorus (mg/L)	Summer	0.126	0.036
Total Nitrogen (mg/L)	Summer	4.31	2.06
Limiting Nutrient	Summer	P	P

Table 6.3. Trophic State (Carlson 1977)

	Bitter Lake	B.L. Sinkhole #19
Secchi Depth	Oligomesotrophic	Mesotrophic
Chlorophyll *a*	Oligotrophic	Mesotrophic
Total Phosphorous	Mesotrophic	Eutrophic
Total Nitrogen	Eutrophic	Eutrophic
Overall Trophic Condition	**Mesotrophic**	**Mesoeutrophic**

Data collected during the 2007 study indicate that **Bitter Lake** may be characterized as mesotrophic and **Bitter Lake Sinkhole #19** as mesoeutrophic according to Carlson's (1977) indices for Secchi depth, chlorophyll *a*, total phosphorus, total nitrogen, and algal community composition (Likens 1975) (Table 6.3). During the summer visit, phosphorus was found to be the limiting nutrient in each lake (Table 6.2).

Biological Data

Phytoplankton

Phytoplankton community composition for **Bitter Lake** was dominated by *Cryptomonas* which made up 20.7 percent of the total count. The diatom *Fragilaria* comprised over nine percent followed by *Peridinium* and the cyanophyte, *Snowella* that totaled about 6.8 percent of the community. Bitter Lake had three blue-green algal genera identified in the sample; *Aphanothece*, *Leptolyngbya* and *Snowella* comprising about twenty-three percent of the soft body algal count.

Bitter Lake Sinkhole #19 phytoplankton analysis resulted in a predominance of small, non-described Dinoflagellates ("small *Peridinium*") comprising over twenty-five percent of the community. *Fragilaria*, *Chlamydomonas*, and *Synedra* were also abundant accounting for fifty percent of the total community. Sinkhole #19 also had three blue-green algal genera identified in the sample, which included *Leptolyngbya* with lesser amounts of *Planktolyngbya* and *Pseudanabaena* all comprising about twenty-two percent of the community composition. In this situation, the presence of Cyanobacteria may be acceptable considering the naturally confined, warm and relatively nutrient rich conditions. It is reasonable to assume that within this habitat type, these nitrogen fixers would be considered a natural component of this unique environment. Phytoplankton diversity for both Bitter Lake and Bitter Lake Sinkhole #19 according to Shannon and Weaver (1949) where high with an equitability of 0.86 and 0.81 respectively.

Diatom Community Composition

A single multiple-substrate diatom sample was collected from both Bitter Lake and Sinkhole #19 to determine community composition. Only sixteen species were identified in each sample suggesting that the natural saline conditions may result in a smaller community adapted to these conditions. Of the 513 cells counted from the **Bitter Lake** sample, *Cymbella pusilla* Grunow comprised about forty percent of the total community with *Nitzschia* and *Amphora* species amounting to another twenty-six percent of the total community. **Bitter Lake Sinkhole #19** had a total of 508 frustules counted, again totaling sixteen species. The dominant species, which comprised about thirty-four percent of the community, was *Fragilaria famelica* (Kützing) Lange-Bertalot. The second most abundant diatom community member was *Brachysira aponina* Kützing which comprised about thirty percent of the community with a dominant Nitzschia species adding another twenty-two percent to the total. Diversity for both Bitter Lake and Bitter Lake Sinkhole #19 samples according to Shannon and Weaver (1949) where moderate to high with an equitability of 0.53 and 0.68 respectively.

Water Quality Status Assessment

Bitter Lake and **Bitter Lake Sinkhole #19** are classified under water quality segment 20.6.4.99 in the *New Mexico Water Quality Standards for Interstate and Intrastate Surface Waters* (NMAC 2007), with designated uses of aquatic life, livestock watering, wildlife habitat and secondary contact and presumed 101(a)(2) uses of primary contact and warmwater aquatic life. Current assessment protocols require a minimum of two separate sampling events for a waterbody, which was not done as part of this study design. However, collected water quality data and information from the Bitter Lakes NWR, New Mexico Department of Game and Fish, and other sources suggest that these two waterbodies fit reasonably within the warmwater aquatic life use designation. All data measured as part of this monitoring survey also support the existing wildlife habitat use. Secondary contact recreation would also be supported for both lakes except for the fact that the public is not allow access to these unique environments especially to engage in these types of activities. Livestock watering would not be supported at either waterbody due to the naturally saline conditions that exist, and it is not reasonable to assume that these uses would or could ever exist within these lakes. Current designated uses listed in the 2010 – 2012 303(d) / 305(b) Integrated List as well as existing uses for both Bitter Lake and Bitter Lake Sinkhole #19 are listed in Table 6.4a and Table 6.4b.

In the interest of more specific and protective standards designations for lakes located within the Bitter Lakes National Wildlife Refuge, it is suggested that a specific standards segment designation be established that includes waterbodies therein such that appropriate uses and associated criteria can be applied to recognize the unique nature of these lakes.

Table 6.4a. Summary of attainment status of designated uses for Bitter Lake.

Designated or Existing Use	Criteria Exceedence	Attainment Status
Warmwater Aquatic Life (existing use)	None	Partially Evaluated *
Secondary Contact	None (not allowed)	Partially Evaluated *
Livestock Watering	None (excessive salinity)	Cannot be supported
Wildlife Habitat	None	Partially Evaluated *

*** Lacking two sampling events necessary to assess, but adequate data to establish and verify existing uses.**

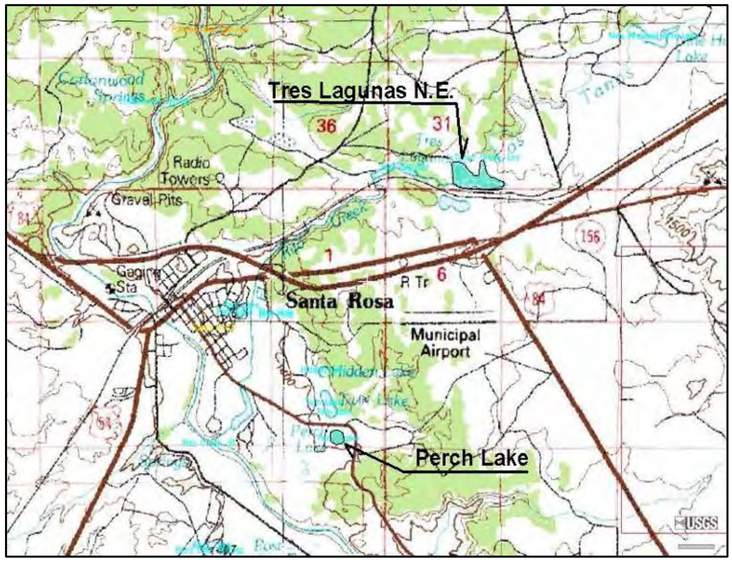
Table 6.4b. Summary of attainment status of designated uses for Sinkhole #19.

Designated or Existing Use	Criteria Exceedence	Attainment Status
Warmwater Aquatic Life (existing use)	None	Partially Evaluated *
Secondary Contact	None (not allowed)	Partially Evaluated *
Livestock Watering	None (excessive salinity)	Cannot be supported
Wildlife Habitat	None	Partially Evaluated *

*** Lacking two sampling events necessary to assess, but adequate data to establish and verify existing uses.**

7.0 Perch Lake and Tres Lagunas Lake, Guadalupe County, June and August 2007

Background



In 2007, SWQB conducted a two-season water quality survey on two waterbodies located near Santa Rosa, New Mexico. **Tres Lagunas, N.E.** is the largest of a series of three small impoundments fed by seasonal runoff from the 102 km^2 (39.5 mi^2) Los Tanos Creek watershed. After leaving the three lagoons, the creek becomes El Rito Creek which proceeds through the center of Santa Rosa before its confluence with the Pecos River. Tres Lagunas has a surface area of approximately 0.12 km^2 (30 ac) resulting in a watershed to lake size ratio of approximately 842:1. The elevation at the dam is about 1,431 meters (4,695 ft) above mean sea level and is located within the Southwestern Tablelands of the Xeric West aggregate ecoregion (Omernik 2006). The lake was originally constructed by the railroad to store water used in the steam locomotives; however, because the water is naturally hard, continued and sustainable use for steam engines was not possible. The concrete dam is the largest and most substantial of two dams completed by the railroad in 1922.

Perch Lake, the second waterbody studied in the Santa Rosa area, is located about 4.3 km (2.4 mi) southeast of Tres Lagunas on the south end of town, and is a natural sinkhole fed by shallow groundwater as is common to many such lakes in the area. The lake and adjacent area serves as a community recreation area where fishing, swimming and picnicking are favorite activities. Another activity common to this sinkhole is the use as a recreational and training site for scuba divers. An airplane fuselage, which was stripped of mechanical parts, was sunk for an underwater point of interest. Perch Lake is located at an elevation of 1,400 meters (4,595 ft) and is also located within the Southwestern Tablelands of the Xeric West aggregate ecoregion (Omernik 2006).

Surface area is about 1.15 hectares (2.84 ac) and the maximum depth measured during the study was 14 meters (46 ft), though maximum depth may be a bit more than this.

Precipitation recorded for Santa Rosa represents a ninety-four year history and averages 36.5 cm (14.4 in.) per year (WRCC – DRI 2009) with pan evaporation averaging 118 cm (46.5 in) per year resulting in an approximate 83 cm (32.8 in) water deficit per year (Gabin and Lesperance 1977).

