Total Maximum Daily Load
for
Lake Ogallala – Keith County, Nebraska

Parameters of Concern: Dissolved Oxygen

Pollutants Addressed: Sulfides/Instantaneous Oxygen Demand

Nebraska Department of Environmental Quality
Planning Unit, Water Quality Division

June 2007

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Executive Summary

Lake Ogallala was included in Category 5 of the 2004 Nebraska Surface Water Quality Integrated Report (NDEQ 2004) as being impaired by low dissolved oxygen, excessive nutrients and chlorophyll *a*. As such, a total maximum daily load must be developed for each impaired parameter in accordance with the Clean Water Act.

At this time the nutrient criteria proposed for inclusion into Title 117 – Nebraska Surface Water Quality Standards has not been approved. Thus, this document only presents the TMDL for dissolved oxygen. Completion of a TMDL for nutrients will be postponed until such a time as USEPA approves the final criteria. Therefore, based on the above and as required by Section 303(d) of the Clean Water Act and 40 CFR Part 130.7, a TMDL for dissolved oxygen has been developed and contained herein to address the dissolved oxygen (DO) impairment.

These TMDLs have been prepared to comply with the current (1992) regulations found at 40 CFR Part 130.7.

1. **Name and geographic location of the impaired waterbody for which the TMDLs are being developed.**
Lake Ogallala, Section 3, Township 14 North, Range 38 West, Keith County, Nebraska, Lat. 41° 13’ 16”, Long. 101° 39’ 50”

2. **Identification of the pollutant and applicable water quality standard**
The pollutants causing the impairment(s) of the water quality standard and designated beneficial use is low dissolved oxygen. Designated uses assigned to Lake Ogallala include: primary contact recreation, aquatic life coldwater class B, agriculture water supply class A and aesthetics (NDEQ 2005). Excessive sediment and nutrient inputs have been determined to be impairing the aesthetic and aquatic life beneficial uses.

3. **Quantification of the pollutant load that may be present in the waterbody and still allows attainment and maintenance of the water quality standards.**
The CE-QUAL-W2 water quality model was employed to determine the scenarios that complied with the water quality criteria. The loading capacities, that if achieved and will result in beneficial use attainment were based upon dissolved oxygen loading, instantaneous oxygen demand loading and macrophyte density and are included in the below table

Scenario	Macrophyte Density (g dry wt/m^2)	DO Loading – kg/hr	DO Loading – kg/day	IOD Loading – kg/hr	IOD Loading – kg/day
1	344	3302	30663	319	5749
2	172	3302	30663	1032	9582
3	688	4128	38329	1032	9582
4	344	4128	38329	1445	13415
5	688	3302	30663	206	1916
6	344	3302	30663	1032	9582
7	172	2477	22997	206	1916

4. **Quantification of the amount or degree by which the current pollutant load in the waterbody, including upstream sources that is being accounted for as background loading deviates from the pollutant load needed to attain and maintain water quality standards.**
Assessment of the water quality data indicated the dissolved oxygen criteria were not met in 36% of the measurements.

5. Identification of the pollutant source categories.

Based on the configuration of Lake Ogallala, the entire pollutant load originates from Lake McConaughy. Both point and nonpoint sources of instantaneous oxygen demand (sulfides, ammonia, etc.) contribute to the North Platte River and ultimately Lake McConaughy. Point sources include wastewater treatment facilities animal feeding operations. Nonpoint sources include, stormwater discharges from sites not covered by NPDES permits and other agriculture, urban and rural run-off.

6. Wasteload allocations for pollutants from point sources.

Because no point sources discharge directly to Lake Ogallala the wasteload allocation will be zero (0).

7. Load allocations for pollutants from nonpoint sources.

Establishment of the load allocation (LA) identifies the dynamic and unique nature of Lake Ogallala and the incoming water from Lake McConaughy and will be established according to the macrophyte density.

Macrophyte Density (g dry wt/m^2)	DO Loading – kg/hr	DO Loading – kg/day	IOD Loading – kg/hr	IOD Loading – kg/day
344	3302	30663	319	5749
172	3302	30663	1032	9582
688	4128	38329	1032	9582
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8 A margin of safety.

These TMDLs contain an implicit margin of safety. During periods of low dissolved oxygen that corresponds with the stratification of Lake McConaughy, water is regularly discharged through the Howell-Bunger valve in order to maintain the DO at the buoy line. However, for this modeling event, all incoming flows were run strictly through the hydro facility and aeration through the Howell-Bunger was not performed. The modeling assumption assumes a worst-case situation of incoming water DO concentration.

9. Consideration for seasonal variation.

The low dissolved oxygen has been observed to occur when Lake McConaughy stratifies. All modeling and allocations were determined based on the period of stratification.

10. Allowances for reasonably foreseeable increases in pollutant loads.

Future growth was not accounted for in this TMDL.

11. Stakeholder Developed Management Plan

Based on the unique configuration and ownership of Lake Ogallala a stakeholder based water quality management plan was prepared. The plan takes into account all uses of the lake and water including; aquatic life support, hydroelectric production and irrigation recreation.

The TMDLs included in the following text can be considered “phased TMDLs” and as such are an iterative approach to managing water quality based on the feedback mechanism of implementing a required monitoring plan that will determine the adequacy of load reductions to meet water quality standards and revision of the TMDL in the future if necessary. A description of the future monitoring (Section 5.0) that is planned has been included.

Monitoring is essential to all TMDLs in order to:

- Assess the future beneficial use status;
- Determine if the water quality is improving, degrading or remaining status quo;
- Evaluate the effectiveness of implemented best management practices.

The additional data collected should be used to determine if the implemented TMDL and watershed management plan have been or are effective in addressing the identified water quality impairments. As well the data and information can be used to determine if the TMDLs have accurately identified the required components (i.e. loading/assimilative capacity, load allocations, in lake response to pollutant loads, etc.) and if revisions are appropriate.

1.0 Introduction

Lake Ogallala was included in Category 5 of the 2006 Nebraska Surface Water Quality Integrated Report not supporting the aquatic life beneficial use with the cause being low dissolved oxygen. The waterbody was also listed as being impaired by excessive nutrients and chlorophyll *a* however; at this time the Department is undergoing the process of refining the nutrient criteria for inclusion into Title 117 – Nebraska Surface Water Quality Standards (Title 117) and waiting on EPA Region 7 approval. The initial assessment was conducted using proposed/draft values – for the purpose of providing some measure of nutrient impacts in Nebraska lakes and reservoirs. The final values may change and thus alter the assessments. Completion of a TMDL for nutrients will be postponed until such a time as USEPA approves the final criteria. Therefore, based on the above and as required by Section 303(d) of the Clean Water Act and 40 CFR Part 130.7, a TMDL for dissolved oxygen has been developed and contained herein to address the dissolved oxygen (DO) impairment.

