Mud Creek
Muscatine County, Iowa

Total Maximum Daily Load
For
Organic Enrichment

March 2003
(Revised June 2003)

Iowa Department of Natural Resources
Water Quality Bureau

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Mud Creek Impaired Segment Length, 14.03 miles	
IDNR Waterbody ID	IA 02-CED-0160-0
Hydrologic Unit Code:	07080206
Location:	Confluence with Sugar Cr. (S10,T78N, R2W, Muscatine Co.) to confluence with an unnamed tributary, (S5, T78N, R1E, Muscatine Co.)
Water Quality Standards Designated Uses	Aquatic life, warmwater limited resource
Watershed Area:	106 square miles
Receiving Water Body	Sugar Creek
Pollutant	organic enrichment/low dissolved oxygen
Pollutant Sources	WWTP effluent, nonpoint sources
Impaired Use	Aquatic life support

The Federal Clean Water Act requires the development of a total maximum daily load (TMDL) for the pollutant(s) that causes a water body to be placed on the State of Iowa impaired waters list [303(d) list]. Mud Creek is on the 1998 impaired waters list for organic enrichment that creates a condition only partially supporting aquatic life.

This document consists of a single TMDL for organic enrichment that will result in water quality in Mud Creek consistent with the Iowa Water Quality Standards. Organic enrichment is a problem tied to low dissolved oxygen concentrations caused by point and nonpoint sources.

This will be a phased TMDL. Phasing TMDLs is an iterative approach to managing water quality that becomes necessary when the origin, nature and sources of water quality impairments are not well understood. In Phase 1, waterbody load capacity, existing pollutant load over this capacity, pollutant sources, and load allocations to these sources are determined from available information. A monitoring plan will ascertain Phase 1 load reduction success as well as whether the calculated Phase 1 load capacity provides water quality adequate to support designated uses. Monitoring activities may include routine sampling and analysis, biological assessment, fisheries studies, and watershed and/or waterbody modeling. Section 5.0 includes a description of planned monitoring.

Phase 1 consists of setting wasteload allocations for point sources and load allocations for nonpoint sources based on evaluation of monitoring data and waterbody and watershed modeling.

Phase 2 will consist of carrying out the Section 5.0 monitoring plan, evaluating collected data, and readjusting TMDL target values as needed.

The Mud Creek TMDL has been prepared in compliance with the current (November 2002) regulations for TMDL development promulgated in 1992 as 40 CFR Part 130.7.

1. Introduction

The Federal Clean Water Act requires the development of a total maximum daily load (TMDL) for the pollutant(s) that causes a water body to be placed on the State of Iowa impaired waters list [303(d) list]. Mud Creek is on the 1998 impaired waters list for organic enrichment caused by both point and nonpoint pollutant sources. Organic enrichment depresses dissolved oxygen concentration in the water column as microorganisms oxidize organic material for metabolism and reproduction. This situation has caused a dissolved oxygen water quality condition only partially supporting the stream's aquatic life designated use.

The TMDL for Mud Creek will determine the maximum oxygen demanding material that the stream can receive without impairment and attain compliance with the Iowa Water Quality Standards.

Specifically this organic enrichment TMDL for Mud Creek will:

- Identify the adverse impact that organic enrichment is having on aquatic life use and link this to water quality criteria compliance.
- Identify an acceptable oxygen demand load (load capacity) that ensures attainment of stream aquatic life use.
- Estimate how much the existing oxygen demand (OD) load exceeds the load capacity.
- Identify OD sources and estimate a load allocation for each source.
- Allocate a pollutant load margin of safety to account for uncertainty.
- Provide a brief implementation plan to guide the IDNR, other agencies, and stakeholders in efforts to reduce loads to acceptable levels.

This TMDL is consistent with a phased-approach: estimates are made of needed pollutant reductions, load reduction controls are implemented, and water quality is monitored for plan effectiveness. Flexibility is built into the plan so that load reduction targets and control actions can be reviewed and updated if monitoring indicates continuing water quality problems.

2. Mud Creek, Description and History

2.1. The Stream (from IDNR water quality assessment)

There is strong evidence of biological impairment in segments of Mud Creek. Stream benthic macroinvertebrate and fish community index levels measured in the segment beginning immediately upstream from the Durant WWTP and ending immediately downstream from the Wilton WWTP were significantly lower in 1996 than index levels measured at regional reference sites from 1994 to 1998. Index levels improved downstream from Wilton but benthic macroinvertebrate index levels remained significantly below those of the reference sites.

Point and nonpoint sources are contributing to biological impairment of Mud Creek. The stream assessment crew observed livestock grazing impacts in the riparian corridor at many locations in the middle and upper reaches of the stream. These are areas of accelerated streambank erosion and organic waste inputs that contribute to poor water quality. The upper reaches of Mud Creek and headwater tributaries also have a large amount of row cropland in close proximity to the stream and many stream reaches have been straightened.

Table 1. Physical Features

WATERBODY NAME:	**Mud Creek**
Hydrologic Unit Code:	07080206
IDNR Waterbody ID	
Location:	Confluence with Sugar Cr. (S10,T78N, R2W, Muscatine Co.) to confluence with an unnamed tributary, (S5, T78N, R1E, Muscatine Co.)
Impaired Segment Length	14.03 miles
Water Quality Standards Designated Use	Aquatic life, B(LR), warm water limited resource.
Receiving Waterbody	Sugar Creek
Watershed Area	67,800 acres (106 sq.mi.)
Main Channel Slope	3.9 feet/mile
Main Channel Sinuosity Ratio	1.28 (ratio)
Stream Density	1.32 miles/square mile
Main Channel Slope Proportion	12.6 (ratio)
Ruggedness Number	232 feet/mile
Slope Ratio	1.67 (ratio)
Number of First Order Streams	51
Basin Stream Order	4

2.2. The Watershed

The Mud Creek watershed lies in Muscatine, Cedar, and Scott Counties in eastern Iowa draining 68,000 acres. Major tributaries of Mud Creek include Big Elkhorn, Little Elkhorn, West Branch Mud and East Branch Mud Creeks. The cities of Walcott, Stockton, Durant and Wilton are adjacent to Mud Creek and have a combined population of 5,500. Ninety percent of the land in the Mud Creek watershed is privately owned and is in agricultural production. Eighty percent of the watershed is in intense row crop with corn and soybeans making up 88% of that. Row cropping is most prevalent in the upper two thirds of the watershed. Some poorly drained areas have been converted to pasture. Most of this pasture is in the lower third of the watershed. Cow/calf and feedlot cattle comprise most of the pasture operations in the watershed.

Table 2, Watershed Characteristics

WATERSHED CHARACTERISTIC:	MUD CREEK
Total Drainage Area	106 square miles
Basin Length	19 miles
Basin Perimeter	57 miles
Average Basin Slope	2.30 %
Basin Relief	175 feet
Effective Basin Width	5.5 miles
Main Channel Length (MCL) (mi)	24
Total Stream Length (TSL) (mi)	140

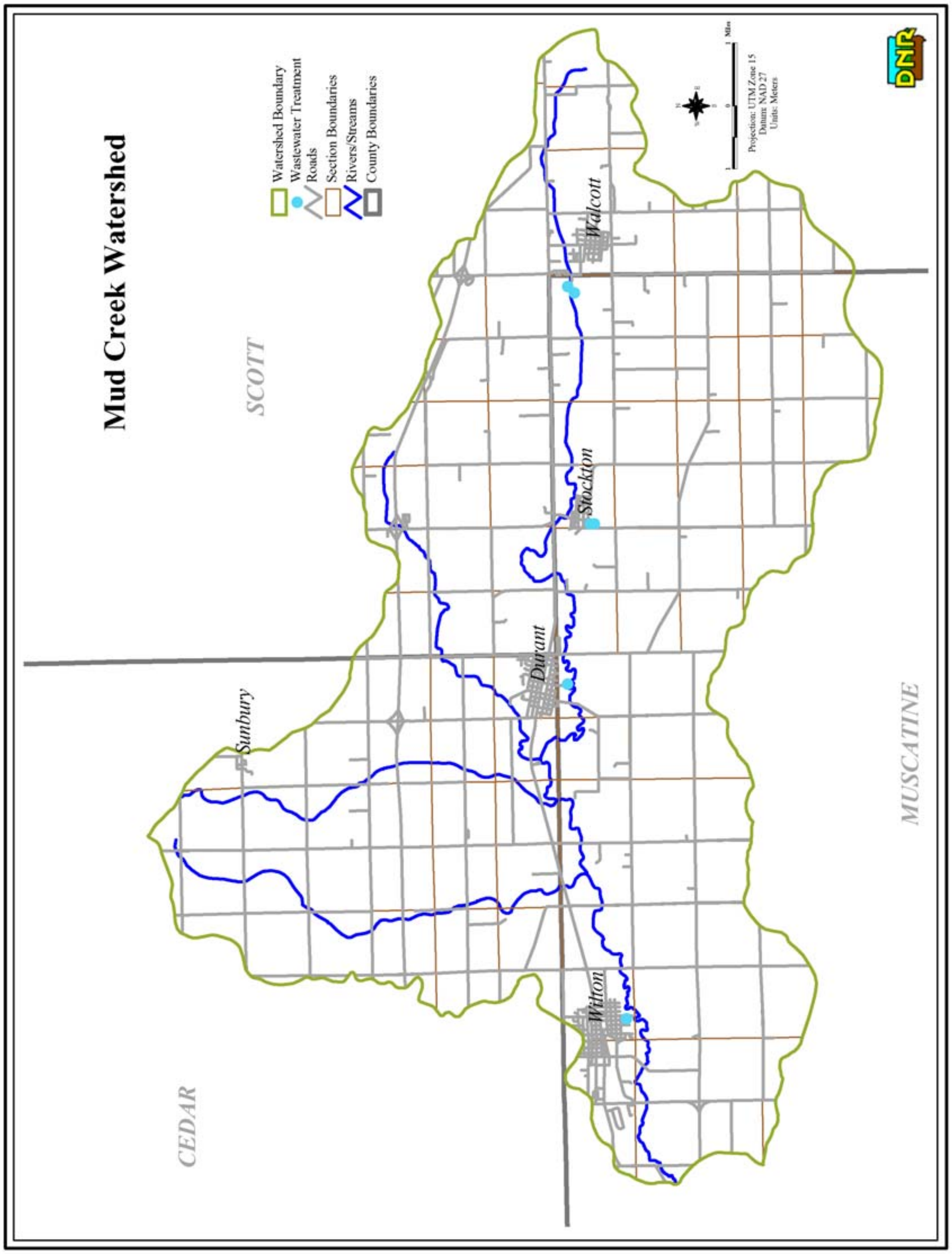
Table 3. Soil and Erosion Variables

% Clay	27%
% Sand	5%
Erosion Factor	0.29
Potential Soil Loss	6.72 tons/acre/year
Potential Sediment Delivery	0.68 tons/acre/year

Table 4. Landuse in the Mud Creek Watershed

Landuse	Watershed, acres	% of total
Water	20	<0.1
Forest	1102	1.62
Grass	11,077	16.3
Row Crop	54,502	80.2
Urban/Artificial	1102	1.62
Barren or no data	197	0.3
Total	68,000	100

Figure 1. Mud Creek and its watershed



3. TMDL for Organic Enrichment

3.1 Problem Identification

Mud Creek was put on the 1998 impaired water list for organic enrichment causing low water column dissolved oxygen concentrations. Data collected in 1996 and 2001 show intermittent drops in DO in some segments of the stream. The water quality issues and problems are detailed in the stream habitat and bioassessment report prepared by the IDNR Water Quality Bureau after extensive fieldwork. Figure 2 is a map of Mud and Sugar Creeks and their watersheds showing the locations of the 1996 IDNR bioassessment sampling sites. Mud Creek flows into Sugar Creek 1.5 miles downstream from Wilton.