Tres Lagunas NE, Macrophyte growth

Tres Lagunas N.E. has lost a significant amount of storage capacity and depth due to eighty-five years of sediment input from the large ephemeral and arid watershed. The overall shallow conditions that currently exist sprout heavy macrophyte blooms in the summer that preclude any chance of a sport fishery. In addition, the lake reportedly went dry a few years prior to this study making a fishery use questionable. The lake now averages less than one meter in depth and becomes choked with macrophytes during warm months suggesting that primary contact, if possible, is not desirable.

Perch Lake, in contrast, provides conditions suitable for stocked rainbow trout and perch with sunfish and some largemouth bass also inhabiting the lake. Currently, the New Mexico Department of Game and Fish is studying the lake to determine if catfish are suitable members of the fish community (Shawn Denny, personal communication). A courtesy dock extends out into three to four meters of clear water and swimming was observed during one of the sampling visits.


Perch Lake: A sink hole, 2007

Physical / Chemical Data

Lake chemistry sampling consisted of total and dissolved nutrients, anions and cations, total and dissolved heavy metals, volatile and semi-volatile organics, radionuclides, bacteria, and cyanide, which cover all water quality criteria pertinent to the protection of designated or existing uses (Table 7.0). Physical measurements collected at both Tres Lagunas N.E. and Perch Lake included Secchi depth, Forel-Ule color, pH, specific conductance, turbidity, dissolved oxygen, and temperature (Table 7.1).

Table 7.0. Chemical analyses performed at each waterbody.

	Perch Lake	Tres Lagunas N.E.
Major Anions and Cations	X	X
Total Nutrients	X	X
Dissolved Nutrients	X	X
Total Mercury and Selenium	X	X
Dissolved Metals	X	X
Radionuclides	X	X
Volatile Organics	X	X
Semi-Volatile Organics	X	X
Cyanide	X	X
E. coli	X	X

Table 7.1. Physical Characteristics for Perch Lake and Tres Lagunas N.E., 2007.

Characteristic	Perch Lake		Tres Lagunas N.E.	
	June 2007	August 2007	June 2007	August 2007
Secchi (m)	7.0	6.0	0.65	0.8
Forel Ule Color	5	9	14	15
Maximum Depth (m)	14.5	3.75 (dock)	1.1	1.3
Euphotic Zone (m)	>14.5	Est. 20	Est. 2.0	Est. 3.0
Surface Area km^2 (Acres)	.01 (2.84)	.01 (2.84)	0.121 (30)	0.121 (30)
Storage Capacity m^3 (Ac. Ft.)	N/A	N/A	MDP	MDP
Anoxic Hypolimnion * (Y/N)	N	N	N	N

Characteristic	Perch Lake		Tres Lagunas N.E.	
	June 2007	**August 2007**	**June 2007**	**August 2007**
Stratified (Y/N) @ depth (m)	N	N	N	Y
pH (s.u.)	7.7	7.39	9.31	9.77
Conductivity (µS)	3076	3142	254	263
Turbidity (NTUs)	0.71	0.74	11.5	9.17
Integrated Sample surface to (m)	14	3.0	1.0	1.0
Dissolved Oxygen ** (mg/L)	8.76	7.02	10.26	7.18
Dissolved Oxygen Bottom (mg/L)	9.0	6.94	9.82	2.56
Temperature ** (°C)	24.6	25.72	23.56	25.44
Temperature Bottom (°C)	14.6	25.7	23.37	21.78

NOTES: * Anoxia exists when DO < 0.5 mg/L
** Dissolved oxygen and temperature are mean values from the epilimnion (upper 1/3 of water column)
MDP = missing data point

Nutrient Data

Currently, lake and reservoir criteria specific to this ecoregion are being developed for total nitrogen and total phosphorous for use as a multiparametric nutrient assessment tool. Until this assessment tool is complete, nutrient assessments are provided using methods and indicators consistent with past assessment practices. However, the draft nutrient assessment protocol for lakes and reservoirs was reviewed and compared using June and August sampling runs for both Perch and Tres Lagunas NE. **Tres Lagunas NE** showed elevated nutrient concentrations, some oxygen depletion in deeper water, limited Secchi depth and four genera of Cyanobacteria that did not exceed 50 percent of the phytoplankton community. Much of the nutrients present may have been bound in macrophytes thus being undetectable in nutrient results. Nitrogen and phosphorus were co-limiting during the June visit and phosphorus was limiting during the August visit. **Perch Lake** possessed excellent water clarity and moderate to low nitrogen and phosphorus concentrations. Phosphorus was determined to be the limiting nutrient during both June and August visits.

Table 7.2. Nutrient Variables

	Month	Perch Lake	Tres Lagunas N.E.
Chlorophyll *a* (µg/L)	June	1.03	1.52
	August	0.14	1.50
Total Phosphorus (mg/L)	June	<0.1	0.09
	August	0.007	0.166
Total Nitrogen (mg/L)	June	1.02	1.14
	August	1.72	3.12
Limiting Nutrient	June	P	N/P
	August	P	P
Secchi Depth	June	7.0	0.65
	August	6.0	0.80

Table 7.3. Trophic State (Carlson 1977)

	Date	Perch Lake	Tres Lagunas N.E.
Secchi Depth	June	Oligomesotrophic	Eutrophic
	August	Oligomesotrophic	Eutrophic
Chlorophyll *a*	June	Oligomesotrophic	Oligomesotrophic
	August	Oligotrophic	Oligomesotrophic
Total Phosphorous	June	Oligotrophic	Eutrophic
	August	Oligomesotrophic	Hypereutrophic
Total Nitrogen	June	Eutrophic	Eutrophic
	August	Eutrophic	Hypereutrophic
Overall Trophic Condition		**Oligomesotrophic**	**Eutrophic**

Data collected during the 2007 study indicate that **Tres Lagunas NE** may be characterized as eutrophic to hypereutrophic and **Perch Lake** as Oligomesotrophic according to Carlson's (1977) indices for Secchi depth, chlorophyll *a*, total phosphorus, total nitrogen, and algal community composition (Likens 1975) (Table 7.3). Phosphorus was the primary limiting nutrient for algal productivity (Table 7.2).

Biological Data

Phytoplankton

Tres Lagunas Macrophyte and Algal growth, 2007.

Phytoplankton community composition for **Tres Lagunas NE** was dominated by small nano-flagellates followed by *Trachelomonas* in the June sample and *Komma* followed by small nano-flagellates in the August sample. The June phytoplankton sample consisted of about five percent of the blue-green *Phormidium* which was replaced by the blue-green *Aphanocapsa* species, in the August sample. It also comprised about five percent of the total community.

Perch Lake phytoplankton results showed no cyanobacteria present in either the June or August samples. Dominant phytoplankton found in the June sample consisted of the green algae *Tetraedron* followed by a species of *Cyclotella*. The third most common member of the community was the green algae *Lagerheimia*, which when added to the two most common phytoplankton identified, totaled over sixty percent of the community. August phytoplankton community was dominated by the genera *Oocystis, Cryptomonas and Achnanthes* whose numbers totaled about fifty percent of the total phytoplankton community composition.

Diatom Community Composition

A single multiple substrate diatom sample was collected from both Tres Lagunas NE and Perch Lake during the June visits to determine community composition. **Tres Lagunas NE** diatom analysis resulted in ten species. *Epithemia sorex* Kützing, a more saline tolerant species, comprised almost sixty percent of the total community. The second most common diatom identified was *Fragilaria vaucheriae* (Kützing) Peterson (28%), which is a diatom common to nutrient enriched waters.

Perch Lake diatom analysis resulted in thirty-one species identified from the single June sample. Most common in the sample was *Achnanthidium minutissimum* (Kützing) Czarnecki which represented almost forty percent of the total community. Second most common was *Mastogloia elliptica* (Agardh) Cleve, which totaled about twelve percent of the total community. Diversity according to Shannon and Weaver (1949) was moderate to low for Perch Lake and moderate to high for Tres Lagunas NE.

Water Quality Status Assessment

Diatom collecting at Tres Lagunas, NE

Tres Lagunas NE is classified in water quality segment 20.6.4.212 where irrigation, coldwater aquatic life, livestock watering, wildlife habitat and primary contact are listed. This is an example where a lake or lakes have been associated with a stream segment, but by nature does not and should not be expected to function as a stream should. It is recommended that Tres Lagunas NE be placed in the more appropriate 20.6.4.99 use category or a like segment designation where comparable waterbodies can be recognized for their specific uses and conditions (Table 7.4b).

Results from this two season study show that these two lentic systems have been misinterpreted in terms of applicable uses, and to some extent are reversed in the uses and applicable criteria associated with them. This sampling effort represented the first water quality survey of these lakes, and original suppositions of existing uses were assembled from various sources, mostly by word of mouth. In fact, the conditions which exist at Tres Lagunas NE are understandable considering the huge erodible and arid watershed to lake size ratio of 842. The railroad constructed this lake to supply water for the steam locomotives, which ultimately was found to be unusable due to the high mineral content. Years of sediment load has resulted in very shallow conditions. Furthermore, accounts of periodic and potential dry periods and concentration of nutrients causing heavy macrophyte blooms suggest that coldwater aquatic life and primary contact cannot be expected at this lake. Exceedences of pH during both sampling visits to Tres Lagunas constitute a determination of non-support for the coldwater designation. However, warmwater aquatic life, secondary contact, and the other uses listed in the following tables are attainable.