1.1 Background Information/Waterbody History

Lake Ogallala is located immediately downstream of Lake McConaughy on the North Platte River in Keith County (Figure 1.1a) and was formed in the late 1930's when the dredging of materials for construction of Kingsley Dam resulted in a large borrow pit (CNPPID 1988). Water supplied to Lake Ogallala is primarily from deep-water releases from Lake McConaughy (Maret and Bazata 1987). The cold temperatures of the water in the releases has been shown to be ideal for survival and growth of salmonid fishes and Lake Ogallala has been known as one of the state's popular put and take trout fishery. The Nebraska Game and Parks Commission (NGPC) manage the reservoir's fishery.

Lake Ogallala is "L" shaped (Figure 1.1b) with the two arms being considerably different. The North-South basins are parallel to Kingsley Dam and resemble a typical reservoir. That is the arm is deeper, has steep gradient banks and no visible current (Maret and Bazata 1987). The Keystone Basin runs perpendicular to Kingsley Dam and at times reflects a river more so than a reservoir, with a uniform depth, narrow channel, visible velocity and shorter detention times.

A critical period for aquatic life occurs when Lake McConaughy stratifies each summer. Water within the hypolimnion becomes depleted of dissolved oxygen and this water is delivered to Lake Ogallala and eventually passes through to either the North Platte River (NP1-40000) or the Sutherland Supply Canal (NP1-40200).

In 1984, the Central Nebraska Public Power and Irrigation District (Central) completed the installation of a 50-megawatt hydroelectric generating facility in response to the encouraged use of renewable energies and altered how the water is delivered to Lake Ogallala. More discussion on this will be provided in Section 2.1.1.

1.1.1 Waterbody Description

1.1.1.1 Waterbody Name: Lake Ogallala

Lake Identification Number: NP1-L0030 (Tile 117 – Nebraska Surface Water Quality Standards)

1.1.1.2 Major River Basin: Missouri River

1.1.1.3 Minor River Basin: North Platte

1.1.1.4 Hydrologic Unit Code 10180014

1.1.1.5 Assigned Beneficial Uses: Primary contact recreation, Aquatic Life Cold Water Class B, Agricultural Water Supply Class A and Aesthetics (Title 117 – Nebraska Surface Water Quality Standards)

1.1.1.6 Major Tributary: North Platte River (NP2-10000) via Lake McConaughy

Figure 1.1a Location of Lake Ogallala in Keith County, Nebraska

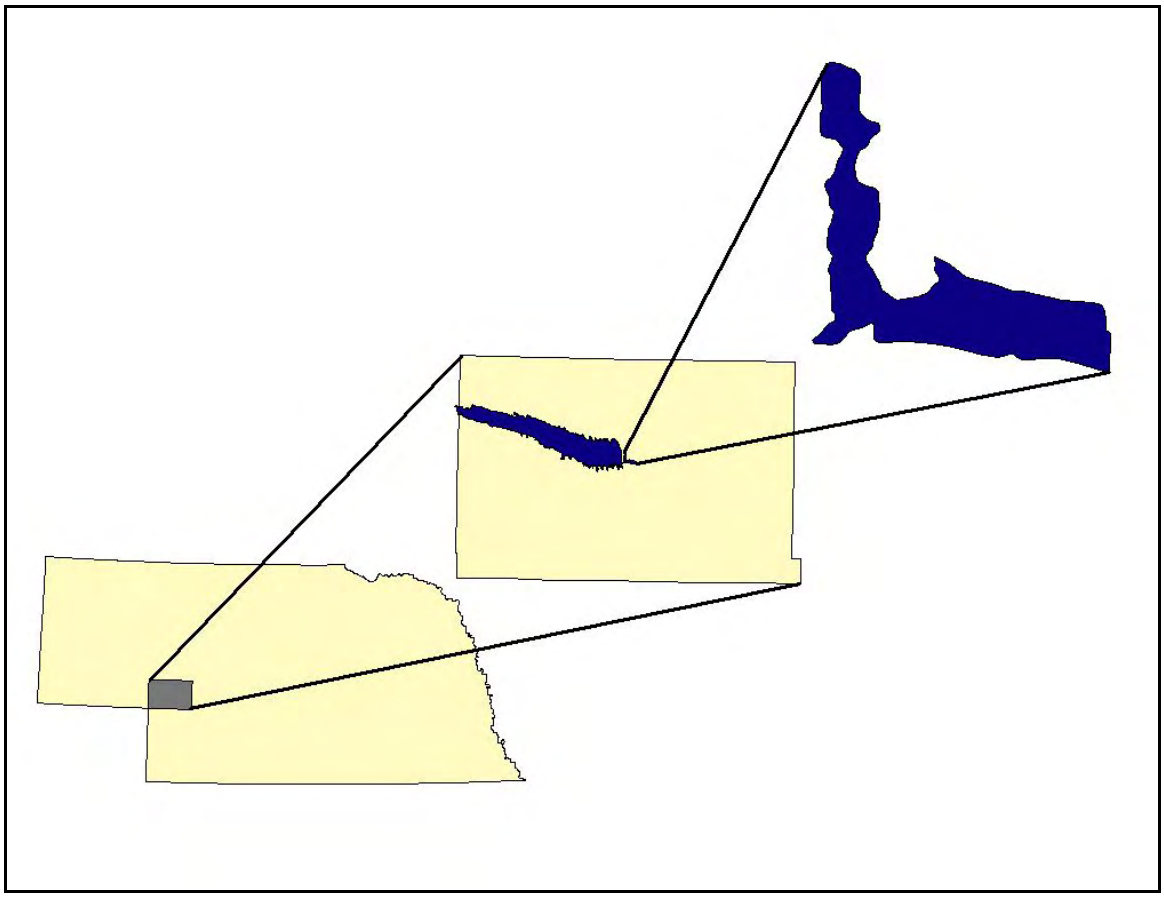
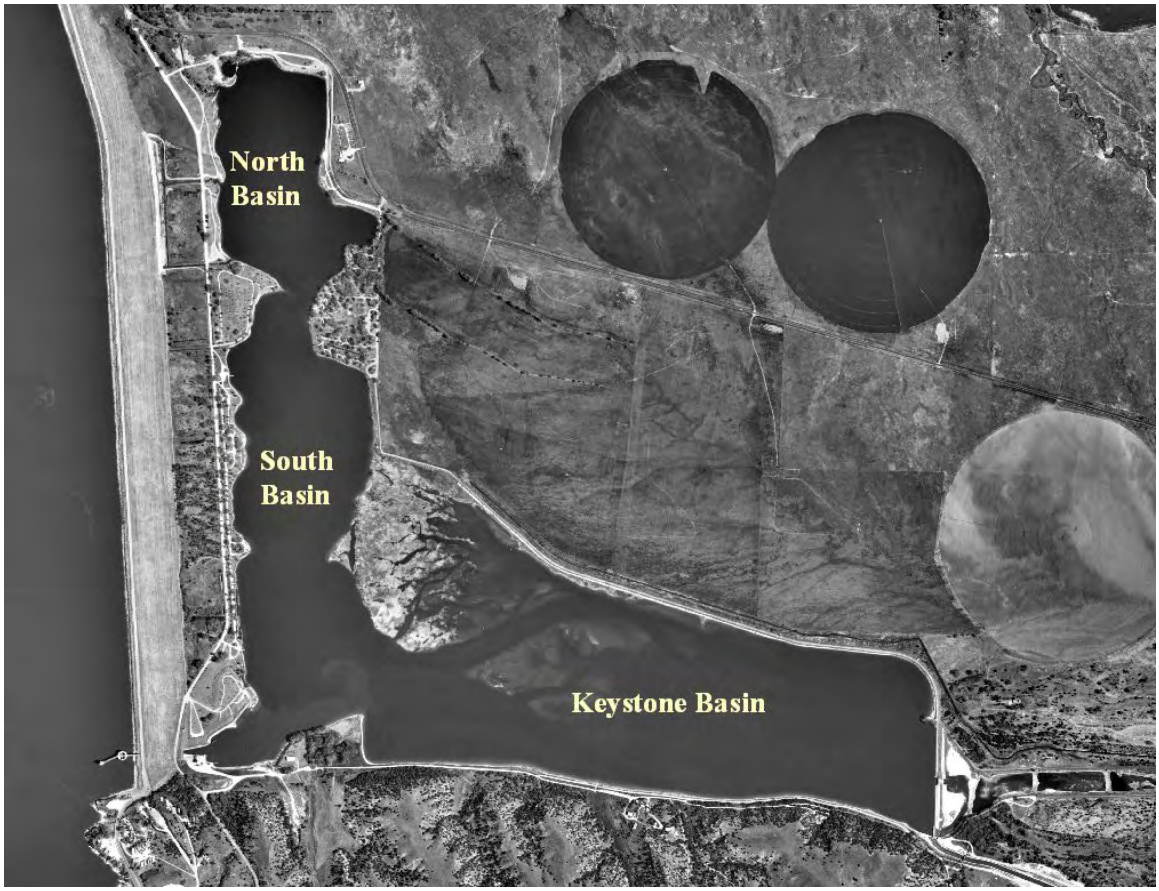