The reach of Mud Creek upstream and downstream from the Wilton WWTP (Figure 2 map, sample sites MD3 and MD4) is dominated by a large meander that has a very low gradient. Stream velocity is very slow in this reach compared to the shallow runs at other sites. The reduction in stream gradient and current velocity has resulted in large deposits of silt and sand adjacent to the Wilton WWTP.

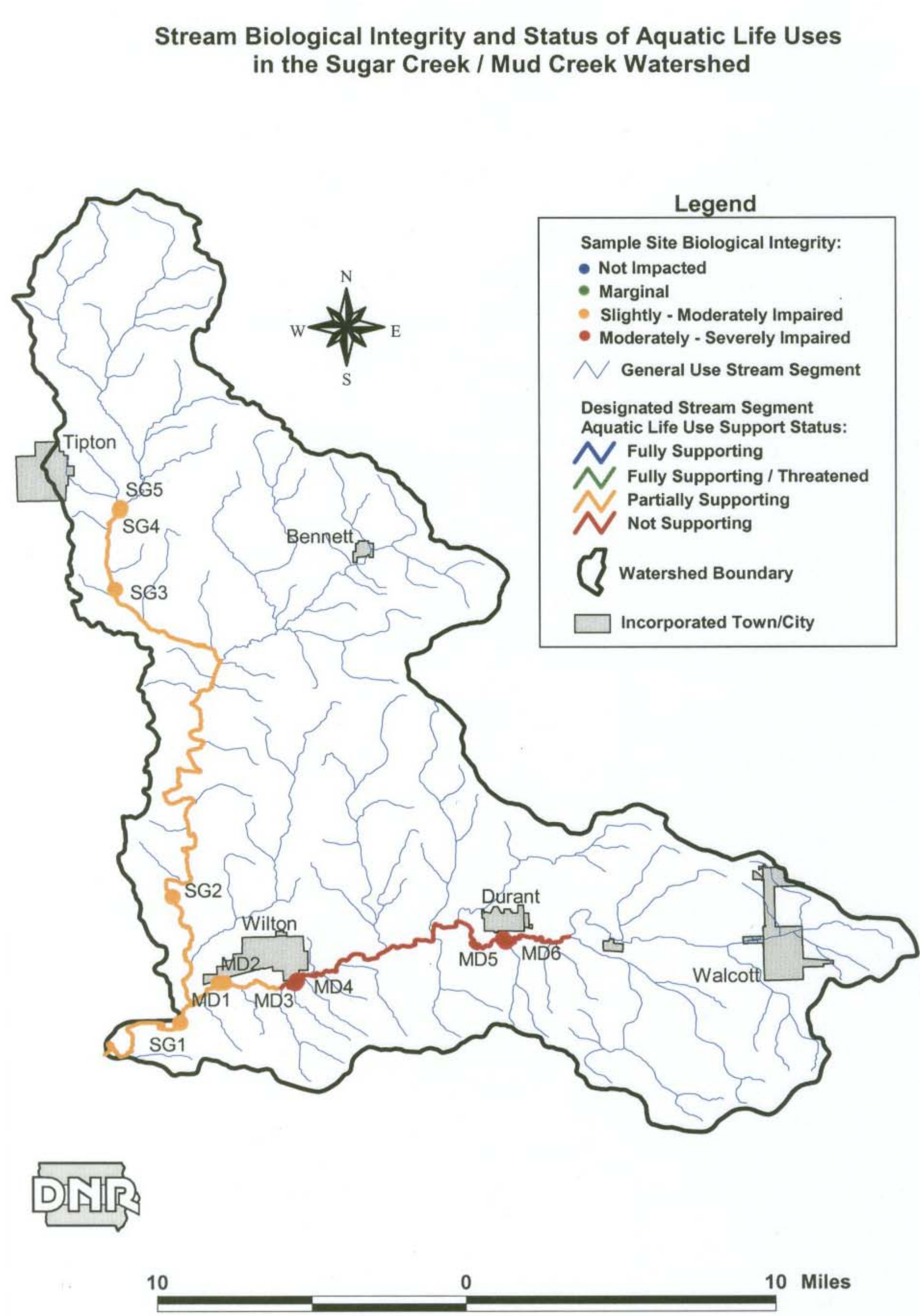
Sediment accumulation has been identified as a primary cause of biological impairment at several sample sites. The habitat at the two sample sites is depositional glide/pool. Benthic macroinvertebrate and fish community integrity was lowest where the greatest silt accumulation was observed. Eroding stream banks were observed at a majority of sample sites and high suspended solids and turbidity were found at stream locations where livestock grazing impacts were most evident.

Mud Creek bank conditions are generally rated as “poor” or “fair”. Over half of the lower bank consists of bare soil and sediment indicating considerable fluctuation in stream stage and active bank erosion. Evidence of cattle trampling the bank was observed. Riparian vegetation ranged from completely herbaceous to dense woody and stream shading varied from 0 to 88% at sample sites..

Biological and chemical sampling data suggest that organic enrichment is the primary cause of aquatic life use impairment in Mud Creek. Evidence of organic enrichment includes:

a) increased abundance of benthic macro invertebrates and fish tolerant of organic pollutants.
b) elevated biochemical oxygen demand (BOD) where the impairment is most apparent, near Wilton and Durant;
c) large differences in dissolved oxygen above and below the saturation concentration.

Figure 2. Bioassessment sampling sites



Impaired Beneficial Uses and Applicable Water Quality Standards
The Iowa Water Quality Standards list the designated uses for Mud Creek as:

- Class "B (LR)", Limited resource warm water. Waters in which flow or other physical characteristics limit the ability of the waterbody to maintain a balanced warm water community. Such waters support only populations composed of species able to survive and reproduce in a wide range of physical and chemical conditions, and are not generally harvested for human consumption. Class B waters are to be protected for wildlife, fish, aquatic and semi-aquatic life, and secondary contact uses.

IDNR staff made the "partially supported" assessment based on information collected during a bioassessment of the stream in 1996 and 1997 for aquatic life uses. The following assessments are from relevant 305(b) Reports:

For the 1996 report. Mud Creek is part of a DNR study evaluating point and nonpoint source impacts to accurately assess stream support of designated uses. Results of the study will not be available until mid-1997 and may change the assessment developed for the 1996 305(b) report.

For 1998 report. The results from 6 stream bioassessments of Mud Creek conducted in Sept. 1996 were used to assess the stream. Fish community IBI scores ranged from 0%-75% of stream reference sites located in the same ecoregion. The aquatic life use was assessed as non-supporting due to the large fraction of diseased fish (11.4%) in Mud Creek below the Durant wastewater treatment plant. The most likely cause is the organic waste load (BOD) from the plant. Fish community health (IBI) scores were low in Mud Creek adjacent to the Durant and Wilton wastewater treatment plant outfalls. Recovery to normal IBI values occurred downstream from the Wilton discharge. Physical habitat scores at bioassessment locations ranked from poor to fairly good.

For the 2000 report. Assessment based on data collected in 1996 as part of the DNR/UHL stream biocriteria project. A series of biological metrics indicative of stream water quality and habitat integrity were calculated from the biocriteria sampling data. The metrics are based on the numbers and types of benthic macroinvertebrate taxa and fish species collected in the sampling reach. The metrics were combined to make a fish community index of biotic integrity (F-IBI) and a benthic macroinvertebrate index (BM-IBI). The indexes rank the biological integrity of a sampling reach on a scale from 0 (minimum) to 100 (maximum).

Going upstream, the F-IBI scores were 43 & 38 (fair), and 18, 18, 16, 13 (poor). The corresponding BM-IBI scores were 33 & 34 (fair), 20, 20, & 27 (poor), and 34 (fair). Aquatic life use support was assessed as not supported based on a comparison of the F-IBI and BM-IBI scores with criteria established specifically for the 2000 Section 305(b) report. The biological assessment criteria were determined from a statistical analysis of data collected at stream ecoregion reference sites from 1994-1998.

From the 2002 report: SUMMARY: The Class B(LR) uses remained assessed as "not supported." Sources of information for this assessment include (1) results of biological monitoring conducted at six sites in 1996 as part of the DNR/UHL watershed assessment project and (2) water quality monitoring conducted at five sites in this stream segment from March to November 2001 by IDNR and UHL in support of TMDL development. EXPLANATION: The Class B(LR) uses remain assessed as "not supported" based on results of biological monitoring conducted in 1996.

2001 TMDL monitoring results show one violation of water quality criteria for dissolved oxygen and ammonia in the 45 samples collected between March and November at five sites. The dissolved oxygen concentration in the sample collected at Site 3 downstream from Durant on August 16, 2001 (4.7 mg/l) violated the 5.0 mg/l water quality criterion. Although no violations of ammonia criteria occurred, maximum values were moderately high for Iowa streams, 0.48 mg/l at Site 1 SE of Wilton, 0.70 mg/l at Site 2 upstream from Wilton, 0.49 mg/l at Site 3 downstream from Durant, 0.42 mg/l at Site 4 at the SE edge of Durant, and 0.19 mg/l at Site 5 upstream from Durant. Four of the six maximum ammonia values occurred on August 16. Biological monitoring integrates cumulative water quality impacts over time and more accurately represents this segment of Mud Creek water quality conditions than short term monthly monitoring

Data Sources

The data sources used in the development of this TMDL were monthly and event monitoring done by the University of Iowa Hygienic Lab (UHL) for the IDNR TMDL program and the IDNR Water Quality Bureau 1996 Mud Creek Habitat Evaluation and Bioassessment that was followed up in 2001.

Interpreting Mud Creek Water Quality Data

The following evaluations were prepared for the 1996 IDNR stream habitat and biological assessment report for six Mud Creek sites shown on the Figure 2 map. These evaluations indicate that the wastewater treatment plant effluent from the cities of Wilton and Durant were associated with the impaired stream conditions.