Swimmers at Perch Lake

Perch Lake in contrast is currently placed within the 20.6.4.99 segment designation where uses of aquatic life, livestock watering, wildlife habitat and secondary contact apply with presumed 101(a)(2) uses of primary contact and warmwater aquatic life. These uses are suitable for Tres Lagunas NE, but Perch Lake has existing uses that require more stringent criteria to afford proper protection of these uses. As a known stocked trout fishery and with the presence of warm water species as well, a marginal coldwater aquatic life use with applicable temperature criteria should protect this use. As observed and documented in the above image, primary contact is commonly enjoyed by visitors as well as scuba divers who frequent the lake for training and recreational purposes. It is recommended that Marginal Coldwater Aquatic Life and associated criteria replace the current Warmwater Aquatic Life use, that Primary Contact replace the current Secondary Contact use, and that Perch Lake be placed within a more representative water quality segment other than 20.6.4.99. All other uses associated with Perch Lake were fully supported during the two visit study (Table 7.4a).

Table 7.4a. Summary of attainment status of designated uses for Perch Lake.

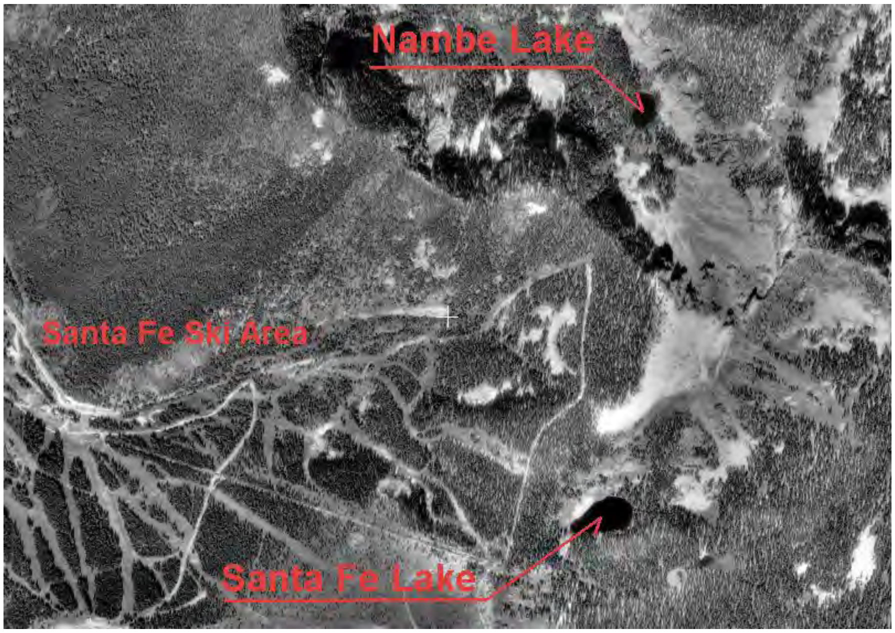
Designated or Existing Use	Criteria Exceedence	Attainment Status
Warmwater Aquatic Life	None	Fully Supporting
Marginal Coldwater Aquatic Life (existing use)	None	Fully Supporting
Secondary Contact	None	Fully Supporting
Primary Contact (existing use)	None	Fully Supporting
Livestock Watering	None	Fully Supporting
Wildlife Habitat	None	Fully Supporting

Table 7.4b. Summary of attainment status of designated uses for Tres Lagunas N.E.

Designated or Existing Use	Criteria Exceedence	Attainment Status
Warmwater Aquatic Life (existing use)	None	Fully Supporting
Coldwater Aquatic Life	pH (2/2)	Not Supporting
Secondary Contact (existing use)	None	Fully Supporting
Primary Contact (presumed use)	None	Fully Supporting
Irrigation	None	Fully Supporting
Livestock Watering	None	Fully Supporting
Wildlife Habitat	None	Fully Supporting

8.0 Santa Fe Lake and Nambe Lake in Santa Fe National Forest Santa Fe County, August 21 and 23, 2007

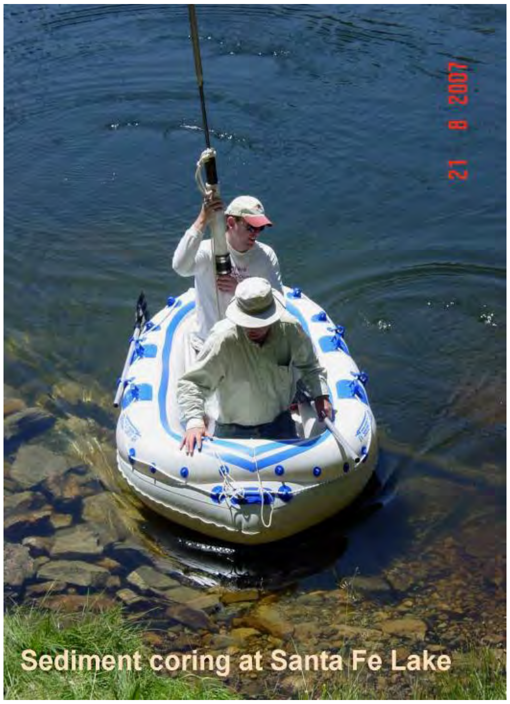
Background



During 2007, a single-visit water quality survey was conducted on two waterbodies located within the Pecos Wilderness of the Santa Fe National Forest near Santa Fe, New Mexico. Both Santa Fe and Nambe Lakes are small, high elevation cirque lakes which were chosen primarily to increase overall understanding of nutrient characteristics of these unique and isolated lake environments, and to conduct a full water quality and biological evaluation of these lakes to update information on current lake conditions.

Santa Fe Lake is a 2.4 hectare (6 acre) natural cirque lake located within a catchment basin of approximately 16 hectares (37 ac), which results in a lake size to watershed ratio of about 6. The lake sits within a glacial cirque at an elevation of 3,554 meters (11,660 ft) above sea level, and

maximum depth encountered during the sampling effort was 6.5 meters (21.3 ft). **Nambe Lake** is a 1.2 hectare (3 ac) cirque lake lying within a catchment basin of about 43.3 hectare (107 ac) resulting in a lake size to watershed ratio of about 36. This lake also lies within a cirque at an elevation of 3,486 meters (11,440 ft) above sea level where maximum depth encountered during the survey was estimated to be about 1.5 (5 ft) in depth. Both Santa Fe Lake and Nambe Lake are located within the Southern Rockies of the Xeric West aggregate ecoregion (Omernik 2006). Precipitation recorded from the National



Sediment coring at Santa Fe Lake

Resource Conservation Service, SNOTEL site 922 (Santa Fe, elevation 11,445 ft) averages 84.6 cm (33.3 in) per year based upon a thirteen year history of record.

These natural, high-elevation glacial cirque lakes represent two of five such lakes studied as part of the nineteen waterbodies included during the 2007 sampling year. The wide variety of lake types studied during 2007 had as the principal goal, to increase understanding of nutrient conditions in varying lake types throughout New Mexico. Since assessment of water quality usually requires a minimum of two data points, a complete assessment was not possible. However, the breadth of information and data collected from these single sampling events will allow for a classification of these waterbodies that will allow for greater protection of existing and future use designations.

Special permission was required from the City of Santa Fe to enter the Santa Fe Lake watershed due to its location within the uppermost portion of the Santa Fe municipal water supply. Nambe Lake is not a significant contributor to a community water supply and may be visited by anyone willing and able to make the high altitude hike to the lake by forest trail. **Santa Fe Lake** was found to have sufficient oxygen and physical characteristics to possibly support a trout population. Although it is not clear if a trout fishery exists, the water quality suitable to support high-quality, cold water aquatic life should be recognized and protected. Livestock are understandably not allowed within the Santa Fe Lake watershed, nor is primary and secondary contact recreation; however, these uses would be supported and easily attainable. Municipal water supply is an existing use for this lake. **Nambe Lake** in contrast is a shallow lake, possibly no more than two meters at the deepest point, which would have no chance of supporting an over-wintering population of trout species. It is, however, the only known location within New Mexico for the Lilljeborg's Peaclam (*Pisidium lilljeborgi*, Esmark & Hoyer, 1886), a state threatened species.

Nambe Lake sampling

Physical / Chemical Data

Lake chemistry sampling consisted of total and dissolved nutrients, anions and cations, total and dissolved heavy metals, volatile and semi-volatile organics, radionuclides, bacteria, and cyanide, which cover all water quality parameters pertinent to the protection of designated or existing uses (Table 8.0). Physical measurements collected at both Santa Fe and Nambe Lakes included Secchi depth, Forel-Ule color, pH, specific conductance, turbidity, dissolved oxygen, and temperature (Table 8.1).

Table 8.0. Chemical analyses performed at each waterbody

	Santa Fe Lake	Nambe Lake
Major Anions and Cations	X	X
Total Nutrients	X	X
Dissolved Nutrients	X	X
Total Mercury and Selenium	X	X
Dissolved Metals	X	X
Radionuclides	X	X
Volatile Organics	X	X
Semi-Volatile Organics	X	X
Cyanide	X	X
E. coli	X	X

Table 8.1. Physical Characteristics for Santa Fe and Nambe Lake, 2007.

Characteristic	Santa Fe Lake	Nambe Lake
Secchi (m)	>6.5	>1.5
Forel-Ule Color	9	6
Maximum Depth (m)	6.5	1.5
Euphotic Zone (m)	>6.5	>1.5
Surface Area km^2 (Acres)	0.024 (6)	0.0.016(4.0)
Storage Capacity m^3 (Ac. Ft.)	60,750 (49.25)	12,150 (9.85)
Anoxic Hypolimnion * (Y/N)	No	No
Stratified (Y/N) @ depth (m)	No	No
pH (s.u.)	7.72	7.86
Conductivity (μS)	22	33

Characteristic	Santa Fe Lake	Nambe Lake
Turbidity (NTUs)	0.62	2.32
Integrated Sample surface to (m)	5.0	0.25
Dissolved Oxygen ** (mg/L)	7.33	7.73
Dissolved Oxygen Bottom (mg/L)	1.2	7.73
Temperature ** (°C)	16.35	13.37
Temperature Bottom (°C)	15.43	13.37

NOTES: * Anoxia exists when DO < 0.5 mg/L
** Dissolved oxygen and temperature are mean values from the epilimnion (upper 1/3 of water column)
MDP = missing data point

Nutrients

Currently, lake and reservoir criteria specific to this ecoregion are being developed for total nitrogen and total phosphorous for use as a multiparametric nutrient assessment tool. Until this assessment tool is complete, nutrient assessments are provided using methods and indicators consistent with past assessment practices. However, the draft nutrient assessment protocol for lakes and reservoirs was reviewed and compared against the August sampling runs for both Santa Fe and Nambe Lakes. This weighted nutrient assessment approach suggests that nutrient enrichment is not a concern within either of these study basins. Table 8.2 shows results for common nutrient variables.