Table 1.1 Physical Description of Lake Ogallala

Parameter	Lake Ogallala
State	Nebraska
County	Keith
Latitude (lake midpoint)	41° 13’ 16”
Longitude (lake midpoint)	101° 39’ 50”
Legal Locations (lake midpoint)	Section 3, Township 14 North, Range 38 West
Surface Area – 1988	650 acres
Shoreline Length	7.3 miles (approximately)
Volume – (live storage at elevation 3122-26.5)	2,281 acre-feet

Figure 1.1b Configuration of Lake Ogallala



1.1.2 Watershed Characterization

1.1.2.1 Physical Features: Lake Ogallala has a very limited watershed (CNPPID 1988) with a majority of the water being delivered from the Lake McConaughy deep-water releases or from drains leading from Kingsley Dam. The watershed contributing to Lake McConaughy exists of approximately 30,000 square miles in Nebraska, Colorado and Wyoming. Above Lake McConaughy are five reservoirs located in Wyoming (Guernsey, Grayrocks, Glendo, Pathfinder and Seminoe). Lake Ogallala is located in the Western High Plains (Level III) ecoregion as defined by Chapman, et al. (2001).

Lake Ogallala and Lake McConaughy were completed in 1940 by the closure of Kingsley Dam by the Central Nebraska Public Power and Irrigation District. Ownership of Lake Ogallala is divided between Central and the Nebraska Public Power District (NPPD) with NPPD owning approximately 1/3 of the lake encompassing most of the Keystone Basin. The Nebraska Game and Parks Commission manage the lake's fishery and recreation areas.

1.1.2.2 Climate: Winters in the area are cold with average low temperatures in the teens with precipitation mainly occurring as snowfall. Summers can be hot with averages high temperatures near 90 but with occasional cool spells. Annual precipitation in the area is approximately 14-17 inches (DNR Data bank). Rainfall can be periodically heavy during the months of May, June and July.

1.1.2.3 Demographics: No municipalities lie adjacent to Lake Ogallala however, the first class city of Ogallala - population 5,142 -lies approximately 7 miles to the southwest. The municipality is part of Keith County, which has shown an approximate 3% growth in the last 10 years. As well, several unincorporated communities reside along the area consisting of mainly seasonal residents and visitors.

1.1.2.4 Land Use: Land use in the North Platte River Basin consists of range, crop, pasture, lakes and wetlands, forest and other uses. Major agricultural products are cattle, corn, sugar beets, dry edible beans, alfalfa and wheat. Most crops require irrigation because annual average precipitation is 14 to 17 inches (NNRC 1975). The largest source of irrigation water is the North Platte River. A system of dams and canals in the river valley, operated by the U.S. Bureau of Reclamation since the early 1900s, diverts water from the river and stores it to irrigate about 300,000 acres. Some groundwater also is used to irrigate (North Platte Natural Resource District Internet Site).

Land use directly surrounding the lake consists of irrigated and dryland crop ground pasture and recreation areas. The University of Nebraska owns and operates 980-acre biological field research station located on the southern shores.

1.1.2.5 Hydroelectric Generating Operation and Water Quantity: Hydropower was considered when Kingsley Dam was constructed but not included however; provisions were made for future additions of a hydroelectric plant. When fossil fuel prices rapidly escalated in the mid-1970s, federal and state policies began encouraging renewable resources such as hydropower to provide for the state's electricity needs. Construction of the Kingsley hydroelectric plant began in 1981 with commercial operation beginning in 1984 (Harza 1988).

Water is released from Lake McConaughy to generate electricity, provide cooling water for NPPD's Gerald Gentleman Station, and satisfy the irrigation requests for Central's customers. Water discharged into Lake Ogallala is released into the North Platte River or the Sutherland Supply Canal. Hydropower production is timed with the daily peak electrical consumption. This action fills the lake in approximately nine hours whereas the draining of the lake occurs continuously. The lake surface elevation during the critical period fluctuates about one meter daily (Kozimor, et. al. 2004) with the lowest volume occurring just prior to generation.