Table 5. Water Quality Conditions:

Map ID	Segment Description	Miles impaired	Magnitude of impairment	
MD1 MD2	Confl. w/ Sugar Creek - confl. w/ unn.trib. S12, T78N, R2W, Muscatine Co.	2.8	Slight	Biological characteristics: low diversity in benthic macroinvertebrate community, moderately tolerant organisms are dominant, sensitive taxa very rare, unbalanced trophic (feeding) groups indicative of organic enrichment. Causes/sources: nutrients & organic matter from municipal wastewater & agricultural sources in watershed; siltation/sedimentation from bank erosion & agricultural practices in watershed cattle grazing with full stream access adversely impacting riparian vegetation, bank conditions, direct inputs of nutrients & organic matter.
MD3 MD4 MD5 MD6	Confl. w/ unn.trib. S12, T78N, R2W, Muscatine Co. - confl. w/ unn.trib. S5, T78N, R1E, Muscatine Co.	11.2	Severe	**Wilton Vicinity**. Biological characteristics: Low diversity in benthic macroinvertebrate community; tolerant organisms are dominant & sensitive taxa very rare; unbalanced trophic (feeding) groups; low numbers of fish,; tolerant fish are dominant; sensitive sp. & habitat specialists are rare Causes/sources: nutrients & organic matter from municipal wastewater & agricultural sources in watershed; siltation/sedimentation from bank erosion & agricultural practices in watershed; high sinuosity, low gradient, slow current enhances silt deposition; dissolved oxygen might be limiting during warm months. **Durant Vicinity.** Biological characteristics: Low diversity in benthic macroinvertebrate community; tolerant organisms are dominant & sensitive taxa very rare; unbalanced trophic (feeding) groups; High incidence of fish with lesions; tolerant fish are dominant; sensitive sp. & habitat specialists are rare. Causes/sources: nutrients & organic matter from municipal wastewater & agricultural sources in watershed; siltation/sedimentation from bank erosion & agricultural practices in watershed; cattle grazing with full stream access adversely impacting riparian vegetation, bank conditions, direct inputs of nutrients & organic matter.

3.2 Potential Pollution Sources

Point Sources

There are three significant permitted point sources that continuously discharge directly to Mud Creek. These are listed in the table below.

Table 6. Mud Creek Point Sources

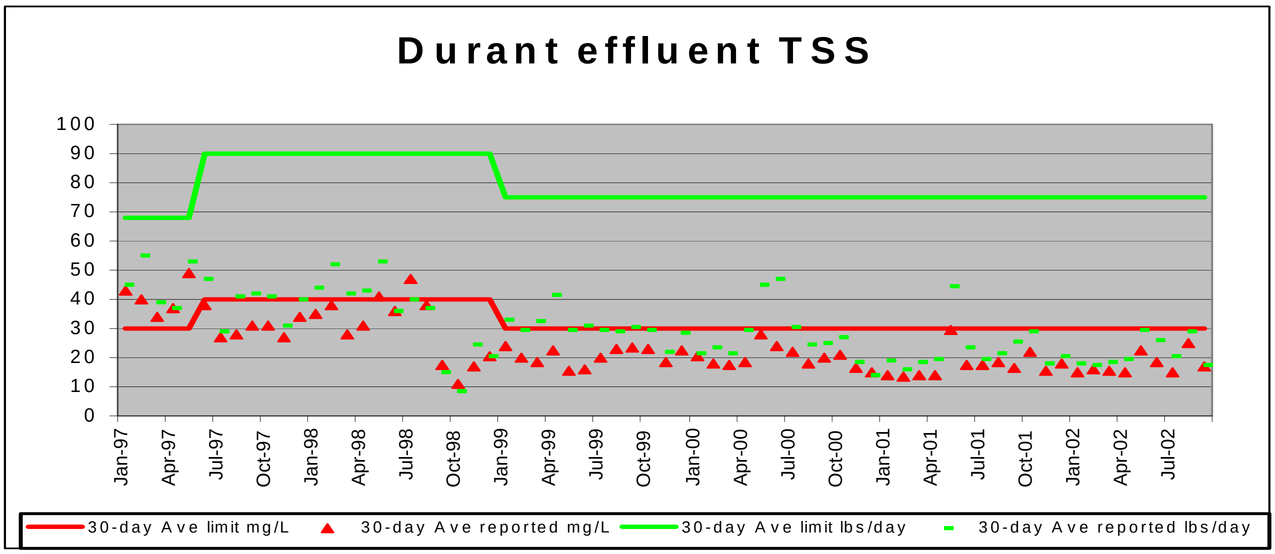
NPDES PERMIT NO.	Facility Name	Treatment Type	Design Flow (MGD)
6-70-78-0-01	Wilton WWTP	Trickling Filter	0.350
6-16-36-0-01	Durant WWTP	Trickling Filter	0.200
6-82-85-0-01	Walcott WWTP	Aerated Lagoon	0.513

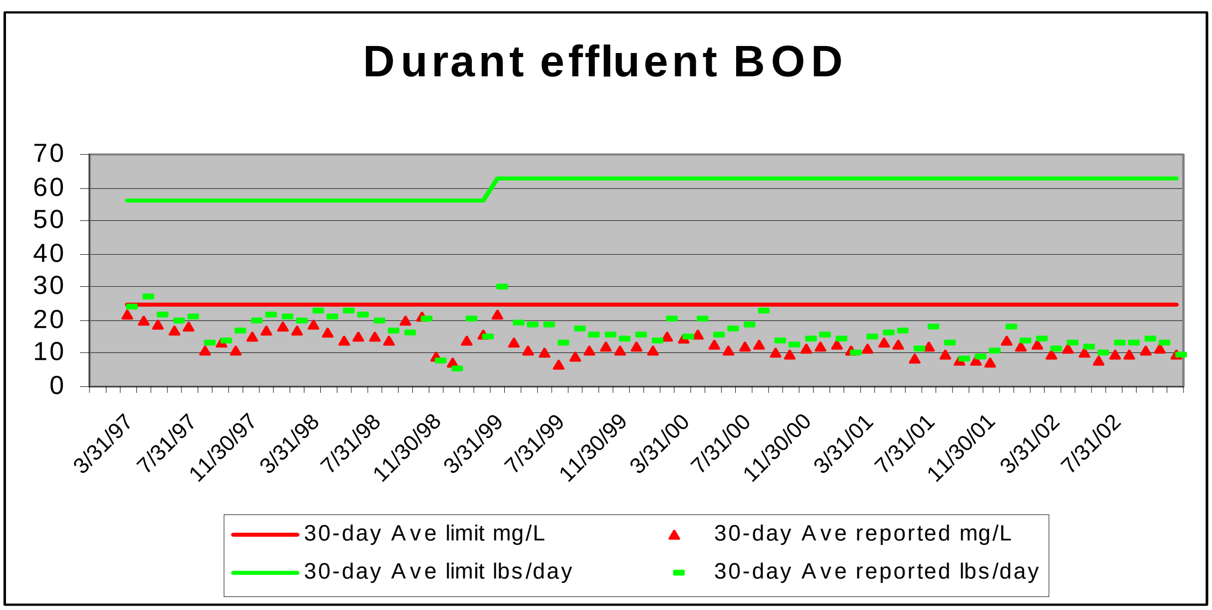
The Durant and Wilton WWTP's have had significant upgrades since 1996 when the stream assessment that resulted in the impaired designation was performed. The Walcott facilities have been evaluated recently and a facility plan has been prepared by an engineer.

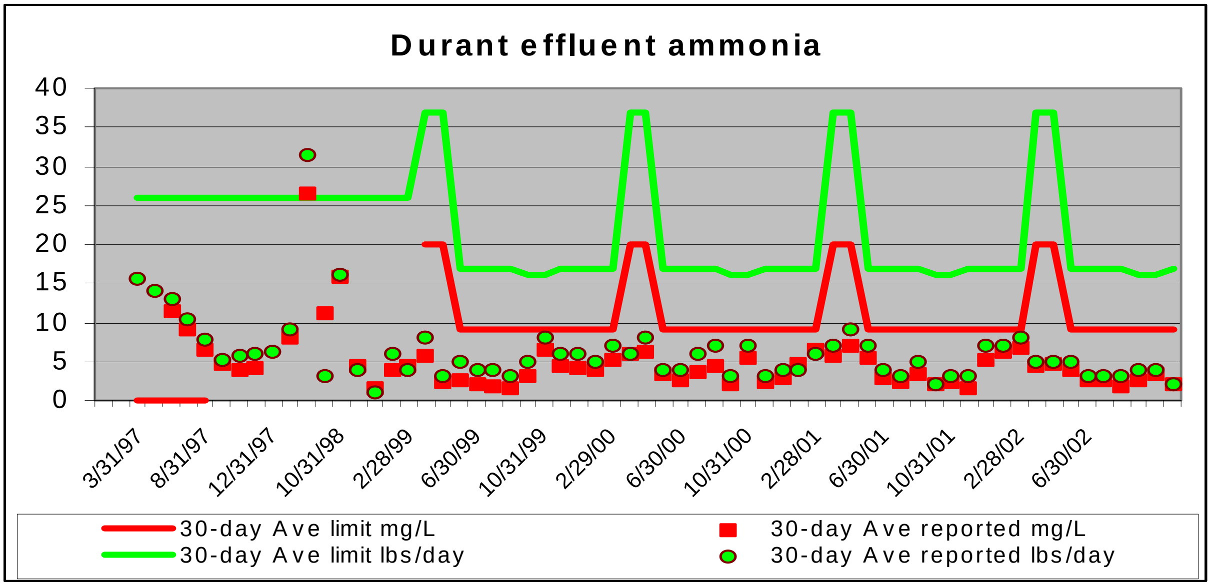
Durant Wastewater Treatment Plant: The Durant plant was essentially replaced in 1999. The new treatment units include bar screens, grit removal, a primary clarifier, two final clarifiers, an aerobic sludge digester, and the upgrade and renovation of the existing trickling filter with new plastic media, cover, and distribution arm. The total project cost was $2,450,000 and the new plant began operating in the summer of 1999..

The following figures show the monthly average values for total suspended solids (TSS), five day carbonaceous biochemical oxygen demand (BOD), and ammonia (NH_3) concentrations (mg/l) and mass (lb/d) since 1997. The solid lines are the existing permit limits. As can be seen, the plants effluent shows great improvement after the completion of renovations.

Durant is the discharge immediately upstream from the low gradient problem stream segment.