Table 8.2. Nutrient Variables

	Season	Santa Fe Lake	Nambe Lake
Chlorophyll *a* (µg/L)	Summer	3.36	2.52
Total Phosphorus (mg/L)	Summer	<0.01	0.011
Total Nitrogen (mg/L)	Summer	0.35	0.67
Limiting Nutrient	Summer	N	N

Data collected during the 2007 study indicate that both **Santa Fe Lake** and **Nambe Lake** may be classified as oligomesotrophic according to Carlson's (1977) indices for Secchi depth, chlorophyll *a*, total phosphorus, total nitrogen, and algal community composition (Likens 1975) (Table 8.3). Chlorophyll, nitrogen and phosphorous results were overall indicative of oligomesotrophic conditions. Nitrogen was the limiting nutrient for both Santa Fe and Nambe Lakes during the single summer visits (Table 8.2).

Table 8.3. Trophic State (Carlson 1977)

	Santa Fe Lake	Nambe Lake
Secchi Depth	Oligomesotrophic	Mesotrophic
Chlorophyll *a*	Mesotrophic	Oligomesotrophic
Total Phosphorous	Oligotrophic	Oligomesotrophic
Total Nitrogen	Oligomesotrophic	Mesotrophic
Overall Trophic Condition	**Oligomesotrophic**	**Oligomesotrophic**

Biological Data

Phytoplankton

Of the total nineteen species comprising the phytoplankton community for **Santa Fe Lake**, the green algae of the genus *Quadrigula*, comprised about fifty-seven percent of the plankton community. Five percent of the community was described as small nano-flagellates with similar numbers of the Cryptophyta and Bacillariophyta. These phytoplankton groups are common to lakes with low to moderate nutrient concentrations. **Nambe Lake** phytoplankton analysis resulted in thirty-two species of which the diatoms *Staurosira* and *Achnanthes* comprised over forty-one percent of the total community. Approximately six percent of the total community consisted of the two Cyanobacteria, *Pseudanabaena* and *Leptolyngbya*. Both lakes showed high diversity with equitability values above 0.86 according to Shannon and Weaver (1949).

Diatom Community Composition

A single multiple substrate diatom sample was collected from both **Santa Fe Lake** and **Nambe Lake** during the summer to determine community composition. Of the 501 cells counted from the **Santa Fe Lake** sample, 46 species of diatoms from 25 genera were identified. The dominant species, which comprised about twenty-nine percent of the community, was *Achnanthidium minutissimum* (Kützing) Czarnecki, followed by *Fragilaria capucina* var. *gracilis* (Østrup) Hustedt. Diversity according to Shannon and Weaver (1949) was high with an equitability value of 0.73. **Nambe Lake** had a total of 32 species represented by nineteen genera, where *Mastogloia elliptica* (Agardh) Cleve, and *Encyonopsis microcephala* (Grunow) Krammer, made up about thirty-nine percent of the community composition. Diatom diversity from the Nambe Lake sample was high with an equitability value of 0.75 according to Shannon and Weaver (1949).

Water Quality Status Assessment

Santa Fe Lake and Nambe Lake are both located within water quality segment 20.6.4.121 in the *New Mexico Water Quality Standards for Interstate and Intrastate Surface Waters* (NMAC 2007), with designated uses of domestic water supply, high quality coldwater aquatic life, irrigation, livestock watering, wildlife habitat, municipal and industrial water supply, and secondary contact with a presumed 101(a)(2) use of primary contact. Current assessment protocols require a minimum of two separate sampling events for a waterbody, where only one visit was conducted on each of these lakes. However, data collected from these lake sampling efforts have been compared with all pertinent criteria established to protect designated uses and served to increase knowledge of the nature and specific characteristics of these high elevation cirque lakes.

Table 8.4a. Summary of attainment status of designated uses for Santa Fe Lake.

Designated or Existing Use	Criteria Exceedence	Attainment Status
High Quality Coldwater Aquatic Life	None	Partially Evaluated *
Primary Contact (presumed use)	None	Partially Evaluated *
Drinking Water Supply	None	Partially Evaluated *
Municipal and Industrial Water Supply	None	Partially Evaluated *
Irrigation	None	Partially Evaluated *
Livestock Watering	None	Partially Evaluated *
Wildlife Habitat	None	Partially Evaluated *

*** Lacking two sampling events necessary to assess, but adequate data to establish and verify existing uses.**

It is important to remind the reader that Santa Fe Lake is located within the upper most part of the Santa Fe watershed and so access is restricted. Special permission was attained from the city before this study was conducted. Fishing, primary contact, irrigation and livestock watering, though supported by the very nature and location of this lake, are not allowed in an effort to protect the municipal water supply. Nambe Lake is not an integral aspect of a water supply and though located within the same water quality segment as Santa Fe Lake, does not experience the same restrictions. Though not formally assessed, uses were supported on the day this study was conducted.

Table 8.4b. Summary of attainment status of designated uses for Nambe Lake.

Designated or Existing Use	Criteria Exceedence	Attainment Status
High Quality Coldwater Aquatic Life	None	Partially Evaluated *
Primary Contact (presumed use)	None	Partially Evaluated *
Drinking Water Supply	None	Partially Evaluated *
Municipal and Industrial Water Supply	None	Partially Evaluated *
Irrigation	None	Partially Evaluated *
Livestock Watering	None	Partially Evaluated *
Wildlife Habitat	None	Partially Evaluated *

*** Lacking two sampling events necessary to assess, but adequate data to establish and verify existing uses.**

9.0 Carson National Forest Lake Studies, Summer 2007 Rio Arriba County, Canjilon Lake (A), August 6, 2007 Taos County, Serpent Lake, July 31; Middle Fork Lake, August 1; and Williams Lake, August 8, 2007

Background

During 2007, a singe-season, water quality sampling survey was conducted on four, high elevation lakes, three of them glacial cirque lakes located within the Carson National Forest of Northern New Mexico. **Canjilon Lake (A)**, is a spring-fed impoundment, located at an elevation of 3,078 meters (10,100 ft), and covers about 1.62 hectare (4 acres) in surface area. It is the uppermost lake in a series of waterbodies which continue along Canjilon creek, and are accessible by taking forest road 559 northeast from the Village of Canjilon to forest road 129 with Canjilon Lake (A) located at the end of this road. The lake is located within the Southern Rockies of the Xeric West aggregate ecoregion (Omernik 2006) where annual precipitation recorded from the closest, long-term weather station at Bateman Ranch averages about 61 cm (24 in) per year (Gabin and Lesperance 1977).

Serpent Lake is a high elevation cirque lake located at 3,578 m (11,740 ft) and lies beneath the 3,912 m (12,835 ft) Jicarita Peak. This natural lake of glacial origin varies in size depending on season and water year, but totaled about 0.2 ha (0.5 ac) during the study visit. At the time of this visit, the lake was about one meter in depth, which precludes the possibility of a viable fishery; however, Tiger Salamander (*Ambystoma tigrinum*) was common within the lake. Serpent Lake is located within the Southern Rockies of the Xeric West aggregate ecoregion (Omernik 2006) where annual precipitation estimated from the closest SNOTEL site at Wesner Springs (3,390 m) is about 81 cm (32 in) per year. Access to the lake is by way of forest trail 19 which begins at the end of forest

road 161 north of Mora, New Mexico near Holman Hill. The trail hike into the lake is approximately 3.3 miles in length and is of moderate difficulty.

Middle Fork Lake is the second high elevation cirque lake included in this study and is located at an elevation of 3,305 m (10,845 ft) on the Middle Fork of the Red River of Northern New Mexico. The lake is about 3.24 ha (8.0 ac). Maximum depth recorded during this single visit sampling effort was 3.3 meters, a sufficient depth to support a trout fishery. Middle Fork Lake is located within the Southern Rockies of the Xeric West aggregate ecoregion (Omernik 2006) where annual precipitation estimated from the closest SNOTEL sites at Tolby (elevation of 3,103 m, 10,180 ft) and Gallegos Peak (2,987 m, 9,850 ft) average about 64 cm (25 in) per year though this estimate may be low due to the lower elevations of these sites compared to Middle Fork Lake. To access the lake trail, leave NM 38 on the east end of the village of Red River and follow NM 578 about 10.5 km (6.5 mi) to the forest service parking area where the 3.2 km (2 mi) and 458 m (1,500 ft) climb begins. Follow forest trail 487 to the lake.