The diurnal fluctuation of water volume matches up with the diurnal respiration and photosynthesis cycle. Meaning the peaks of dissolved oxygen occur when the basin is at or near maximum volume and the valley is when the lake volume is lowest.

2.0 Dissolved Oxygen TMDL

2.1 Problem Identification

Lake Ogallala was first included on the 2002 Nebraska Section 303(d) list as impaired by low dissolved oxygen. The waterbody remained assessed as impaired due to low dissolved oxygen and was included in Category 5 of both the 2004 and 2006 Nebraska Surface Water Quality Integrated Reports (NDEQ 2004, NDEQ 2006). The following sections detail the extent and nature of the water quality impairments related to low dissolved oxygen in Lake Ogallala.

2.1.1 Water Quality Conditions

The NGPC has taken advantage of the cold water in Lake Ogallala since 1949 for the establishment and maintenance of a unique trout fishery (Hutchinson 1986). The Control Tower has an intake at approximately 135 feet below the surface of Lake McConaughy (elevation 3,265 feet). Prior to the installation and operation of the hydroelectric unit in 1984, dissolved oxygen in the tail water was not a concern. During this time, the Control Tower gates in the release structure were open only a small amount to regulate the outflow from Lake McConaughy. The energy from the water coming through the Control Tower was expended through the pool of water, approximately 26-feet deep, and the dissipating blocks on the floor of the stilling basin at the outlet of the Control Tower (CNPPID 1988). This turbulence entrained oxygen into the water and the combination of temperature and oxygen were ideal for the survival and growth of trout species.

After completion of the hydro, water is released through Kingsley Dam with the control tower gates completely open all of the time. The flow is controlled by the wicket gates in the hydro and the energy from the falling water passing through the hydro drives the turbine and thus generates power (CNNPID 1988). Construction of the Kingsley Hydro included a Howell-Bunger bypass valve as a means of releasing water through the plant without running through the turbine. The bypass valve is now used on a regular basis during the summer to aerate the water entering Lake Ogallala and maintain the dissolved oxygen level in the water.

In response to the dissolved oxygen issues, the NDEQ (formerly the Nebraska Department of Environmental Control), the NGPC and Central conducted a joint study of the water quality and potential impacts to the fishery. A result of these studies was the development of site-specific dissolved oxygen criteria for Lake Ogallala. The criteria was proposed before and approved by the Environmental Control (Quality) Council (Council) on May 20, 1988, signed by then Governor Orr on August 23, 1988 and approved by EPA Region 7 on October 18, 1988. Amendments to the site-specific criteria were approved by the Council on March 8, 1991, signed by the governor on April 10, 1991 and approved by EPA Region 7 on August 5, 1991.

2.1.2 Water Quality Criteria Violated and/or Beneficial Uses Impaired

The *Aquatic Life* – Site Specific Dissolved Oxygen water quality criteria for Lake Ogallala is not being met. The site specific criteria is as follows:

The following criteria shall apply from July 1 through October 15 as specified. When the Kingsley Hydropower Plant is in operation (generating electricity), these criteria are based on water temperature measurements taken continuously and averaged every hour in the powerhouse of the Kingsley Hydropower Plant and on dissolved oxygen measurements taken continuously and averaged every 10 minutes form Lake Ogallala at the midpoint of the buoy line (1987 location at the outer edge of the stilling basin) at a one meter depth. For the purposes of calculating a seven-day mean, seven day mean minimum and thirty-day mean values at the buoy line, seven-day and thirty day calculation periods shall be based on a sequence of days not to include any day in which Kingsley Hydropower Plant is not in operation. The following criteria may also be based on temperature and dissolved oxygen measurements taken from Lake Ogallala at any location except the metalimnion and hypolimnion when the lake exhibits thermal stratification.

When the daily mean temperatures are 18℃ or less the following criteria shall apply:

- *One-day minimum of not less than 3.0 mg/l.*
- *Daily mean of not less than 4.0 mg/l and no more than 20% of the one-day mean values shall not be less than 4.2 mg/l.*
- *Seven-day mean of not less than 4.3 mg/l.*

When daily mean water temperatures exceed 18℃ for four consecutive days of operation, the following criteria shall apply for as long as daily mean water temperatures continue to exceed 18℃. These criteria take effect on the fifth day of the daily mean water temperatures exceeding 18℃.

- *One-day minimum of not less than 4.0 mg/l.*
- *Daily mean of not less than 5.0 mg/l.*

When daily mean water temperatures exceed 18℃ for fifteen consecutive days of operation or when daily mean water temperature exceeds 20 ℃ the dissolved oxygen criteria for Class B – Coldwater Aquatic Life shall apply as long as daily mean water temperatures continue to exceed 18℃. These criteria take effect on the sixteenth day of daily mean water temperatures exceeding 18℃ or on the first day after daily mean water temperatures exceed 20 ℃.

In implementing the criteria, if an interruption in the operation of Kingsley Hydropower Plant exceeding 24 hours occurs during the count of days leading to a change in criteria, the count of days shall be suspended until the plant in back in operation. The first new day of operation shall be counted as the next consecutive day in the original count of days.

Dissolved Oxygen Criteria for Class B – Coldwater Aquatic Life Shall apply during the periods of October 16 through June 30.

The Class B – Coldwater Aquatic Life Dissolved Oxygen Criteria

- One-day minimum of not less than 5.0 mg/l from April 1 through June 30.
- One-day minimum of not less than 4.0 mg/l from July 1 through March 31.
- Seven-day mean minimum of not less than 5.0 mg/l from July 1 through March 31.
- Seven-day mean of not less than 6.5 mg/l from April 1 – June 30.
- Thirty-day mean of not less than 6.5 mg/l from July 1 – June 30.

2.1.3 Data Sources

As a condition of the Federal Energy Regulatory Commission's permit, under the Clean Water Act Section 401 certification, Central has conducted water quality monitoring in Lake Ogallala since 1986. Weekly monitoring is conducted at six stations usually commencing in early June and ending in October. The data is then submitted to the NDEQ as an annual report.

2.1.4 Water Quality Assessment

The results of the dissolved oxygen data assessments for the years 1999-2004 are provided in Table 2.1.4.

2.1.4.1 Aquatic Life Assessments: In 1997, Lake Ogallala was chemically treated with rotenone for the purpose of removing undesired fish species specifically, common carp, white sucker and alewife. Following the renovation, salmonids were returned in an effort to restore the NGPC management goal of maintaining a quality put and grow salmonid fishery (Madson and Eichner, 1996). In the years following, fish kills involving trout were reported to have occurred on both Lake Ogallala and the connected Sutherland Supply canal. The extent of kills was not well documented in terms of the percentage of the population impacted; however one report by the NGPC identified several hundred trout involved.