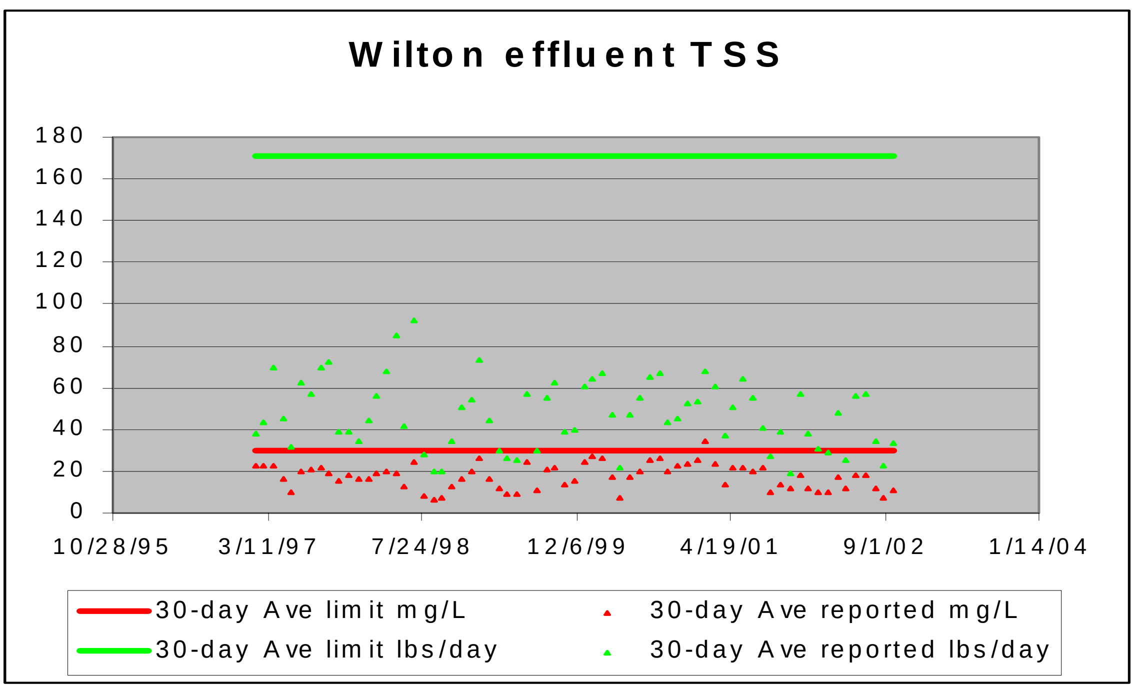


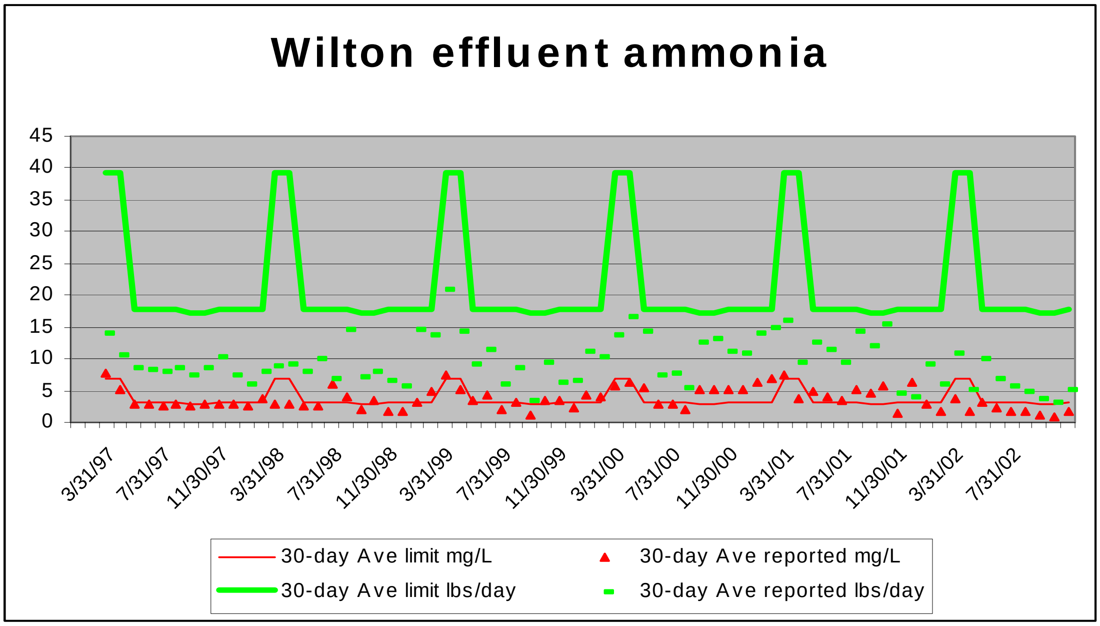


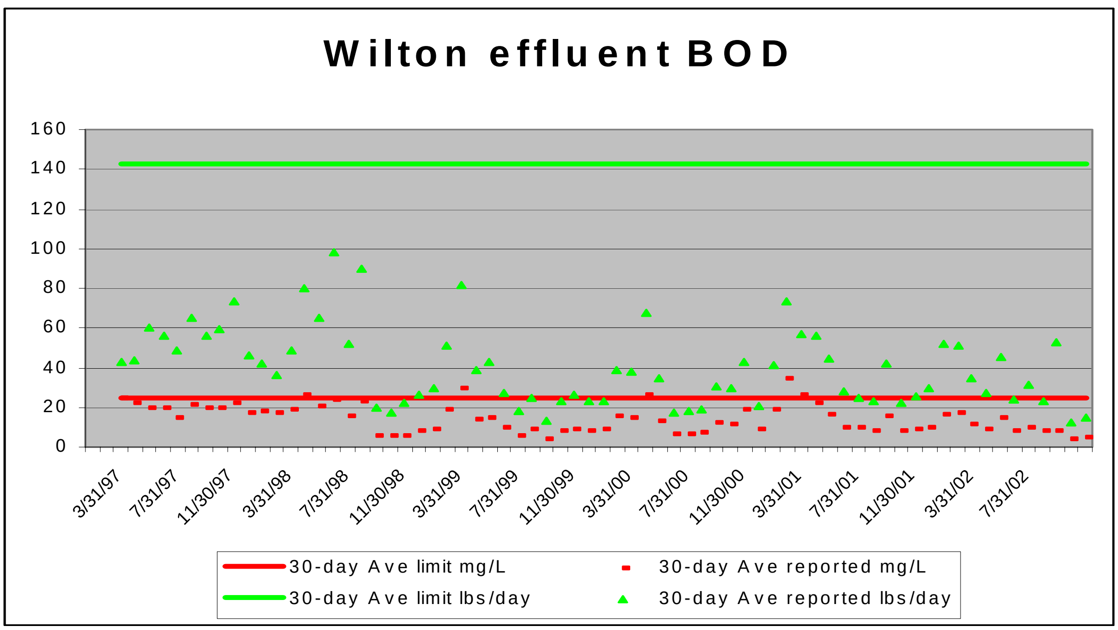


Wilton Wastewater Treatment Plant: The Wilton WWTP received upgrades that were completed in 2001. The upgrades included increased pumping capacity and equalization storage to remediate plant wet weather bypasses and an aerobic sludge digester and sludge storage tank. The total project cost was $1,794,000 and the new units became operational September 8, 2001.

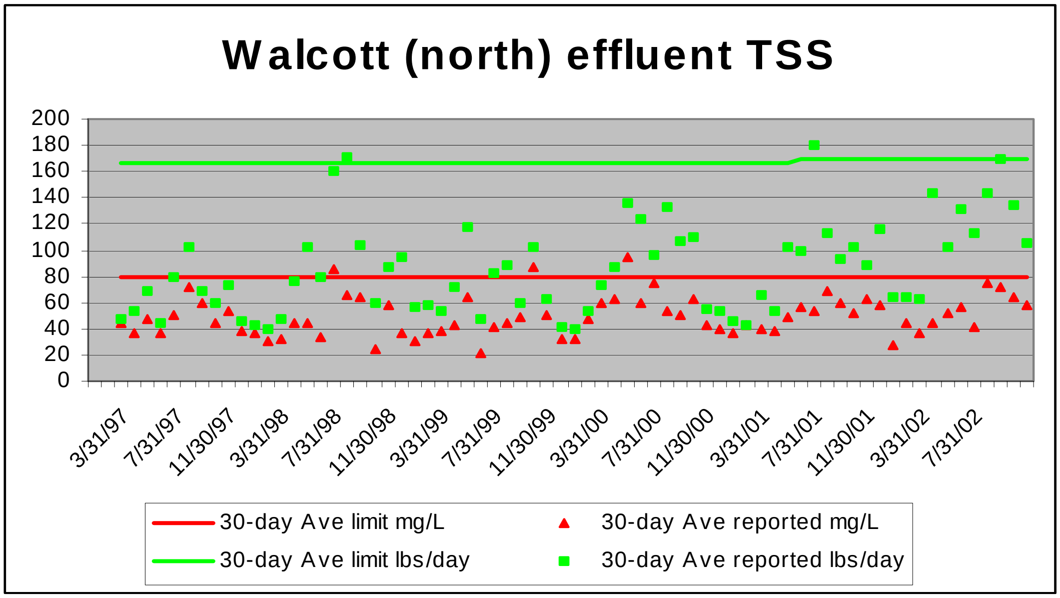
The following figures show the effluent monthly average values for TSS, five day carbonaceous oxygen demand (BOD), and NH3 concentrations (mg/l) and mass (lb/d) for Wilton since 1997. The solid lines are the existing permit limits. As can be seen, the plants effluent improves after the completion of renovations.







Walcott, North and South Wastewater Treatment Plants: The Walcott wastewater treatment facilities consist of two three-cell aerated lagoons across from one another on Mud Creek. The two Walcott aerated lagoons are in the process of being reconfigured from two separate systems operating in parallel to a single system with all of the aerated lagoon cells being operated in series, i.e., a six celled aerated lagoon. These changes are being made due to recent ammonia limit requirements and permit violations at both the north and south plants over the last few years.



Walcott (north) effluent TSS
200
180
160
140
120
100
80
60
40
20
0
3/31/97
7/31/97
11/30/97
3/31/98
7/31/98
11/30/98
3/31/99
7/31/99
11/30/99
3/31/00
7/31/00
11/30/00
3/31/01
7/31/01
11/30/01
3/31/02
7/31/02
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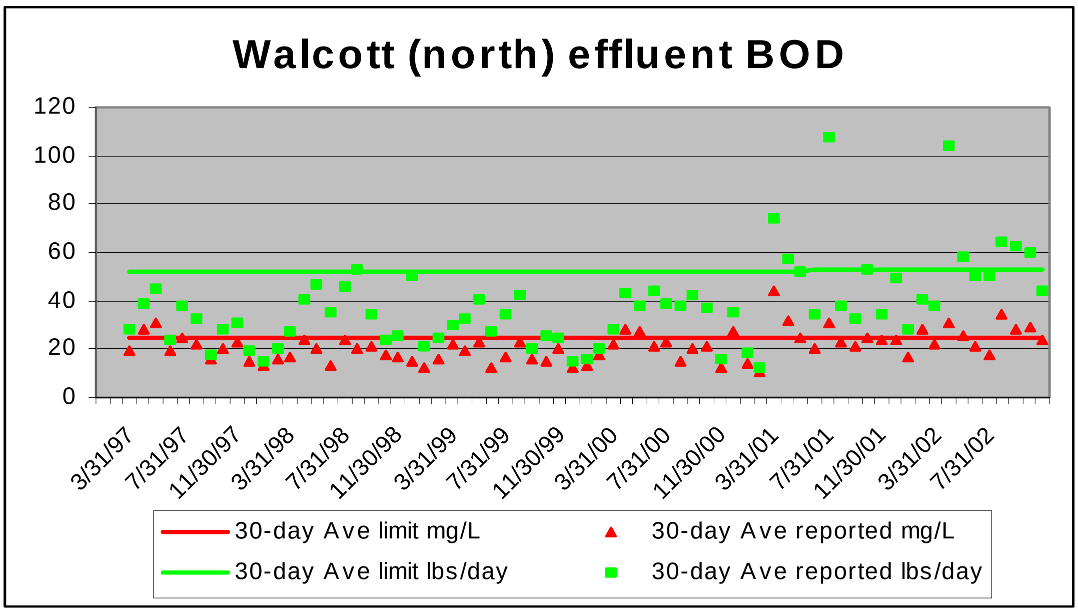
30-day Ave reported mg/L
30-day Ave limit lbs/day
30-day Ave reported lbs/day