Middle Fork Lake, 2007

Williams Lake is located about five kilometers due south of Middle Fork Lake, but access is typically gained from the southern side of the Sangre de Cristo mountains via Forest Trail 62 in Taos Ski Valley. The two mile hike into the lake ends at the cirque that lies below Wheeler Peak, the highest mountain in New Mexico, at an elevation of 4,011 m (13,161 ft). Williams Lake is a 3.2 ha (8 ac) glacially-derived shallow lake located at an elevation of 3,389 m (11,120 ft) and may hold an estimated 32,000 cubic meters of water. It lies within the Southern Rockies of the Xeric West aggregate ecoregion (Omernik 2006). Though adequate, long-term weather stations are sparse in this mountainous area, the higher elevation at this lake when compared to Middle Fork suggests that yearly precipitation may be closer to 76 cm (30 in) per year.

Williams Lake, 2007

Physical / Chemical Data

Lake chemistry sampling consisted of total and dissolved nutrients, anions and cations, total and dissolved heavy metals, volatile and semi-volatile organics, radionuclides, bacteria, and cyanide, which cover all water quality parameters pertinent to the protection of designated or existing uses (Table 9.0). Physical measurements included Secchi depth, Forel-Ule color, pH, specific conductance, turbidity, dissolved oxygen, and temperature (Table 9.1).

Table 9.0. Chemical analyses performed for each lake.

Samples Collected	2007 Lake Studies in Carson National Forest			
	Canjilon (A)	Serpent Lake	Middle Fork	Williams Lake
Major Anions and Cations	X	X	X	X
Total Nutrients	X	X	X	X
Dissolved Nutrients	X	X	X	X
Total Mercury and Selenium	X	X	X	X
Dissolved Metals	X	X	X	X
Radionuclides	X	X	X	X
Volatile Organics	X	X	X	X
Semi-Volatile Organics	X	X	X	X
Cyanide	X	X	X	X
E. coli	X	X	X	X

Table 9.1. Physical Characteristics for Carson National Forest Lakes, 2007

Physical Characteristics	Canjilon (A)	Serpent Lake	Middle Fork	Williams Lake
Secchi (m)	>1.5	>1.0	>3.3	>1.2
Forel-Ule Color	10	Tannin color	10	9
Maximum Depth (m)	1.5	1.0	3.3	1.2
Euphotic Zone (m)	>1.5	>1.0	>3.3	>1.2
Surface Area km^2 (Ac)	.0239 (5.9)	.002 (0.5)	.0324 (8.0)	.0321 (7.9)
Storage Capacity 10^6 M^3 (Ac. Ft.)	Est. 30 AF	Est. 3 AF	Est. 25 AF	Est. 25 AF
Anoxic Hypolimnion (Y/N)*	N	N	N	N
Stratified (Y/N) @ depth (m)	N	N	N	N
pH (s.u.)	≈ 7.46	7.04	8.52	7.47
Conductivity (μS)	138.7	50	125	163

Physical Characteristics	Canjilon (A)	Serpent Lake	Middle Fork	Williams Lake
Turbidity (NTUs)	0.75	1.78	1.13	4.58
Integrated Sample surface to (m)	1.0	0.10	2.5	1.0
Dissolved Oxygen Surface (mg/L)**	8.52	5.9	6.06	6.89
Dissolved Oxygen Bottom (mg/L)	9.51	5.9	6.06	7.33
Temperature (°C)**	17.7	15.26	16.49	12.53
Temperature Bottom (°C)	17.54	15.26	15.1	9.11

NOTES: * Anoxia exists when DO < 0.5 mg/L
** Dissolved oxygen and temperature are mean values from the epilimnion (upper 1/3 of water column)

Canjilon Lake (A) sampling resulted in a single exceedence for *E. coli*. Cattle are permitted to graze in close proximity to the lake and a cow carcass was found within a few feet of waters edge at the time of this sampling visit. All other physical and chemical sampling results were below levels of concern. **Serpent Lake** showed no elevated levels for physical and chemical analytes during this sampling effort except for a 5.9 mg/L dissolved oxygen result that was slightly below the 6.0 mg/L criteria applicable for the protection of the high quality coldwater aquatic life use that exists for this waterbody. **Middle Fork Lake and Williams Lake** both showed no chemical or physical exceedences of water quality criteria. In all four lake surveys, current water quality assessment protocols require a minimum of two sets of water quality data before determination of use attainment can be made. Therefore, in the case of both Canjilon and Serpent Lakes, the single exceedence for *E. coli* and low oxygen does not result in a determination of nonsupport for their designated or existing uses.

Dead cow on shore of Canjilon Lake.

Nutrients

Currently, lake and reservoir criteria specific to this ecoregion are being developed for total nitrogen and total phosphorous for use as a multiparametric nutrient assessment tool. Until this assessment tool is complete, nutrient assessments are provided using methods and indicators consistent with past assessment practices. However, the draft nutrient assessment protocol for lakes and reservoirs was reviewed and compared against the sampling results for Canjilon, Serpent, Middle Fork and Williams Lakes, all of which were sampled within the growing season for this ecoregion. Except for a slight elevation in chlorophyll *a* concentrations for Canjilon Lake (A), nitrogen, phosphorus, chlorophyll and cyanobacterial components of this assessment tool were below levels of concern further supporting the determination that nutrients were not a significant concern at these four Carson National Forest lakes during this study. Canjilon Lake should be seen as a natural spring fed lake of relatively high elevation, but is not, in fact, a glacially created cirque lake, but within the defined coldwater category. This distinction places Canjilon Lake (A) well below nutrient target concentrations that further support the overall nutrient and trophic assessments. Table 9.2 shows results for common nutrient variables.

Table 9.2. Nutrient Variables

	Canjilon (A)	**Serpent**	**Middle Fork**	**Williams**
Chlorophyll *a* (µg/L)	1.74	0.69	0.47	1.12
Total Phosphorus (mg/L)	0.035	0.32	0.026	0.008
Total Nitrogen (mg/L)	0.66	1.39	0.41	0.38
Limiting Nutrient	P	P	N/P	P

Trophic State

Data collected during the 2007 study indicate that Canjilon Lake (A) may be classified as mesotrophic, and Serpent Lake as mesotrophic to possibly early dystrophic or more similar to a bog lake due to the slight presence of organic acids or tannin color observed during the survey (Cole 1983). Both Middle Fork and Williams Lakes are classified as oligomesotrophic according to Carlson's (1977) indices for Secchi depth, chlorophyll *a*, total phosphorus, total nitrogen, and algal community composition (Likens 1975) (Table 9.3). Except for the presence of one species in Middle Fork Lake, the presence of cyanobacteria was rare to non-existent in lake phytoplankton communities further supporting these trophic classifications. Phosphorus was the limiting nutrient for algal


Middle Fork Lake, 2007

productivity for all lakes except Middle Fork Lake where nitrogen and phosphorus were co-limiting during the sampling visit (Table 9.2).

Table 9.3. Trophic State (Carlson 1977)

TSI	Canjilon (A)	Serpent	Middle Fork	Williams
Secchi Depth	Mesotrophic	Mesotrophic	Oligotrophic	Mesotrophic
Chlorophyll *a*	Oligomesotrophic	Oligotrophic	Oligotrophic	Oligomesotrophic
Total Phosphorous	Eutrophic	Eutrophic	Eutrophic	Oligomesotrophic
Total Nitrogen	Mesotrophic	Eutrophic	Mesotrophic	Mesotrophic
Overall Trophic Condition	**Mesotrophic**	**Mesotrophic to Early Dystrophic**	**Oligomesotrophic**	**Oligomesotrophic**

Biological Data

Phytoplankton

Cryptomonads, specifically *Cryptomonas* and *Komma* species dominated phytoplankton community composition at **Canjilon Lake (A)**, representing about forty-three percent of the total community. This significant representation by members of the Cryptomonadaceae is expected in mesotrophic conditions with moderate to low nutrient concentrations. A total of twenty genera were identified in the sample. Similarly, of the twenty-three species identified from the **Serpent Lake** phytoplankton sample, the three most common members were all Cryptomonads represented by *Cryptomonas*, *Mallomonas* and *Komma* species. Phytoplankton analysis of the **Middle Fork Lake** sample was dominated by the green algae, and the second most abundant was the Cyanophyte genus *Microcystis* which represented about twenty-one percent of the community composition. Most common was the green algae *Sphaerocystis* with *Komma*, the common Cryptomonad member, comprising sixteen percent of the community composition. **Williams Lake** phytoplankton results were dominated by five diatom genera, totaling ninety-five percent of the total phytoplankton community. Of the total 344 cells counted during the analysis, only fourteen cells were not diatoms. Most common was the diatom *Achnanthes,* which by itself comprised over 43 percent of the community. *Navicula, Staurosira and Amphora sp.* were among the other common phytoplankton identified. Diatoms or the Bacillariophyta in general, are similar to the Cryptophyta in that these groups seem to prefer environments with moderate to low nutrient load (Likens 1975), which may be expected for the high elevation cirque lakes being discussed. In all four cases, diversity according to Shannon and Weaver (1949) was very high with resulting equitability values in the 0.84 to 0.96 range.

Diatom Community Composition

Mayfly hatch at Williams Lake, 2007.

A single multiple substrate diatom sample was collected from each of the four Carson National Forest Lakes to determine community composition. **Canjilon Lake (A)** diatom analysis resulted in thirty-seven species with the most common being *Staurosira construens* var. *venter* (Ehrenberg) Hamilton, which comprised fifty-two percent of the total community. The next two most common diatom identified from the sample were *Nitzschia perminuta* (Grunow) Peragallo and *Opephora martyi* Heribaud, which combined accounted for eighteen percent of the community. Diversity was moderately high with an equitability value of 0.56. **Serpent Lake** diatom community composition consisted of thirty-four species identified with *Staurosirella pinnata* (Ehrenberg) Williams et Round and *Achnanthidium minutissimum* (Kützing) Czarnecki being the two most common members in the sample and totaled over fifty-nine percent of the total community. Diversity was moderate with an equitability value of 0.64. **Middle Fork Lake** diatom community analysis resulted in forty-two species identified where *Opephora martyi* Heribaud and *Staurosirella pinnata* (Ehrenberg) Williams et Round were the two most common species identified, comprising forty-five percent of the total community. Diversity was high with an equitability value of 0.67. **Williams Lake** resulted in the highest species richness with fifty-one species identified and appears very similar in dominant species to both Serpent and Middle Fork Lakes. *Staurosirella pinnata* (Ehrenberg) Williams et Round and *Opephora martyi* Heribaud comprising almost sixty percent of the total community. *Achnanthidium minutissimum* (Kützing) Czarnecki was the third most common. As with

Canjilon Lake (A), 2007.

the other three lakes discussed here, Williams Lake diatom diversity was high with a resulting equitability value of 0.58 according to Shannon and Weaver (1949).