Along with the fish kills, during the same time stressed trout were observed in both waterbodies. Trout were also observed to be emigrating from Lake Ogallala to the Sutherland Supply Canal potentially as a means of seeking a refuge. During this time dissolved oxygen samples yield various results ranging from below the water quality criteria to super-saturation.

Table 2.1.4 Dissolved Oxygen Profile Data and Assessment Information

Station Identification	Years Data Available	Number of Profiles	Number of Violations	Percentage of Violations	Number Needed to Assess as Impaired
1	2002	12	2	17%	4
4	1999	17	1	6%	4
5	1999, 2002	32	3	9%	6
5A	1999	17	3	18%	4
6	1999, 2001	41	13	32%	8
6N	2002	13	3	23%	4
7	1999, 2002	33	22	67%	7
8	1999, 2001-02	45	26	58%	8
9	2001	26	11	42%	6
9N	2002	13	2	15%	4
North End	2004	22	11	50%	5
12&12B	2001-02	38	9	24%	7
13	2001-02	45	11	24%	8
14	2001-02	56	19	34%	10
15	2001-02	36	11	31%	7
16	2001-02	44	16	36%	8
17	2001-02	43	20	47%	8
18	2001-02	44	14	32%	8
19	2001-02	53	23	43%	9
20	2001-02	53	25	47%	9
Total		**683**	**245**	**36%**	**79**

2.1.5 Pollutants Targeted

Dissolved oxygen levels in natural waters are dependent upon the physical, chemical and biochemical activities prevailing in the waterbody (APWA, et. al 1975). Sources of dissolved oxygen include photosynthesis and water surface-atmosphere interactions. The primary sinks for dissolved oxygen are oxidation of organic materials and respiration by aquatic plants and organisms. The impacts to aquatic life are the manifestation of low dissolved oxygen (Terrene 2000).

Water discharged from Kingsley Dam contains extremely high Immediate Oxygen Demand (IOD) during the "critical period" in late summer when dissolved oxygen levels are at or near zero in the hypolimnetic waters draining from Lake McConaughy (Hoagland, et. al. 2000).

IOD is the quantification of those oxygen-demanding constituents that react more quickly – usually less than 24 hours. The 14th Edition of Standard Methods contained an analytical procedure for IOD to capture the load imposed by ferrous iron, sulfite, sulfide and aldehyde. Standard Methods 16th Edition eliminated the IOD test for various reasons however, the text does state:

"Although only the 5-day Biochemical Oxygen Demand (BOD) is described here, many variations of oxygen demanding measurements exist. These include using shorter or longer incubation periods…"

Data collection and analysis in 2001 utilized the flexibility of the BOD procedure and refer to a shortened incubation times (6, 12 and 24 hours) as IOD. IOD constituents in the Kingsley Discharge have been identified to primarily be hydrogen sulfide (H_2S) and ammonia. Although ammonia and H_2S are identified separately, with the primary focus of the TMDL being dissolved oxygen, the constituents will not be addressed separately but as IOD.

Another dissolved oxygen sink comes from the biological oxidation of organic matter or BOD.

2.1.6 Potential Pollutant Sources

2.1.6.1 Point Source: No point sources discharge to Lake Ogallala. Point sources discharge or have the potential to discharge to waters in the watershed above Lake McConaughy/Lake Ogallala. Facility types include: municipal wastewater treatment facilities, confined animal feeding operations, aquaculture facilities and industrial facilities. The facilities that have been issued a National Pollutant Discharge Elimination System Permit (according to EPA's Permit Compliance System) above Lake McConaughy in Nebraska are shown in Figure 2.1.6.1a.

Animal feeding operations that have been issued State of Nebraska permits, required for construction and operation of livestock waste control facilities (LWCF) if the operation has discharged, or has the potential to discharge, livestock waste to waters of the State are also considered potential sources. Figure 2.1.6.1b shows the facilities above Lake McConaughy/Lake Ogallala. These facilities are designed to contain any run-off that is generated by storm events that are less in intensity than the 25 year, 24-hour rainfall.

2.1.6.2 Nonpoint Sources: Nonpoint sources that may contribute to the organic loading of Lake McConaughy/Lake Ogallala include irrigation return flow, agricultural run-off, unregulated stormwater discharges, stream bank and gulley erosion and improper application and management of biosolids (manure, municipal sludge and septage).

2.1.6.3 Natural Sources: Although natural sources of organic loading do exist in the watershed, it is difficult to differentiate these contributions from the nonpoint source loading. Therefore, for this TMDL, natural sources will be combined into the load allocation.

2.2 TMDL Endpoint

The endpoint for this TMDL will be based on the site-specific water quality criteria established for Lake Ogallala.