Walcott (north) effluent BOD
120
100
80
60
40
20
0
3/31/97
7/31/97
11/30/97
3/31/98
7/31/98
11/30/98
3/31/99
7/31/99
11/30/99
3/31/00
7/31/00
11/30/00
3/31/01
7/31/01
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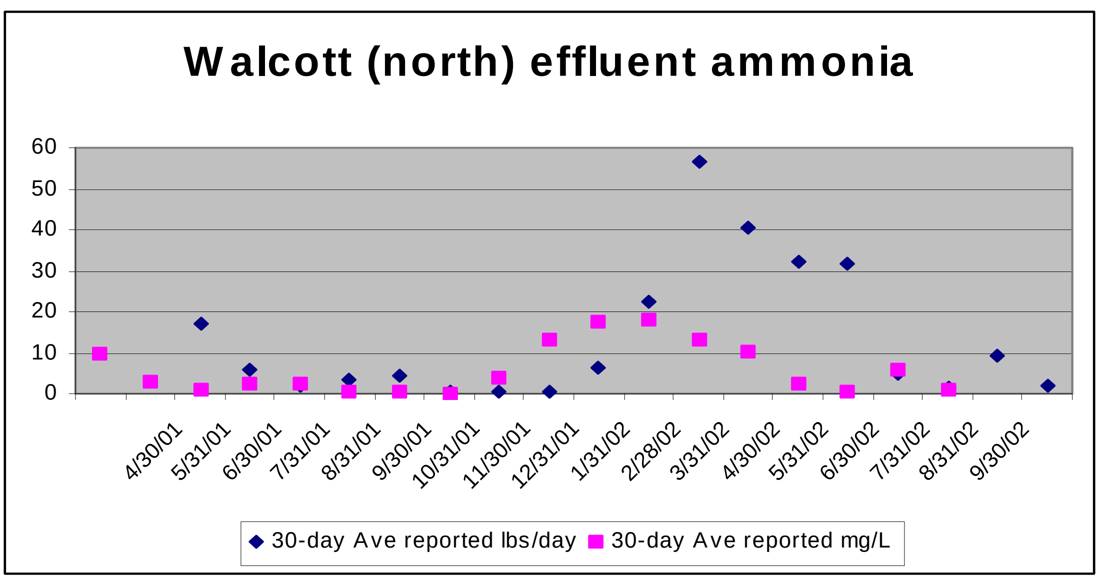
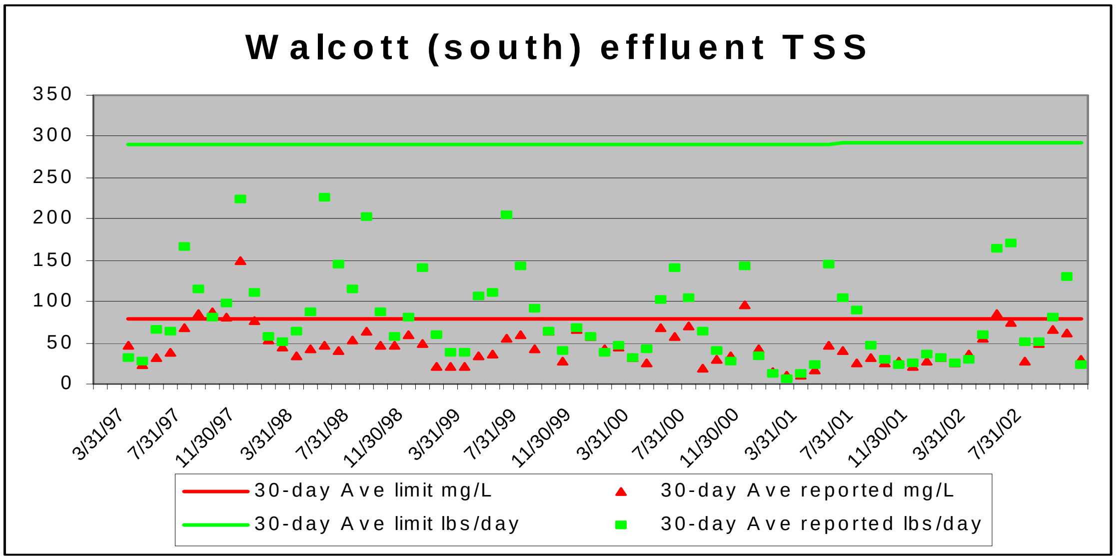
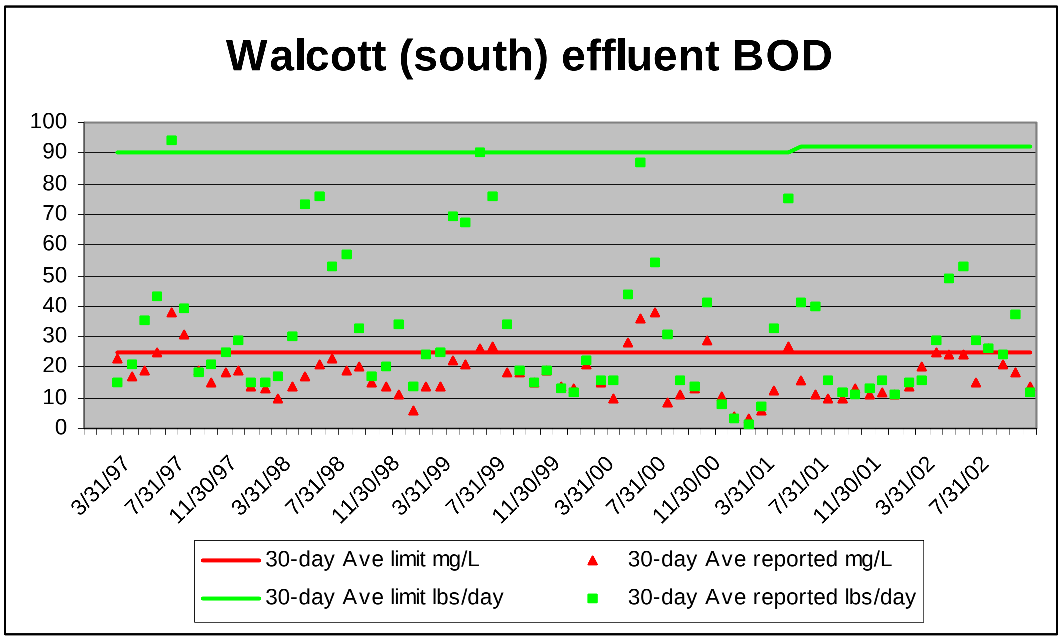
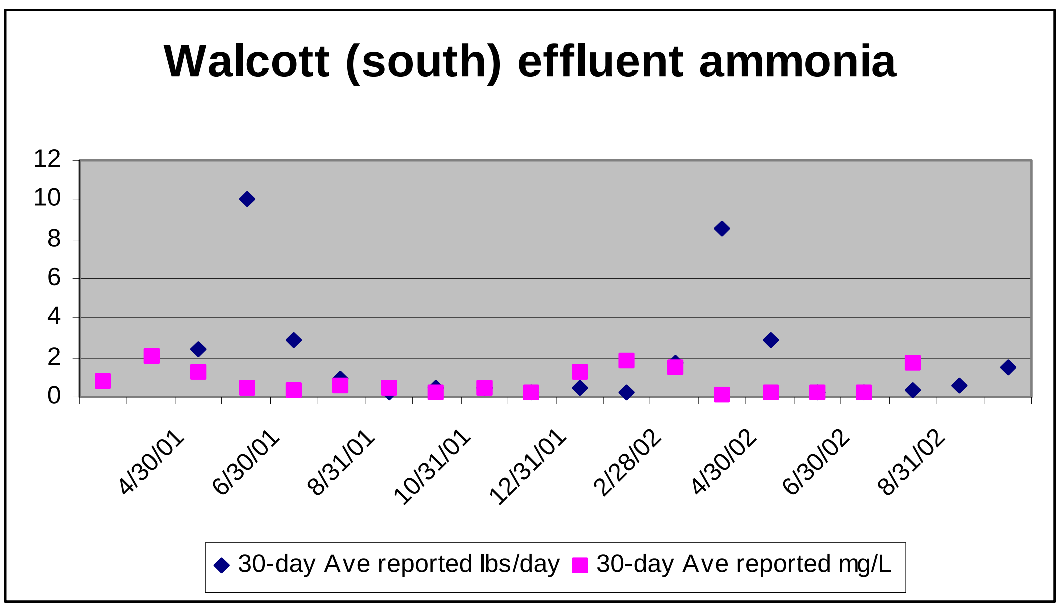
30-day Ave reported mg/L
30-day Ave limit lbs/day
30-day Ave reported lbs/day



Walcott (north) effluent ammonia
60
50
40
30
20
10
0
4/30/01
5/31/01
6/30/01
7/31/01
8/31/01
9/30/01
10/31/01
11/30/01
12/31/01
1/31/02
2/28/02
3/31/02
4/30/02
5/31/02
6/30/02
7/31/02
8/31/02
9/30/02
30-day Ave reported lbs/day
30-day Ave reported mg/L


Walcott (south) effluent TSS
350
300
250
200
150
100
50
0
3/31/97
7/31/97
11/30/97
3/31/98
7/31/98
11/30/98
3/31/99
7/31/99
11/30/99
3/31/00
7/31/00
11/30/00
3/31/01
7/31/01
11/30/01
3/31/02
7/31/02
30-day Ave limit mg/L
30-day Ave reported mg/L
30-day Ave limit lbs/day
30-day Ave reported lbs/day


Walcott (south) effluent BOD
100
90
80
70
60
50
40
30
20
10
0
3/31/97
7/31/97
11/30/97
3/31/98
7/31/98
11/30/98
3/31/99
7/31/99
11/30/99
3/31/00
7/31/00
11/30/00
3/31/01
7/31/01
11/30/01
3/31/02
7/31/02
30-day Ave limit mg/L
30-day Ave reported mg/L
30-day Ave limit lbs/day
30-day Ave reported lbs/day


Walcott (south) effluent ammonia
12
10
8
6
4
2
0
4/30/01
6/30/01
8/31/01
10/31/01
12/31/01
2/28/02
4/30/02
6/30/02
8/31/02
30-day Ave reported lbs/day
30-day Ave reported mg/L

NPDES permits for both the North and South Walcott plants were issued April 17, 2001. Each of these permits includes a compliance schedule intended to achieve compliance with final ammonia limits. These compliance schedules are identical in their timing and requirements and are summarized below.