<u>Water Quality Status Assessment</u>

Canjilon Lake (A) is classified under water quality segment 20.6.4.119 in the *New Mexico Water Quality Standards for Interstate and Intrastate Surface Waters* with designated uses of domestic water supply, fish culture, high quality coldwater aquatic life, irrigation, livestock watering, wildlife habitat and secondary contact with primary contact as a presumed use (Table 9.4a). A complete assessment is not possible due to the single sampling event. However, the characterization of this lake, based on the data collected, suggests that Canjilon Lake (A) is a viable, year-round trout fishery due to the ten fish stocking occurrences that are scheduled from May through October of each year (Rick Castell, Personal Communication). It is questionable that this lake could consistently support a reproducing trout fishery due to the shallow nature of the lake, but it is reasonably to assume that this lake will support a coldwater aquatic life use on a yearly basis especially considering the large number of trout that are stocked each year. This spring fed impoundment is a favorite camping and fishing destination for the recreating public. During the sampling visit, cattle were in the immediate vicinity of the lake and a fresh and bloated cow carcass was only a few feet away from the water's edge. This situation may explain the one exceedence of the *E. coli* criterion, and suggests that these recreational lakes may benefit by excluding grazing livestock from immediate lakeshore areas. It is also suggested that consideration be given to reclassification of this lake by placing it within a more suitable water quality segment specific to small, coldwater lakes, instead of the current stream segment where it now resides.

Table 9.4a. Summary of attainment status of designated uses for Canjilon Lake (A).

Designated or Existing Use	Criteria Exceedence	Attainment Status
High Quality Coldwater Aquatic Life	None	Partially Evaluated *
Domestic water supply	None	Partially Evaluated *
Primary Contact (presumed use)	1/1 (*E. coli*)	Partially Evaluated *
Fish culture	None	Partially Evaluated *
Irrigation	None	Partially Evaluated *
Livestock Watering	None	Partially Evaluated *
Wildlife Habitat	None	Partially Evaluated *

* Lacking two sampling events necessary to assess, but adequate data to establish and verify existing uses

Serpent Lake is classified within water quality segment 20.6.4.99 in the *New Mexico Water Quality Standards for Interstate and Intrastate Surface Waters* with designated uses of warmwater aquatic life, livestock watering, and wildlife habitat with an existing use of coldwater aquatic life and a presumed use of primary contact (Table 9.4b). While a complete assessment is not possible due to the single sampling event, the characterization of this high-elevation cirque lake is possible and necessary. Though Serpent Lake sampling resulted in a dissolved oxygen value slightly below the 6.0 mg/L criterion, this single exceedence will not result in an impairment because two data points are required to assess individual designated use attainment. This suggests that this cirque lake, like many high elevation natural lakes of this type, may be best served by placement within water quality segments that reflect the actual nature of these lake types. Serpent Lake is a very shallow waterbody that lies within a glacial cirque at an elevation that assures total freezing in the winter months. This natural condition precludes any possibility of providing a sustainable fishery; however, specialized organisms have adapted to these conditions and form a unique aquatic community that should be protected within a water quality segment specific to similar lake types.

Table 9.4b. Summary of attainment status of designated uses for Serpent Lake.

Designated or Existing Use	Criteria Exceedence	Attainment Status
Coldwater Aquatic Life (existing use)	None	Partially Evaluated *
Primary Contact (presumed use)	None	Partially Evaluated *
Livestock Watering	None	Partially Evaluated *
Wildlife Habitat	None	Partially Evaluated *

* Lacking two sampling events necessary to assess, but adequate data to establish and verify existing uses

Middle Fork Lake is classified under water quality segment 20.6.4.123 in the *New Mexico Water Quality Standards for Interstate and Intrastate Surface Waters* with designated uses of domestic water supply, fish culture, high quality coldwater aquatic life, irrigation, livestock watering, wildlife habitat and secondary contact (primary presumed) (NMAC 2007). Though a water quality assessment of physical and chemical data is not possible due to the single sampling visit, it is practical to characterize the lake and compare results to applicable uses. Based upon these data, it is recommended that Middle Fork Lake be placed within a water quality segment specific to this lake type, and possibly shared with lakes of similar type and uses. This action would remove Middle Fork Lake from the stream segment where it now resides and afford it specific uses shared with other lakes of similar characteristics.

Table 9.4c. Summary of attainment status of designated uses for Middle Fork Lake.

Designated or Existing Use	Criteria Exceedence	Attainment Status
High Quality Coldwater Aquatic Life	None	Partially Evaluated *
Primary Contact (presumed use)	None	Partially Evaluated *
Domestic Water Supply	None	Partially Evaluated *
Fish Culture	None	Partially Evaluated *
Irrigation	None	Partially Evaluated *
Livestock Watering	None	Partially Evaluated *
Wildlife Habitat	None	Partially Evaluated *

* Lacking two sampling events necessary to assess, but adequate data to establish and verify existing uses

Williams Lake is classified under water quality segment 20.6.4.123 in the *New Mexico Water Quality Standards for Interstate and Intrastate Surface Waters* with designated uses of domestic water supply, fish culture, high quality coldwater aquatic life, irrigation, livestock watering, wildlife habitat and secondary contact (primary presumed) (NMAC 2007). Though a water quality assessment of physical and chemical data is not possible due to the single sampling visit, it is practical to characterize the lake and compare results to applicable uses. Williams Lake is similar with respect to Middle Fork Lake in elevation, lake type and water quality segment, but differs in size, depth, accessibility and practical fishery use potential. This suggests that the designated use for fish culture may not be practical. As a very shallow lake, the prospect of supporting an over wintering trout population is not possible. However, a complex and specialized biological community reflected in the phytoplankton, diatom and benthic macroinvertebrate community speaks to the uniqueness of this natural cirque lake. Eventually, this lake, as with all glacially formed, lakes will succumb to the erosive contributions from the surrounding mountains to finish filling and become the marsh and meadow that is the fate of all such lakes. No water quality criteria exceedences were detected from the single visit (Table 9.4d). It is recommended that Williams Lake be placed within a water quality segment specific to this lake type, and possibly shared with lakes of similar characteristics and uses. This action would remove this lake from the stream segment where it now resides and afford it specific water quality standards criteria shared with other lakes with similar characteristics.


Williams Lake, 2007.

Table 9.4d. Summary of attainment status of designated uses for Williams Lake.

Designated or Existing Use	Criteria Exceedance	Attainment Status
High Quality Coldwater Aquatic Life	None	Partially Evaluated *
Primary Contact (presumed use)	None	Partially Evaluated *
Domestic Water Supply	None	Partially Evaluated *
Fish Culture	None	Partially Evaluated *
Irrigation	None	Partially Evaluated *
Livestock Watering	None	Partially Evaluated *
Wildlife Habitat	None	Partially Evaluated *

*** Lacking two sampling events necessary to assess, but adequate data to establish and verify existing uses.**

10.0 Small Municipal Park Lakes of Eastern New Mexico, Summer 2007: Lake Van, Chaves County, June 11, 2007 Ned Houk Lake, Curry County, August 14, 2007 Bosque Redondo Lake, De Baca County, August 15, 2007

Background

During 2007, a singe-season, water quality sampling survey was conducted on three, municipal park lakes, in east-central and south eastern New Mexico. **Lake Van** is located on the eastern edge of the community of Dexter, New Mexico about 27 km (17 mi) south-east of the city of Roswell, NM. Elevation at the lake is 1,045 meters (3,430 ft) and is located within the Southern Deserts of the Xeric West aggregate ecoregion (Omernik 2006). Lake water is supplied from a groundwater well located adjacent to the lake. The lake has a surface area of 10 hectare (24.7 ac) with an estimated storage capacity of 0.987 x 10^6 m^3 (80 af). Though relatively small in contribution, annual precipitation from the nearby community of Hagerman, and the long-term weather station in Roswell average about 33 cm (13 in) per year with pan evaporation averaging 128 cm (50.2 in) resulting in a deficit of 96 cm (37.9 in) per year (Gabin and Lesperance 1977). Fishing is a favorite recreational activity at Lake Van, where summer warmwater catfish and winter trout are stocked, maintained and monitored by the New Mexico Department of Game and Fish. The town of Dexter manages and maintains the surrounding park that includes a small boat ramp and picnic areas.

Ned Houk Park Lake is the larger of two groundwater supplied community park lakes managed and maintained by the City of Clovis, New Mexico. This lake represents one of three municipal park lakes studied in 2007 from the east-central and south-eastern regions of New Mexico. Ned Houk is located about 13 km (8 mi) north of the city of Clovis, New Mexico near the border of New Mexico and Texas. Elevation at the lake is 1,296 meters (4,251 ft) and is located within the Western High Plains of the Xeric West aggregate ecoregion (Omernik 2006). The lake has a surface area of 1.6 hectare (4 ac) with an estimated storage capacity of 0.24 x 10^6 m^3 (80 af). Though primarily groundwater fed, annual precipitation from the nearby community of Clovis indicates average rainfall at 43 cm (17 in) per year with pan evaporation averaging 112 cm (44 in) resulting in a deficit of 71 cm (28 in) per year (Gabin and Lesperance 1977). Summer fishing for catfish and stocked winter trout fishing is a favorite recreational activity at Lake Van. Picnic and group recreational areas are provided as well.