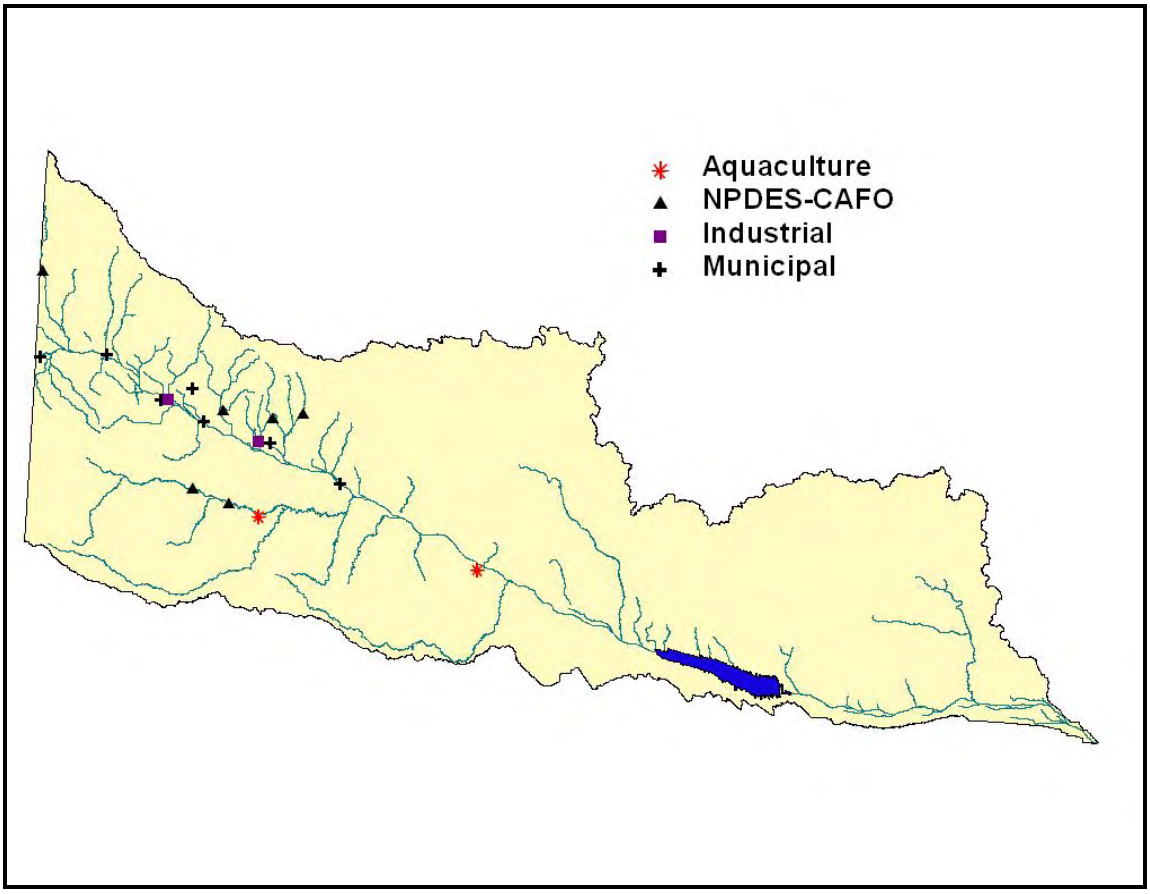
2.2.1 Numeric Water Quality Criteria

Water quality criteria established for the protection of the aquatic life coldwater class B beneficial and the site-specific water quality criteria for Lake Ogallala found in Title 117, Chapter 4, Section 003.02B1a (NDEQ 2002) as described in Section 2.1.2 above.

2.2.2 Aquatic Life

Site-specific water quality criteria for Lake Ogallala were developed and approved as a result of multiple studies conducted in 1985-87. The goal of the criteria is to protect the existing Coldwater Class B use (support year round populations of cold water aquatic life but do not support natural reproduction of salmonid populations).

Figure 2.1.6.1a NPDES Permitted Facilities in the above Lake McConaughy/Lake Ogallala



Ultimately, the best measure of the aquatic life beneficial use support will be the aquatic life – in the case of Lake Ogallala the salmonid fishery. The NGPC fishery management goal for Lake Ogallala is a quality put and grow salmonid fishery. While there are other species present (walleye, white bass and perch), they do not biologically fit into a waterbody where the management goal is to provide a quality salmonid fishery (Madsen and Eichner, 1996).

Although not part of the fishery management scheme, the non-salmonids would be afforded protection by the criteria established for salmonids. This is based on *EPA's Ambient Water Quality Criteria for Dissolved Oxygen* which states; "there is little published data regarding the dissolved oxygen requirements of most non-salmonid species, there is apparently enough anecdotal information to suggest that many cool water species more sensitive to dissolved oxygen depletion than warmwater species" (EPA 1986).

Given the management goal of maintaining a quality put and grow fishery, the primary TMDL endpoint will be measured by the growth, survival of salmonids stocked in Lake Ogallala. The applicable dissolved oxygen criteria are set to achieve this outcome. The specific goals are provided in table 2.2.2. Monitoring to evaluate these goals will be provided in Section 5.0.

Figure 2.1.6.1b Animal Feeding Operations Above Lake McConaughy/Lake Ogallala Issued or Requesting a State Construction of Operating Permit or Requesting an Inspection

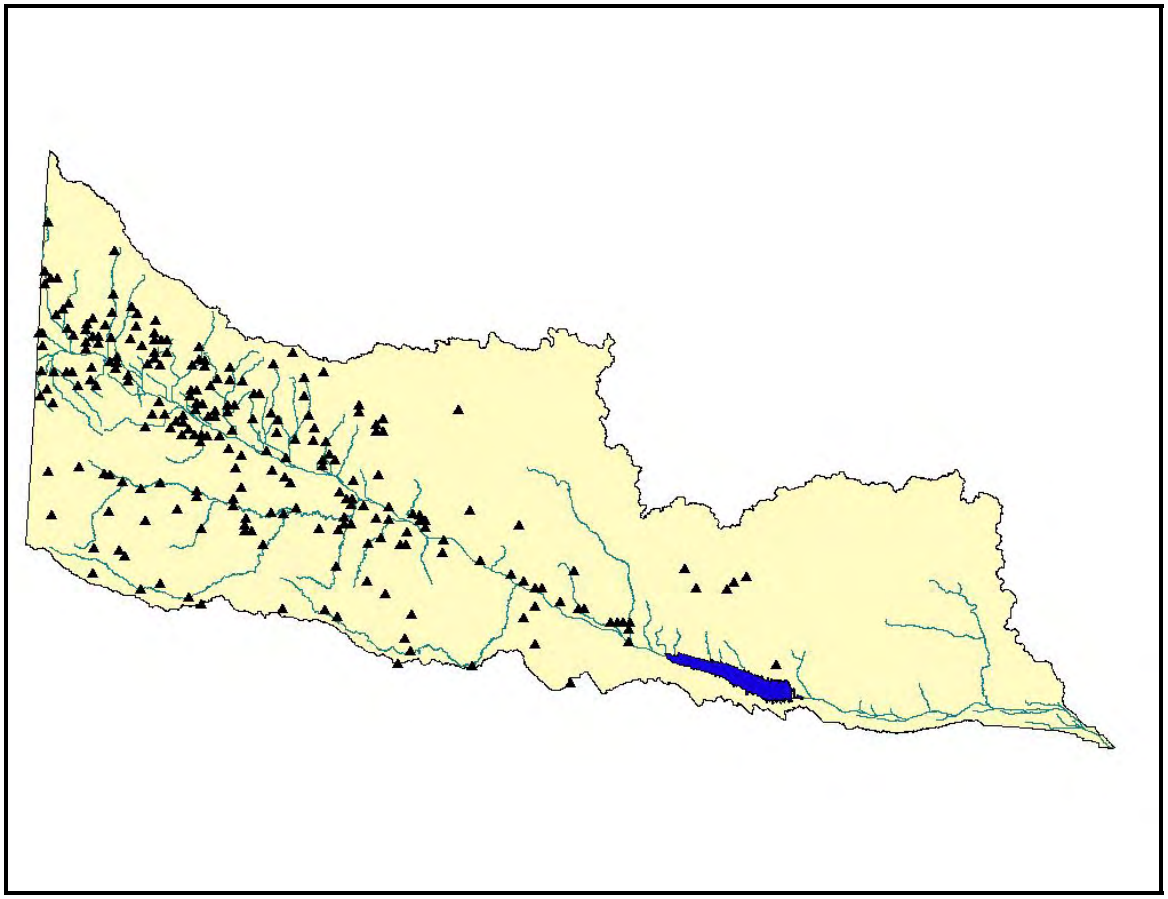


Table 2.2.2 Salmonid Fishery Assessment Goals

Goal Description	Measurement	Quantitative Value	Frequency of Assessment
Return by Weight	Relative Weight	1.0	Annual
Return by Number	Survival	25%	Annual