- Monitor ammonia from June 1, 2001 to May 31, 2002 to determine the ability of the facilities to meet ammonia limits.
- Submit a report summarizing the plants' ability to comply with the final ammonia limits by June 30, 2002.
- Comply with final ammonia limits by July 1, 2002 if it is demonstrated that the plants can comply with the limits.
- Submit a preliminary engineering report by September 1, 2002 if improvements are needed. The report needs to include a schedule for making needed improvements to comply with final ammonia limits by July 1, 2005.
- Submit annual progress reports and achieve compliance by July 1, 2005.

The city has performed the required ammonia monitoring, determined that improvements to the treatment facilities are needed, and hired an engineer to prepare the report. The engineer has submitted a preliminary report proposing that the two aerated lagoons be connected by a siphon under Mud Creek and be operated as a series of five or six cells rather than as two plants operated in parallel.

It should be noted that the technology based TSS limit for aerated lagoons in Iowa is 80 mg/l. Despite these relatively high permit limits there have been some rather recent TSS violations at both the north and south facilities. There have also been some CBOD5 permit violations that indicate operational trouble or organic overloading. The north plant has the more severe problems. Presumably these deficiencies will be addressed by the proposed plant improvements.

In July 2002 the city's consultant requested a wasteload allocation based on discharge and ammonia limits calculated on a monthly basis. This resulted in higher early spring limits when low temperatures make nitrification difficult to achieve in aerated lagoons but would not impact limits for the months of July through October when low flow and high temperature create the critical stream condition. The Walcott facility discharges into a downstream segment that is designated general use for seven miles where it becomes a limited resource warm water stream. The Durant WWTP discharges 9.8 miles downstream from Walcott and the Wilton plant discharges 10.3 miles downstream from Walcott. Volatile suspended solids discharged from the Walcott plants would have minimal impact on the sediment oxygen demand in a stream segment 20 miles downstream.

<u>Minor permitted facilities</u>: The other permitted point sources in the watershed are very small, don't discharge CBOD5 or ammonia, or are controlled discharge

lagoons that don't discharge at low flow. There are not any NPDES permitted agricultural operations in the watershed.

Non-point Sources

There are several non-point source categories contributing to Mud Creek; row crop agriculture, animal feeding and grazing operations, stormwater runoff from two large truckstops on I-80 near Walcott, and urban runoff from the four small cities in the watershed. As noted below, one kind of non-point source, livestock in Mud Creek and its tributaries, acts like a point source during low flow.

Rapid transport of pollutants during high flow results in short residence time that decreases the local impact of oxygen demanding nonpoint source pollutants. On the other hand, slow removal of pollutants in the slow moving water of low flow conditions can result in oxygen depletion, nutrient enrichment, and even eutrophication.

The significance of wet weather discharges from nonpoint sources on dissolved oxygen is very site specific. During wet weather, stream flow is high allowing for higher transport and assimilative capacity in the stream for pollutants. However, pollutant deposition and accumulation on streambed and pool areas may exert a critical demand on dissolved oxygen during low flow conditions. When nonpoint sources are identified as major sources of oxygen depletion, then runoff conditions that occurred some time before the critical low flow period need to be evaluated to capture these nonpoint impacts.

Modeling for oxygen demand usually focuses on pollutant discharges during dry periods when low flow conditions prevail, i.e., at base flow rate. Pollutant discharges during low flow conditions are usually constant, reflecting their point source origin. The base flow rate also fluctuates seasonally. Typically in Iowa, high flow occurs in the spring and early summer and lower flows occur during late summer and early fall. These seasonal flow patterns mean that the critical period for Iowa streams, including Mud Creek, is usually in August and September. In general, these hydrologic conditions become "steady state" and dissolved oxygen conditions tend to be impacted mostly by constant point sources such as treated municipal wastewater. These times of low flow and minimum dilution also coincide with the highest seasonal temperatures leading to the worst case impact on stream water quality.

In the case of Mud Creek there are riparian land uses that cause NPS impacts without precipitation driven runoff. The soils along the stream corridor are hydric and generally unsuitable for row crops. Because of this, the corridor is used for pasture and livestock have access to long sections of the stream and stream banks. The organic and nitrogenous stream inputs from livestock in and near the stream occur at all times, including low flow conditions. That makes this sort of non-point source indistinguishable in effect from a continuous point source load.

Natural Background Conditions
Natural background contributions have not been separated from the from the non-point source load.

3.3 TMDL Endpoint

There are two water quality targets for this TMDL:
1. A reduction in modeled oxygen demand to a level where DO does not drop below numeric criteria (see Table 7) at protected low flow conditions, currently 1 cfs.
2. A Mud Creek biological community that is not impaired as determined using the bioassessment procedures and criteria that established the impairment.

Criteria for Assessing Water Quality Standards Attainment
Numeric Water Quality Standards Criteria**:** There are numeric water quality criteria for dissolved oxygen. The stream criteria are shown in Table 7.

Table 7. Iowa Stream Criteria for Dissolved Oxygen

	Aquatic life, cold water	Aquatic life, significant resource water	Aquatic life, limited resource water
Minimum value for at least 16 hours of every 24-hour period	7.0 mg/l	5.0 mg/l	5.0 mg/l
Minimum value at any time during every 24-hour period	5.0 mg/l	5.0 mg/l	4.0 mg/l

Selection of Environmental Conditions
The “critical condition” for which this organic enrichment TMDL applies is the Phase 1 protected low flow of 1 cfs. The stream has been modeled under this flow regime for the point source BOD and NOD discharges that are assumed to be constant throughout the year. The point source NPDES permit limits are measured as maximum day and 30 day average concentrations or loads.

Non-point loads are associated with high flow events and for this TMDL are measured as annual averages. Non-point source controls are targeted for precipitation events that cause significant runoff carrying sediment and oxygen demanding organic material that settles in slow moving reaches of Mud Creek.

In addition to event driven non-point sources there are continuous pollutant impacts from livestock in and near the stream.

Waterbody Pollutant Loading Capacity
The Phase 1 load capacity of Mud Creek is based on a protected low flow of 1 cfs for the Walcott, Durant, and Wilton wastewater treatment plant discharges. The stream has been modeled at the protected flow condition with a widely used stream water quality model called QUAL2E. Mud Creek was divided into 25

reaches of varying length for the model. The dissolved oxygen condition for the impaired segment was modeled for protected flow conditions and calibrated with data for the stream collected in September 2001 at five sites. The 25 numbered segments are shown in Figure 3.

3.4. Pollution Source Assessment

Existing Oxygen Demand Load and Departure from the Load Capacity
The following figure shows the water quality DO criteria of 5 mg/l, the modeled values using the existing waste load allocations and the modeled stream DO values if revised waste load allocations developed for this TMDL are used. The modeled DO concentrations dip below 5 mg/l in the low gradient segment near Wilton using the existing waste load allocations. If the revised allocations are used, then the model shows the DO staying over 5 mg/l.

The model shows that there are two segments that have significant DO depletion at critical low flow conditions. In Figure 3, these are model segments 22 and 23 that run from mile 22 to mile 16, upstream to downstream. These segments are the very low gradient stretch of Mud Creek around the City of Wilton.

The QUAL2E model of Mud Creek also demonstrates that sediment oxygen demand (SOD) plays an important role in the depletion of DO in the impaired stream segment. Sediment oxygen demand is caused by the oxidation of accumulated organic material in bottom sediments and often has the greatest impact on small streams like Mud Creek. The event-driven non-point sources of this material are eroded organic-enriched soils, plant detritus, and feedlot runoff that contribute to SOD during periods of high flow when sediment and other entrained materials settle in low velocity segments. This settled material is one of the mechanisms of NPS impact on the impaired segment.

The other sources of SOD are the suspended solids found in the effluent of wastewater treatment plants. For Mud Creek there are two wastewater treatment plants that are near enough to have an impact on the problem segment. These are the Durant and Wilton trickling filter facilities. The solids generated from attached growth treatment processes are the result of the sloughing off of chunks of living and dead organisms from the filter media. This material is more readily settled in plant clarifiers than solids from a suspended growth process. Typically, 80% of sludge solids are volatile suspended solids.

Based on the 1996 bio-assessment there were serious impacts below both the Durant and Wilton outfalls. Since then both of these plants have had major upgrades. It can be seen from the charts of the Durant monitoring data for TSS, BOD, and ammonia that there was a dramatic improvement in effluent quality after the facility improvements came on line in 1999. For the Wilton WWTP the story is similar. There have not been any permit violations since the solids handling improvements became operational.