Bosque Redondo Park Lake is a 6.7 km (4.15 mi) drive from the center Fort Sumner, New Mexico and is reached via State road 84, then east to county road 272 south to the lake park. From the air or topographic maps, it seems that the now enhanced series of long, slender and curved ponds is in fact the remnant of a classic, oxbow bend in the Pecos River. Elevation at the park is 1,210 meters (3,970 ft) and is located within the Southwestern Tablelands of the Xeric West aggregate ecoregion (Omernik 2006). Of the four distinguishable ponds associated with the remnant oxbow, the third in the series appears to be the largest and most popular for the recreating public and so it was the lake selected for sampling. This pond is 4.1 hectare (10.2 ac) in surface area with an estimated 37,000 m^3 (30 af) of storage. Total combined surface acreage for all ponds is about 12.14 ha (30 ac) with combined storage of around 123,000 m^3 (100 af) of storage volume. Water is supplied via water diversion from the Pecos River to sustain the fishery and park area. Fishing is a popular activity at the park with bass, bluegill, catfish and winter trout. Annual precipitation from the nearby Fort Sumner weather station averages 37 cm (14.9 in) (WRCC – DRI 2009) per year with pan evaporation averaging 122 cm (48 in) resulting in a deficit of 85 cm (33.5 in) per year (Gabin and Lesperance 1977).

Physical / Chemical Data

Lake chemistry sampling consisted of total and dissolved nutrients, anions and cations, total and dissolved heavy metals, volatile and semi-volatile organics, radionuclides, bacteria, and cyanide, which cover all water quality parameters pertinent to the protection of designated or existing uses

(Table 10.0). Physical measurements collected at these lakes included Secchi depth, Forel-Ule color, pH, specific conductance, turbidity, dissolved oxygen, and temperature (Table 10.1).

Table 10.0. Chemical analyses performed for each lake.

Samples Collected	Municipal Park Lakes – Summer 2007		
	Lake Van	Ned Houk Lake	Bosque Redondo
Major Anions and Cations	X	X	X
Total Nutrients	X	X	X
Dissolved Nutrients	X	X	X
Total Mercury and Selenium	X	X	X
Dissolved Metals	X	X	X
Radionuclides	X	X	X
Volatile Organics	X	X	X
Semi-Volatile Organics	X	X	X
Cyanide	X	X	X
E. coli	X	X	X

Table 10.1. Physical Characteristics for Municipal Park Lakes, 2007

Physical Characteristics	Lake Van	Ned Houk Lake	Bosque Redondo
Secchi (m)	0.6	0.25	1.0
Forel Ule Color	12	16	16
Maximum Depth (m)	1.25	1.8	1.1
Euphotic Zone (m)	Est. 3.0	0.8	>1.1
Surface Area km^2 (Ac)	0.1 (24.7)	.016 (4.0)	.134 (30)
Storage Capacity 10^6 M^3 (Ac. Ft.)	0.0987 (Est. 80)	.024 (Est. 20)	0.123 (Est 100)
Anoxic Hypolimnion (Y/N)*	N	N	N
Stratified (Y/N) @ depth (m)	N	Y (1)	N
pH (s.u.)	7.85	9.0	7.23

Physical Characteristics	Lake Van	Ned Houk Lake	Bosque Redondo
Conductivity (μS)	4,389	400	3,236
Turbidity (NTUs)	15.2	54.6	6.62
Integrated Sample surface to (m)	1.0	1.5	1.0
Dissolved Oxygen Surface (mg/L)**	8.71	9.72	6.48
Dissolved Oxygen Bottom (mg/L)	8.72	6.55	4.83
Temperature (°C)**	26.83	26.9	26.28
Temperature Bottom (°C)	26.81	24.24	25.78

NOTES: * Anoxia exists when DO < 0.5 mg/L
** Dissolved oxygen and temperature are mean values from the epilimnion (upper 1/3 of water column)


Lake Van, Dexter, New Mexico, 2007

The three municipal lakes described herein were sampled on one occasion and at one station so that the few exceedences of water quality criteria observed do not constitute an impairment listing. According to current assessment protocols, individual designated use attainment is usually determined based on a minimum number of 2 data points; however any such result exceeding established criteria are included.

Lake Van experienced one exceedence of the total recoverable selenium criterion for chronic aquatic life use and wildlife habitat (5 μg/L). The sample result was 7 μg/L or 2 μg/L over the criterion. The *E. coli* criterion for primary contact recreation applicable to this segment is 410 coliform forming units (cfu) per 100 milliliters (mL); however the result from the single analysis was 52.8 cfu/100 ml, well below the standard. All other criteria were within acceptable levels at Lake Van during the sampling visit.

Ned Houk Park Lake showed a substantial exceedence for dissolved aluminum, where both chronic aquatic life (87 μg/L) and acute aquatic life (750 μg/L) criteria were exceeded with an analytical result of 810 μg/L. Communication with John Meier, park manager at Ned Houk Park

Lake, indicated that this was the first he had heard of elevated aluminum in the lake water and confirmed that no known ill affects have been observed in waterfowl or fishery uses. He confirmed that the Ogallala aquifer water supplying the lake is pumped from a depth of four hundred feet and is the same water used by the majority of inhabitants of the area. This elevated aluminum may be derived from parent soils in the region, but this has not been confirmed. There was also a slight exceedence of the marginal coldwater aquatic life (MCWAL) temperature criterion of 25ºC with a result of 25.2ºC. This criterion is established to protect the seasonal winter trout fishery and should not apply to the summer months when warmwater aquatic life uses are applicable and catfish are the resident fish population. All other physical and chemical criteria were well within acceptable limits based upon the single sampling visit.


Ned Houk Park Lake, 2007

Physical and chemical sampling results from **Bosque Redondo Lake** near Fort Sumner showed one slightly elevated result for adjusted gross alpha pertaining to the designated use of livestock watering; the criterion is 15 pCi/L and the analytical result was 15.8 pCi/L. It is accepted that in some areas groundwater may naturally contain radionuclides and this is thought to be the case in the Fort Sumner groundwater supply. Two other slight criteria exceedences were the result of applying marginal coldwater aquatic life criteria for dissolved oxygen and temperature to measurements taken during the summer. The occurrence of criteria exceedences due to off-season assessment as in the case of lakes with both marginal and warmwater aquatic life uses may suggest the need to implement a seasonal applicability of specific criteria pertinent to the season the waterbody was sampled. All other physical and chemical criteria were well below levels of concern at Bosque Redondo Park Lake.


Bosque Redondo Park Lake, 2007.

Nutrients

Currently, lake and reservoir criteria specific to this ecoregion are being developed for total nitrogen and total phosphorous for use as a multiparametric nutrient assessment tool. Until this assessment tool is complete, nutrient assessments are provided using methods and indicators consistent with past assessment practices. The draft nutrient assessment protocol for lakes and reservoirs was reviewed and compared against the sampling visits to Lake Van, Ned Houk Lake and Bosque Redondo Lake for sampling conducted within the growing season for the respective ecoregion. All three lakes exceeded the threshold levels for chlorophyll *a*, and total nitrogen concentration, and both Lake Van and Ned Houk Lakes exceeded the threshold level for Secchi Depth. However, total phosphorus and percentage of cyanobacteria present in samples from all three lakes were below proposed threshold levels. For both Lake Van and Ned Houk Lakes, pumped groundwater into small, shallow, man-made, closed-basin lakes, where evaporation and consequent concentration of nutrients is unavoidable, elevated nutrient concentrations may be an unavoidable result. However, these municipal park lakes are maintained as artificial waterbodies designed to provide recreation and fishing for local residents and to this extent appear to be functioning for their designed purposes. Bosque Redondo Lake is an off channel lake that receives water from the nearby Pecos River and overflow from the lake returns to the river downstream of the lake area. This results in a potential for nutrient flushing from the lake basin over time, which reduces the severity of nutrient concentrations (Table 10.2).

Table 10.2. Nutrient Variables

	Lake Van	Ned Houk Lake	Bosque Redondo
Chlorophyll *a* (µg/L)	7.66	39.35	7.66
Total Phosphorus (mg/L)	0.064	0.112	0.034
Total Nitrogen (mg/L)	1.93	1.61	1.20
Limiting Nutrient	P	N/P	P

Trophic state determinations for these three 2007 lake studies indicate that Lake Van, Ned Houk and Bosque Redondo may be classified as eutrophic according to Carlson's (1977) indices for Secchi depth, chlorophyll *a*, total phosphorus, total nitrogen, and algal community composition (Likens 1975) (Table 10.3). As earlier discussed, these small, confined and low-flow waterbodies have little chance to flush nutrients from their respective lake basins, which results in recycling of nutrients and any added nutrient load from immediate watershed areas, loafing waterfowl and other wildlife. Phosphorus was the limiting nutrient for algal productivity at both Lake Van and Bosque Redondo Lake. Ned Houk Lake was co-limiting for both nitrogen and phosphorus during the summer visit (Table 10.2).