2.2.3 Selection of Critical Environmental Conditions

As stated above, water is delivered to Lake Ogallala from deep water releases from Lake McConaughy. Past studies have shown that during the summer Lake McConaughy exhibits strong thermal and chemical stratification. This also corresponds with the time when water temperatures are generally elevated. Based upon these concerns, the critical conditions will be those that occur July 1 to October 15 or whenever Lake McConaughy exhibits thermal stratification and the hydro is being operated. This is based on historical measurements of stratification in Lake McConaughy.

2.2.4 Waterbody Pollutant Loading Capacity

TMDLs are required to include an estimation of the greatest amount of loading that a waterbody can receive without violating water quality standards. Dissolved oxygen concentrations are not a direct result of pollutant loads rather a response to pollutants, climatic and physical influences on the waterbody. Circulation, water quality monitoring and modeling have shown Lake Ogallala to be quite unique from a hydrologic, hydraulic and management standpoint. CE-QUAL-W2 modeling efforts have demonstrated the most significant factors contributing to low DO in Lake Ogallala are macrophyte respiration, IOD caused by hydrogen sulfide oxidation and low DO water from Lake McConaughy's hypolimnion (Kozimor, et. al. 2004).

Macrophyte density will vary depending upon nutrient contribution, season and the rough fish (common carp and white sucker) population. A static loading scenario may not be appropriate to address the dynamic nature of the waterbody. CE-QUAL-W2 modeling identified multiple scenarios that would result in meeting the water quality criteria for DO. These scenarios can be found in Table 2.2.4a and the associated loading can be found in table 2.2.4b.

Table 2.2.4a Scenarios that Comply with the Dissolved Oxygen Criteria

Scenario	Macrophyte Density (gram dry weighy/m^2)	Influent (Lake McConaughy) Dissolved Oxygen	IOD (mg/l)
1	172	8	2.5
2	688	10	2.5
3	344	10	3.5
4	688	8	0.5
5	344	8	2.5
6	172	6	0.5

Table 2.2.4b Loadings Associated with Scenarios That Comply with DO Criteria

Scenario	Macrophyte Density (g dry wt/m^2)	DO Loading – kg/hr	DO Loading – kg/day	IOD Loading – kg/hr	IOD Loading – kg/day
1	172	3302	30663	1032	9582
2	688	4128	38329	1032	9582
3	344	4128	38329	1445	13415
4	688	3302	30663	206	1916
5	344	3302	30663	1032	9582
6	172	2477	22997	206	1916

2.3 Pollutant Source Assessment

For this TMDL, the loading was estimated using a combination of models and chemical data. CE-QUAL-W2 was the water quality model was utilized.

2.3.1 Existing Conditions/Loadings

Loadings were established for constituents used in the calibration and scenario runs based on August 2000 conditions and data. The values were determined in the units of average kg/hour during hydropower operation and in kg/day during periods of running and resting (Kozimor, et. al. 2004). The values can be found in Table 2.3.1.

Table 2.3.1 Existing Conditions/Loading (2000) Based on Empirical Data and Modeling

Parameter	Loading (kg/hour)	Loading (kg/day)
DO	2525	23578
IOD	1476	12860
Total Phosphorus	10.8	96.6
Total Nitrogen	369	3235
Chlorophyll *a*	0.26	2.29
Organic Material	1748	15574
	Density grams dry weight/m^2	
Macrophytes	688	

2.3.2 Reductions Necessary to meet Loading Capacity

For the purposes of implementation planning and source control, it is important to note the reductions necessary to meet the loading capacity values. Section 2.2.2 describes the dynamic nature of the waterbody and the importance of the role macrophytes play in the dissolved oxygen concentrations in Lake Ogallala. Table 2.3.2 provided the load and macrophyte reductions combinations for the scenarios 1-7 as modeled.

Table 2.3.2 Reductions From 2000 Conditions to Meet Complying Scenarios

Scenario	Maximum Macrophyte Density Reduction	Percent Reduction From 2000 Density	DO Loading Increase – kg/hr	DO Loading Increase – kg/day	IOD Loading Reduction – kg/hr	IOD Loading Reduction kg/day
1	516	75%	773	7085	444	3278
2	688	0%	1599	14751	444	3278
3	344	50%	1599	14751	31	0
4	688	0%	773	7085	1270	10944
5	344	50%	773	7085	444	3278
6	516	75%	0	0	1270	10944

2.3.3 Linkage of Sources to Endpoint

No point sources discharge to Lake Ogallala and due to the limited watershed, a majority of the water delivered is from Lake McConaughy. In March 1982 the 8th Circuit Court ruled in *Missouri vs. the Department of the Army* that reduction of oxygen caused by the dam did not constitute the "addition" of a pollutant from a "point source". Based on this finding, the entire source of the pollutants in Lake Ogallala is due to nonpoint sources.

2.4 Pollutant Allocations

A TMDL is defined as:

$$\text{TMDL} = \text{Loading Capacity} = \text{WLA} + \text{LA} + \text{Background} + \text{MOS}$$

2.4.1 Wasteload Allocation

As stated in Section 2.3.3 no point sources discharge to Lake Ogallala therefore the WLA will be "zero". Point sources do discharge to the Lake McConaughy watershed and a discussion of this will be provided in the management plan.

2.4.2 Load Allocation/Natural Background

Establishment of the load allocation (LA) identifies the dynamic and unique nature of Lake Ogallala and the incoming water from Lake McConaughy and will be established according to the macrophyte density. The load allocations will also include the contribution from background sources. The LA can be found in Table 2.4.2.

Table 2.4.2 Load Allocation Based on Observed Macrophyte Density

Macrophyte Density (g dry wt/m^2)	DO Loading – kg/hr	DO Loading – kg/day	IOD Loading – kg/hr	IOD Loading – kg/day
172	3302	30663	1032	9582
688	4128	38329	1032	9582
344	4128	38329	1445	13415
688	3302	30663	206	1916
344	3302	30663	1032	9582
172	2477	22997	206	1916

2.4.3 Margin of Safety

During periods of low dissolved oxygen that corresponds with the stratification of Lake McConaughy, water is regularly discharged through the Howell-Bunger valve in order to maintain the DO at the buoy line. However, for this modeling event, all incoming flows were run strictly through the hydro facility and aeration through the Howell-Bunger was not performed. The modeling assumption assumes a worst-case situation of incoming water DO concentration.