Figure 3. Qual2e model reaches

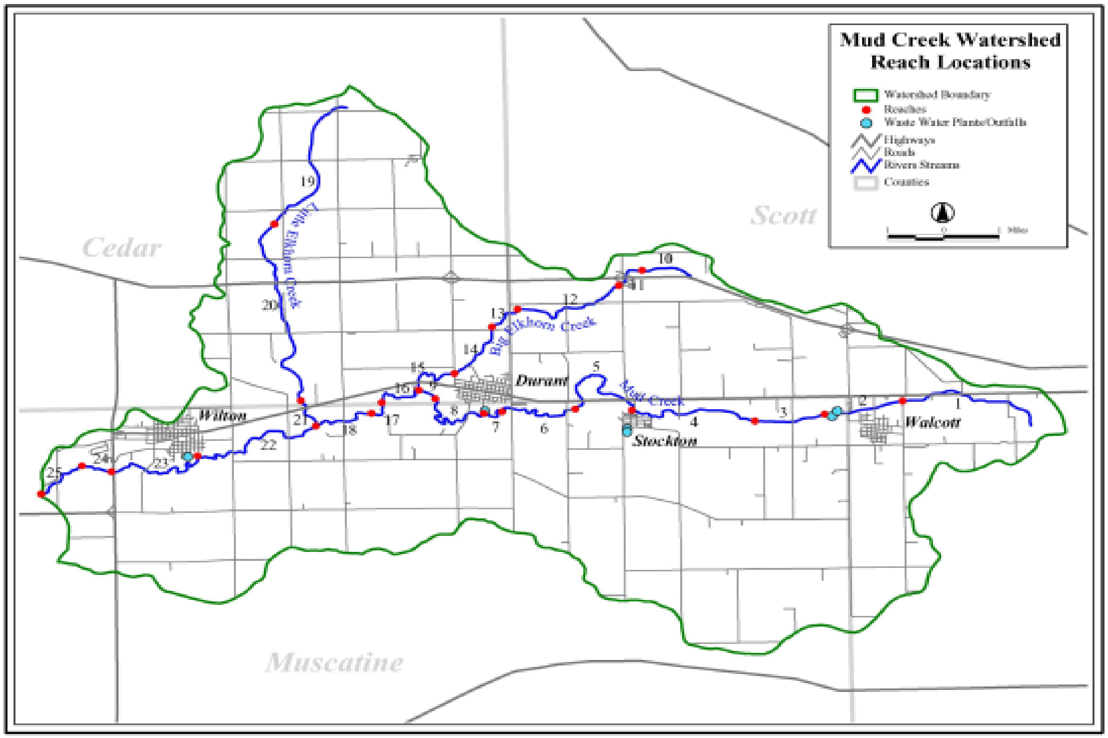
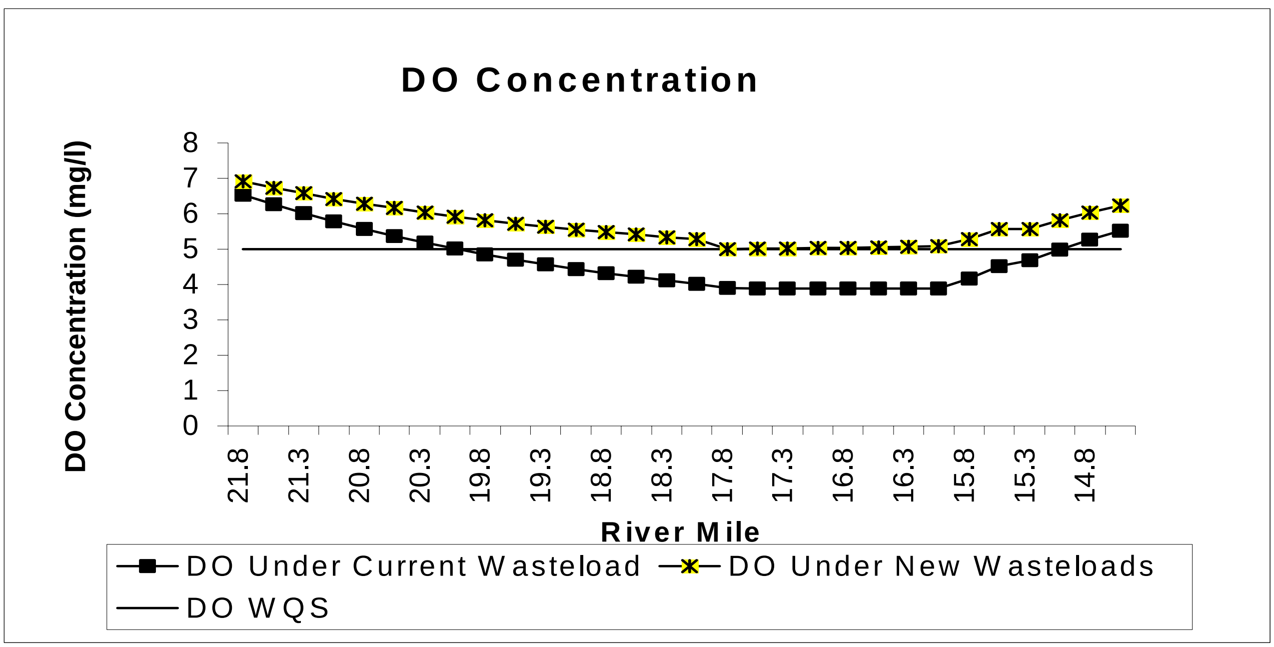


Figure 4. Modeled DO versus river mile, reaches 22 and 23



Linkage of Sources to Endpoint

The loads causing the organic enrichment and consequent dissolved oxygen concentration reduction originate from both point and nonpoint sources. To meet the TMDL endpoint of 5 mg/l dissolved oxygen at protected flow, oxygen demand from both point and nonpoint sources need to be reduced by the difference between the existing loads and the allocated loads.

3.5 Pollutant Allocation

Waste Load Allocation

Table 8 shows the current wasteload allocations for the three significant wastewater treatment plant discharges to Mud Creek. The North and South Walcott discharges will be combined into one NPDES permitted discharge since they are located very near to each other. The existing CBOD5 limits are 25 mg/l in all instances. This is the technology based standard for CBOD5.

The ammonia limits are seasonal and take into account ammonia toxicity to aquatic life at various life stages. Ammonia also creates a significant oxygen demand on receiving waters. Modeling of Mud Creek at protected flow conditions shows that the dissolved oxygen problem in the segment around Wilton is sensitive to ammonia reduction and not very sensitive to CBOD5 reduction. Because of this, the adjustments to the three facilities wasteload allocations have been to the seasonal ammonia limits.

Table 8. Current wasteload allocations for Mud Creek permitted discharges

Summer			
Facility Name	**Design Flows (mgd)**	**NH3-N (mg/l)**	**CBOD5 (mg/l)**
Walcott(N+S)	0.513	7	25
Durant	0.2	13.7	25
Wilton	0.35	4.3	25
Winter			
Facility Name	**Design Flows (mgd)**	**NH3-N (mg/l)**	**CBOD5 (mg/l)**
Walcott(N+S)	0.513	14.2	25
Durant	0.2	31	25
Wilton	0.35	10.18	25
Spring/fall			
Facility Name	**Design Flows (mgd)**	**NH3-N (mg/l)**	**CBOD5 (mg/l)**
Walcott(N+S)	0.513	7.5	25
Durant	0.2	13.7	25
Wilton	0.35	4.64	25

Another important component of the DO problem in reaches 22 and 23 is sediment oxygen demand (SOD). As described in the pollution source assessment (section 3.3), most SOD originates from non-point sources during high flow and settles as velocities diminish in these two low gradient reaches. The stream was modeled several times with various combinations of protected flow, ammonia reduction and SOD reduction.

SOD is used in the TMDL as a placeholder for “unexplained” oxygen demand originating from sources other than the three wastewater treatment plant point sources included in the QUAL2E modeling. SOD is a compartment in QUAL2E that would be an input if SOD monitoring data were available. As such, this “unexplained” non-point source oxygen demand originates to some extent in both the sediment and the water column.

A second phase work plan will measure in-situ SOD and continuously measure water column dissolved oxygen using temperature and DO data-loggers in the problem segment of Mud Creek. This work will provide additional information on the oxygen dynamics of Mud Creek that will clarify what part of NPS oxygen demand originates in sediment and what part is in the water column.

The Phase 1 wasteload allocations for the three plants are in Table 9. The WLA’s are based on a protected flow of 1 cfs and an SOD reduction of 50%. The critical flow condition will occur in the summer or late fall.

The basis for these wasteload allocations is a protected flow of 1 cfs as found in the current Iowa Water Quality Standards for Mud Creek. Supported by field notes and other information, IDNR staff have concluded that protected flow should be 2 cfs, not 1 cfs. A rationale and justification for the 2 cfs protected flow is being prepared by state water quality standards staff to initiate state rule making that may amend the Mud Creek WQS protected flow. The TMDL wasteload allocations are those found in Table 9 unless the Water Quality Standards for Mud Creek are revised.

A rule revision to the Mud Creek Water Quality Standard is being developed concurrent with TMDL Phase 1 activities. The proposed WQS revisions are following the appropriate administrative and technical Water Quality Standards processes. Meanwhile, tentative endpoints and wasteload allocations have been developed based on the proposed protected flow of 2 cfs. These tentative WLA values can be found in Appendix B, Protected Flow Discussion.

Table 9. Phase 1 TMDL wasteload allocations for Mud Creek permitted discharges, protected flow = 1 cfs					
Summer (with 50% SOD reduction in both Reach 22 & 23)					
Facility Name	**Design Flows (mgd)**	**NH3-N (mg/l)**	**NH3-N (lb/d)**	**CBOD5 (mg/l)**	**CBOD5 (lb/d)**
Walcott(N+S)	0.513	3	12.8	25	107
Durant	0.2	2	3.3	25	42
Wilton	0.35	2	5.8	25	73
Winter (No SOD Reduction is needed)					
Facility Name	**Design Flows (mgd)**	**NH3-N (mg/l)**	**NH3-N (lb/d)**	**CBOD5 (mg/l)**	**CBOD5 (lb/d)**
Walcott(N+S)	0.513	9	39	25	107
Durant	0.2	6.5	10.8	25	42
Wilton	0.35	9	26.3	25	73
Spring/fall (with 50% SOD Reduction in both Reach 22 & 23)					
Facility Name	**Design Flows (mgd)**	**NH3-N (mg/l)**	**NH3-N (lb/d)**	**CBOD5 (mg/l)**	**CBOD5 (lb/d)**
Walcott(N+S)	0.513	4	17.1	25	107
Durant	0.2	6	10.0	25	42
Wilton	0.35	1	2.9	25	73

Load Allocations

The non-point source load allocation for this TMDL is based on event-driven sediment oxygen demand or low flow continuous NPS oxygen demand (livestock in the stream) in the two reaches of Mud Creek where reduced velocity allows sediment originating from non-point sources to settle. This sediment contains organic material that contributes significant SOD. In general, SOD load allocations are based on higher flow conditions than point source wasteload allocations. Runoff conditions occur during rainfall events and snowmelt. The load allocated to nonpoint source SOD is therefore applicable to periods of higher flow. The load allocation for sediment oxygen demand and low flow continuous NPS oxygen demand is 50% of existing loads at a protected flow of 1 cfs. .

PF = 1 cfs						
Reach NO.	**Stream Flow (cfs)**	**Flow Volume (kcf)**	**SOD Conc. (mg/l-day)**	**SOD (lb/day)**	**No. of Elements**	**Sub-total SOD(lb/day)**
Reach 22	2.44	5.57	-19.17	-6.7	16	**107**
Reach 23	2.98	7	-8.11	-3.5	8	**28**

Load allocation at a protected flow of 1 cfs with a 50% SOD and low flow continuous NPS oxygen demand reduction required.
Total SOD and low flow continuous NPS oxygen demand load = 135 lb/d: Needed load reduction = 68 lb/d

The Phase 1 Load Allocation for total SOD and low flow continuous NPS oxygen demand is 68 pounds per day (a 50% reduction).

Margin of Safety

The margin of safety for this TMDL is implicit. Targeting both numeric load allocations and setting a target based on biological assessments ensure that water quality standards will be achieved. Future monitoring will guide adaptive management of this watershed through better characterization of pollutant sources and effectiveness of control methods. If future biological assessment of the impaired segment of Mud Creek indicates continued impairment, this TMDL will be reopened and wasteload and load allocations will be adjusted.

4. Implementation Plan

This TMDL implementation plan provides guidance for agencies and stakeholders working to improve Mud Creek water quality. This plan has two components, one for point source discharges at low flow and one for nonpoint source discharges driven by rainfall events when stream flow is higher.

Point Sources

The existing wasteload allocations meant to protect the local stream segment near the wastewater treatment plant discharges and the revisions generated by this TMDL to protect reaches identified in the bioassessment will be incorporated into revised NPDES permits.

Nonpoint Sources:

A re-evaluation of watershed nonpoint sources of organic and nitrogenous oxygen demanding material and their delivery to the stream is needed. Since most of these are associated with runoff and entrained sediment, controls that reduce erosion in the Mud Creek watershed and remove animals from the immediate vicinity of the stream will reduce water column organic enrichment. The *Mud Creek Watershed Project* was started in 2000 to address agricultural nonpoint pollutant sources and implement best management practices in the watershed. It was initiated by the Muscatine County SWCD.