Table 10.3. Trophic State (Carlson 1977)

TSI	Lake Van	Ned Houk Lake	Bosque Redondo
Secchi Depth	Eutrophic	Hypereutrophic	Eutrophic
Chlorophyll *a*	Eutrophic	Eutrophic	Eutrophic
Total Phosphorous	Eutrophic	Hypereutrophic	Eutrophic
Total Nitrogen	Eutrophic	Eutrophic	Eutrophic
Overall Trophic Condition	**Eutrophic**	**Eutrophic**	**Eutrophic**

Biological Data

Phytoplankton

Lake Van, 2007.

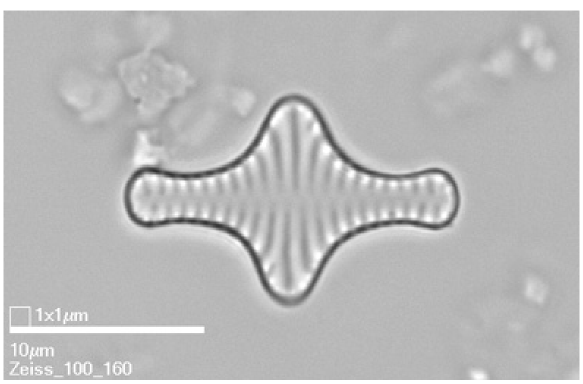
Diatoms, represented by the genus *Nitzschia* and *Navicula* comprised about thirty percent of the **Lake Van** phytoplankton community composition, which included a total of thirty-one genera from the day of the sampling visit. What the taxonomist described as small nano-flagellates followed with over fourteen percent of the total community. Though the taxonomist did not provide a species level account, members of the genus *Nitzschia* are common to waters with moderate to high nutrient loads. Four species of blue-green Cyanobacteria were identified totaling twenty-two cells with eighteen cells belonging to the genus *Pseudoanabaena*. The blue-green algae would account for about twenty-seven percent of the soft-bodied phytoplankton community, but only thirteen percent of the total phytoplankton community which included the Bacillariophyta.

Ned Houk Park Lake, 2007.

Ned Houk Park Lake phytoplankton results showed the most common named member of the community as the toxic blue-green *Coelosphaerium,* which comprised about twelve perent of the total count. Seven blue-green species were identified from a total soft-bodied algal subset of twenty-seven genera, and of the soft-bodied phytoplankton counted, excluding the diatoms, made up about forty-eight percent of the total soft-bodied community. Of the seven blue-green genera listed, six are known to produce cyanotoxins when conditions allow. This significant contribution to the phytoplankton community by these Cyanophytes is not surprising considering the nature of this small, shallow, closed-basin, groundwater fed lake, however, the presence of this algal component suggests that some risk may exist for animals that drink from the lake or humans who immerse themselves, should conditions support the proliferation of these algal types.

Bosque Redondo Lake phytoplankton results were dominated by two Dinoflagellate species, *Peridinium and Peridiniopsis,* which when combined, totaled almost thirty-four percent of the total community. The second most common was the Cryptophyte, *Komma,* whose numbers constituted nine percent of the community. Blue-green algae (cyanobacteria) were present, but as a relatively small portion of the total community. Five species of cyanobacteria were present and two can, at times, become toxic. However, only 35 individual cells were observed and included in the formal analysis totaling about fifteen percent of the soft bodied phytoplankton and eleven percent of the total community which includes the Bacillariophyta.

Diatom Community Composition



A single multiple substrate diatom sample was collected from each of the three municipal park lakes during each lake sampling visit to determine community composition. **Lake Van** diatom analysis resulted in twenty-three species with the most common being *Tabularia fasciculata* (Agardh) Williams et Round, which comprised sixty-eight percent of the total community. The next two most common diatoms identified from the sample were *Achnanthidium minutissimum* (Kützing) Czarnecki and *Denticula kuetzingii* Grunow. Diversity was somewhat low due to the large percentage of the dominant species resulting in an equitability value of 0.46. **Ned Houk Lake** community composition consisted of thirty species identified with *Navicula gregaria* Donkin, comprising twenty-one percent of the community, followed by *Aulacoseira granulate* (Ehrenberg) Simonsen and *Synedra acus* Kutzing. Twelve species of the genus *Nitzschia* were the most common group, these generally being more tolerant of enriched nutrient conditions. Diversity was high with an equitability value of 0.84. **Bosque Redondo Lake** diatom community analysis resulted in twenty-four species identified with *Staurosirella pinnata* (Ehrenberg) Williams et Round totaling forty-five percent and in combination with *Staurosira construens* var. *venter* (Ehrenberg) Hamilton, totaling seventy-five percent of the total community composition. Both of these were formerly of the genus *Fragilaria*, but are now recognized within their own genus. Due to the dominance by these two species, diversity was moderate with equitability value of 0.49.

Water Quality Status Assessment

Lake Van is classified under water quality segment 20.6.4.99 in the *New Mexico Water Quality Standards for Interstate and Intrastate Surface Waters* with designated uses of warmwater aquatic life, livestock watering, wildlife habitat and secondary contact, an existing use of marginal coldwater aquatic life, and a presumed use of primary contact (NMAC 2007). A slight exceedence of total recoverable selenium was detected for both warmwater aquatic life and wildlife habitat. A slight exceedence of the 25º C temperature criterion for marginal coldwater aquatic life was observed, however the applicability of this use in summer months is questionable as only warmwater fish are stocked during this season. The recorded temperature during the summer visit was well within the 32.2º C warmwater aquatic life criterion appropriate during the warm summer months (Table 10.4a). A segment specific temperature criterion should be discussed and adopted for this lake that first, protects the existing marginal coldwater use, and two, is more appropriate of the seasonal fishery provided at Lake Van. Though a water quality assessment of designated use attainment was not possible due to the single sampling visit, it is practical to characterize the lake and compare results to applicable uses.

Table 10.4a. Summary of attainment status of designated uses for Lake Van.

Designated or Existing Use	Criteria Exceedance	Attainment Status
Livestock Watering	None	Partially Evaluated *
Marginal Coldwater Aquatic Lake	1/1 (Se, Temp)	Partially Evaluated *
Warmwater Aquatic Lake	1/1 (Se)	Partially Evaluated *
Primary Contact (presumed use)	None	Partially Evaluated *
Wildlife Habitat	1/1 (Se)	Partially Evaluated *

*** Lacking two sampling events necessary to assess, but adequate data to establish and verify existing uses.**

Ned Houk Park Lake is classified under water quality segment 20.6.4.99 in the *New Mexico Water Quality Standards for Interstate and Intrastate Surface Waters* with designated uses of warmwater aquatic life, livestock watering, wildlife habitat and secondary contact, an existing use of marginal coldwater aquatic life, and a presumed use of primary contact (NMAC 2007). A single acute exceedence for dissolved aluminum was detected that is applicable to the existing aquatic life uses (Table 10.4b). One slight exceedence of the 25º C temperature criterion was measured, but this may be an inappropriate and often unattainable condition to expect in summer months when only warm water fish species are stocked and the temperature measured was well within the warmwater criterion of 32.2º C. A segment specific temperature criterion should be discussed and adopted for this lake that protects the marginal cold water use in cold months and protects the warmwater aquatic life use in the summer months. Though a water quality assessment of designated use attainment was not possible due to the single sampling visit, it is practical to characterize the lake and compare results to applicable uses.

Table 10.4b. Summary of attainment status of designated uses for Ned Houk Lake.

Designated or Existing Use	Criteria Exceedence	Attainment Status
Marginal Coldwater Aquatic Life	Al (1/1), Temp (1/1)	Partially Evaluated *
Warmwater Aquatic Life	Al (1/1)	Partially Evaluated *
Primary Contact (presumed use)	None	Partially Evaluated *
Wildlife Habitat	None	Partially Evaluated *
Livestock Watering	None	Partially Evaluated *
Wildlife Habitat	None	Partially Evaluated *

*** Lacking two sampling events necessary to assess, but adequate data to establish and verify existing uses.**

Bosque Redondo Park Lake is classified under water quality segment 20.6.4.99 in the *New Mexico Water Quality Standards for Interstate and Intrastate Surface Waters* with designated uses of warmwater aquatic life, livestock watering, wildlife habitat and secondary contact, an existing use of marginal coldwater aquatic life, and a presumed use of primary contact (NMAC 2007). A slight exceedence of the livestock watering criterion for adjusted gross alpha was noted (Table 10.4c). Both temperature and dissolved oxygen criteria were also exceeded as they apply to the marginal coldwater aquatic life use; however these were in complete support of the warmwater aquatic life use which is the existing aquatic life use present during the summer months when this study was conducted. Though a water quality assessment of designated use attainment was not possible due to the single sampling visit, it is practical to characterize the lake and compare results to applicable uses. As such, a segment specific temperature criterion should be discussed and adopted for this lake that protects the marginal cold water use in colder months and protects the warmwater aquatic life use during the summer.

Table 10.4c. Summary of attainment status of designated uses for Bosque Redondo Lake.

Designated or Existing Use	Criteria Exceedence	Attainment Status
Marginal Coldwater Aquatic Life	DO (1/1), Temp (1/1)	Partially Evaluated *
Warmwater Aquatic Life	None	Partially Evaluated *
Primary Contact (presumed use)	None	Partially Evaluated *
Wildlife Habitat	None	Partially Evaluated *
Livestock Watering	Gross alpha (1/1)	Partially Evaluated *
Wildlife Habitat	None	Partially Evaluated *

*** Lacking two sampling events necessary to assess, but adequate data to establish and verify existing uses.**

Though sampling resulted in several exceedences of water quality criteria, these single exceedences will not result in impairment determinations at this time since assessment of water quality data to determine individual designated use attainment usually requires a minimum of two data points. However, the breadth of information and data collected from these single sampling events will allow for further classification of these waterbodies allowing for proper protection of existing and future use designations.

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