3.0 Water Quality Conditions of Lake McConaughy

Reservoir water quality is a reflection of the watershed. That is, reservoirs act as sinks for pollutants originating in the upland area. Several factors influence how pollutants are expressed in a reservoir including, volume, pollutant concentration, retention time and climatic conditions. Water quality data and observations are assessed to determine the beneficial use support for these reservoirs. Available data was assessed during preparation of the 2004 Integrated Report and Lake McConaughy was included as a Category 1 waterbody, meaning all uses are supported.

That being said, due to the configuration of the two waterbodies, the constituents being delivered to and discharged from Lake McConaughy overwhelmingly influence the water quality in Lake Ogallala. The North Platte River watershed above Lake McConaughy covers three states and approximately 29,000 mi^2. Water quantity and quality control is provided by the five upstream reservoirs however, the uncontrolled area from the last Wyoming dam to Lake McConaughy is 8,647 mi^2.

Water quality models and monitoring have shown IOD due to H_2S and low DO water from Lake McConaughy to be two of the most significant water quality factors affecting DO in Lake McConaughy. Both of these conditions can be attributed to processes occurring in the hypolimnion. H_2S forms during the decomposition of organic material and the bacterial reduction of sulfates (APWA, et. al 1975). Along with this, during periods of thermal stratification respiration can exceed production of dissolved oxygen. These conditions may occur in any productive waterbody but are magnified with increased productivity.

The combination of Lake McConaughy and Lake Ogallala, allow for the capture and storage of snowmelt and other high flows and a more constant release to meet downstream uses. This combination and 64 years of operation has allowed for the capture, retention and accumulation of pollutants that are not being expressed in Lake McConaughy to the point of causing impairment but are in Lake Ogallala.

4.0 Implementation Plan

Derivation of an implementation plan will need to evaluate the use of management and protection techniques or a combination of these. For the purposes of this "management" will be defined as improving the lake to enhance the uses and "protection" will be defined as the prevention of further or future adverse impacts (Holdren et. al. 2001). It will also be important to consider both lake and watershed management in the plan. Although watershed management is vital, it may not be the sole answer. For example, deposited sediments and nutrients in Lake McConaughy can attribute to dissolved oxygen impairments in Lake Ogallala for several years. Management techniques should be tailored to compliment not replace each other (Holdren et. al. 2001).

An observation of water pollution control practices reveals three principle components:

- Reduction or elimination of the source
- Retain at the point or origin
- Treatment

The extent of the application of these techniques is dependent on the cost, benefits, feasibility and the expected level of success. Successful management of waterbody pollutants often requires a combination of these components due to the diffuse pollutant sources and the size of the contributing watershed.

The accompanying management plan has been developed primarily for addressing DO concerns in Lake Ogallala, recognizing the impacts of the hypolimnetic discharge from Lake McConaughy. The water quality management plan was developed by NDEQ, NGPC, NPPD and CNPPID. These entities play a role in the managements of the waterbody and the primary focus of this section will be protection of the aquatic life and the continued use of the water for multiple purposes.

4.1 Reasonable Assurances

Effective management of point and nonpoint source pollution in Nebraska necessarily requires a cooperative and coordinated effort by many agencies and organizations, both public and private. Each organization is uniquely equipped to deliver specific services and assistance to the citizens of Nebraska to help reduce the effects of nonpoint source pollution on the State's water resources. Appendix A lists those entities that may be included in the implementation process. These agencies have been identified as being responsible for program oversight or fund allocation that may be useful in addressing and the impacts of pollutants delivered to Lake McConaughy and the impacts of low DO in Lake Ogallala. Participation will depend on the agency/organization's program capabilities.

5.0 Future Monitoring

Monitoring of Lake Ogallala and Lake McConaughy will be conducted in the future to determine if the water quality and aquatic life is improving, degrading or remaining status quo. As well, monitoring will be conducted to evaluate the effectiveness of implemented management practices. Monitoring planned and the entities responsible are described in Table 6.0.

Table 5.0 Future TMDL Related Monitoring Activities for Lake Ogallala and Lake McConaughy

Agency Responsible	Action	Frequency
NPPD	Vegetation Surveys[1]	At least once annually during anticipated peak of growing season
CNPPID	Buoy Line Dissolved Oxygen Monitoring[1]	June -October 15: When Hydro is Online
CNPPID	Dissolved Oxygen Profile Monitoring[1]	Weekly June-October 15
NGPC	Creel, Angler and Salmonid Population Survey[1]	Once Annually
NDEQ	Water Quality Monitoring[2]	Once Monthly, May-October
NDEQ	Watershed Monitoring[3]	Bi-weekly April-September, Monthly October-March

[1] Lake Ogallala
[2] Lake McConaughy and Lake Ogallala
[3] Ambient Stream Monitoring program

6.0 Public Participation

The availability of the TMDLs in draft form was published in Ogallala-Keith County News and several other newspapers with the public comment period running from May 14, 2007 to June 18,2007. These TMDLs were also made available to the public on the NDEQ's Internet site and electronic announcements were sent to interested stakeholders. No comments were received.

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Appendix A – Federal, State Agency and Private Organizations Included in TMDL Implementation

FEDERAL

- *Bureau of Reclamation*
- *Environmental Protection Agency*
- *Fish and Wildlife Service*
- *Geological Survey*
- *Department of Agriculture - Farm Services Agency*
- *Department of Agriculture - Natural Resources Conservation Service*

STATE

- Nebraska Association of Resources Districts
- Department of Agriculture
- Department of Environmental Quality
- Department of Roads
- Department of Water Resources
- Department of Health and Human Services
- Environmental Trust
- Game and Parks Commission
- Natural Resources Commission
- University of Nebraska Institute of Agriculture and Natural Resources (IANR)
- UN-IANR: Agricultural Research Division
- UN-IANR: Cooperative Extension Division
- UN-IANR: Conservation and Survey Division
- UN-IANR: Nebraska Forest Service
- UN-IANR: Water Center and Environmental Programs

LOCAL

- Natural Resources Districts
- County Governments (Zoning Board)
- City/Village Governments

NON-GOVERNMENTAL ORGANIZATIONS

- Nebraska Wildlife Federation
- Pheasants Forever
- Nebraska Water Environment Association
- Nebraska Corn Growers Association, Wheat Growers, etc.
- Nebraska Cattlemen's Association, Pork Producers, etc
- Other specialty interest groups
- Local Associations (i.e. homeowners associations)