Reasonable Assurance

In developing waste load allocations for the permitted facilities in the Mud Creek watershed, assumptions were made which depend on reductions in the load allocation from non-point sources. To ensure water quality standards are met, there must be reasonable assurance that non-point sources contributing to the water quality problems in Mud Creek will be addressed. This assurance is provided by a water quality project funded with EPA Section 319 non-point source grant funds, which is assessing the non-point sources contributions. If necessary, NPDES permits will be amended following the 319 assessment and subsequent implementation of non-point control measures to ensure that water quality standards are ultimately achieved. The 319 project was initiated June

2001 by the Muscatine County Soil and Water Conservation District to address the impairments to the aquatic life in Mud Creek.

The Mud Creek watershed is approximately 60,000 acres. Excess nutrients and organic material getting to the stream are contributing to excess sediment oxygen demand. This results in low dissolved oxygen levels in the stream leading to impairments to the aquatic life community. A watershed assessment will be completed in the spring of 2003 along a one-half to one-mile wide corridor along Mud Creek and its major tributaries. This assessment will focus on sources of nutrients and other organic material that has direct access to the stream. This includes open feedlots, riparian pastures, and production agricultural land. Once major contributors are identified, the project will identify priority areas for installation of best management practices designed to reduce the load of organic material to the stream. The Mud Creek Water Quality Project was initiated in July 2001, and has thus far has received $290,000 from EPA 319 grant funds and $118,000 in grant funds from the Iowa Department of Agriculture and Land Stewardship – Division of Soil Conservation. The project is currently funded through June 2005, but may be extended if additional watershed work is needed. Once the watershed assessment has identified best management practices that would reduce the non-point source loading, grant funds will be prioritized to implement those practices. Ultimately, through monitoring and assessment of water quality in response to the implementation of both point and non-point measures, decisions on additional actions necessary to ensure water quality standards will be made. Local watershed groups would be expected to play a major part in this adaptive management of the watershed.

Oxygen Demand Reduction Goal

In addition to correction of the water quality impairment in Mud Creek, the oxygen demand reductions identified in this TMDL are necessary to protect public and privates interests in the Mud Creek watershed. If future evaluations of the stream dissolved oxygen condition indicate that the oxygen demand reduction goal is inadequate to prevent impairment, the TMDL will be revised and new allocations will be made.

5. Monitoring and Evaluation Plan

The monitoring plan for Mud Creek is aimed at assessing the stream's support of aquatic life. The monitoring and evaluation plan for Mud Creek will consist of the following:

1. Measurement of aquatic life support using habitat and biological assessment methods.
2. Additional watershed and stream modeling to improve understanding of impact and adequacy of allocations to protect the stream and to assess the effectiveness of implemented management practices.

3. Estimate or measure continuous stream flow and dissolved oxygen concentration using stage recorders and DO probes.
4. Measurement of sediment oxygen demand to clarify its impact.

Most of this work will be done in 2003 and 2004. Significant improvements have been made to the Durant and Wilton wastewater treatment plants and the effect of these improvements on the stream impairment needs to be determined. The WWTP improvements were completed after the initial stream 1996 assessments that led to Mud Creek's listing as an impaired stream.

Phase 1 Project Report
A Phase 1 Project Report will be prepared by IDNR by March 31, 2004. This report will include the watershed and NPS pollutant source assessment, the results from the bio-assessment, interpretation of collected flow and dissolved oxygen data, and an evaluation of measured and modeled SOD.

6. Public Participation

Public meetings regarding the procedure and timetable for developing the Mud Creek TMDL were held on January 14, 2002, in Des Moines, Iowa; and on January 28, 2002 in Durant, Iowa. The initial public notice period was from March 20, 2003 to April 11, 2003. During this period the draft TMDL was available to the public on the IDNR Internet site and the draft TMDL was electronically distributed to local and statewide stakeholders.

Many efforts by IDNR TMDL staff have been made to inform and listen to local and statewide stakeholders during the development of this TMDL. As noted previously two public meetings were held early in the TMDL development process. Additionally, the TMDL project manager and other IDNR staff attended three meetings in the watershed and were in frequent contact with the coordinator for the NPS Mud Creek Watershed Project, Matt McAndrew. A description of public participation efforts follows.

- September 25, 2002, Mud Creek Watershed Project meeting, Walcott City Hall. IDNR TMDL staffers present were Marian Maas, TMDL/WQA Section Supervisor, and Bill Graham, TMDL Technical Coordinator and Mud Creek TMDL project manager. Attending were producers, NRCS and IDALS-DSC staff, and other local stakeholders.
- March 20, 2003, Draft Mud Creek TMDL goes out on public notice. Distributed statewide on IDNR newswire, emailed directly to state stakeholders, distributed to local stakeholders by Matt McAndrew.
- March 25, 2003, Mud Creek Watershed Project meeting, Muscatine. IDNR TMDL staff present was Bill Graham, TMDL Technical Coordinator and Mud Creek TMDL project manager. Attending were wastewater treatment plant operators, engineers, agricultural producers, and other local stakeholders.

- April 10, 2003, Draft Mud Creek TMDL meeting, Wilton bank building. IDNR TMDL staff present were Marian Maas, TMDL/WQA Section Supervisor, Bill Graham, TMDL Technical Coordinator and Mud Creek TMDL project manager, and Jeff Tisl, non-point source specialist from the IDNR 319 NPS program. Attending were producers, NRCS and IDALS-DSC staff, and other local stakeholders. Meeting included presentations by Matt McAndrew, Marian Maas, Jeff Tisl, and Bill Graham on the draft TMDL.
- June 17, 2003, Meeting with Iowa Water Pollution Control Association stakeholders at their annual conference in Sioux City, Iowa. Association members have had questions about the Mud Creek TMDL and the TMDL process in general because TMDLs can affect the operation of wastewater treatment plants.

Some of the public and stakeholder comments received expressed concern with TMDL development, particularly data quality, stream modeling, and TMDL processes in general. Comments and suggestions received have been incorporated into the final TMDL where appropriate. The changes in the final TMDL involve improved terminology precision and clarification of the use of sediment oxygen demand (SOD) as a pollutant load.

Stakeholder comments have also shown the need for a technical advisory committee (TAC) that will review complex procedures such as watershed and waterbody modeling. This committee will provide credibility with the public and additional assurance that TMDL development is scientifically reliable. It will consist of academics and technically oriented stakeholders and will evaluate complex, important, and/or potentially controversial TMDLs.

7. References

Stream Watershed Assessment to Support Development of Total Maximum Daily Loads (TMDLs), August 2001, Iowa Department of Natural Resources, Water Resources Section, Wallace State Office Building, Des Moines, Iowa

Iowa. 1996. *Iowa Administrative Code 567, Chapter 61, Iowa Water Quality Standards.*

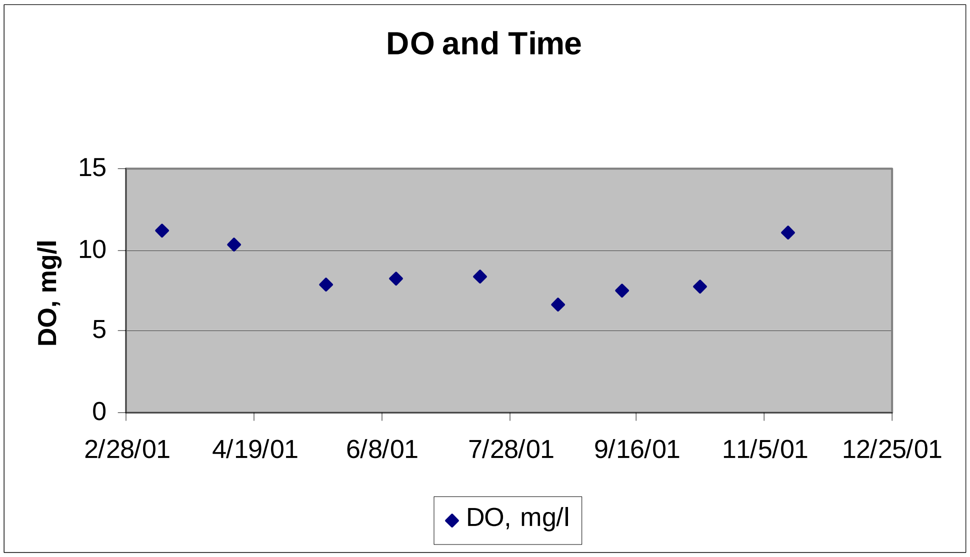
The Enhanced Stream Water Quality Models Qual2E and Qual2E-UNCAS: Documentation and User Manual, May 1987, USEPA, Environmental Research Laboratory, EPA 600 3-87 007

USDA/Natural Resources Conservation Service. 1998. Iowa Field Office Technical Guide Notice No. IA-198. “Erosion and Sediment Delivery Procedure”, Section I, Erosion Protection.

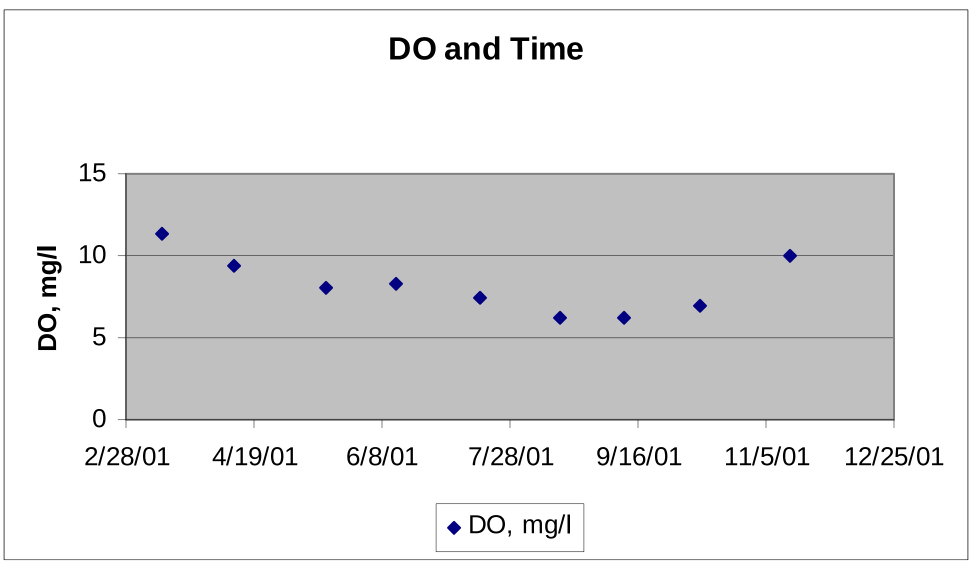
USDA-SCS. 1979. United States Department of Agriculture, Soil Conservation Service. 1979. Soil Survey of Muscatine County, Iowa.

Appendix A. Data and Data Evaluation

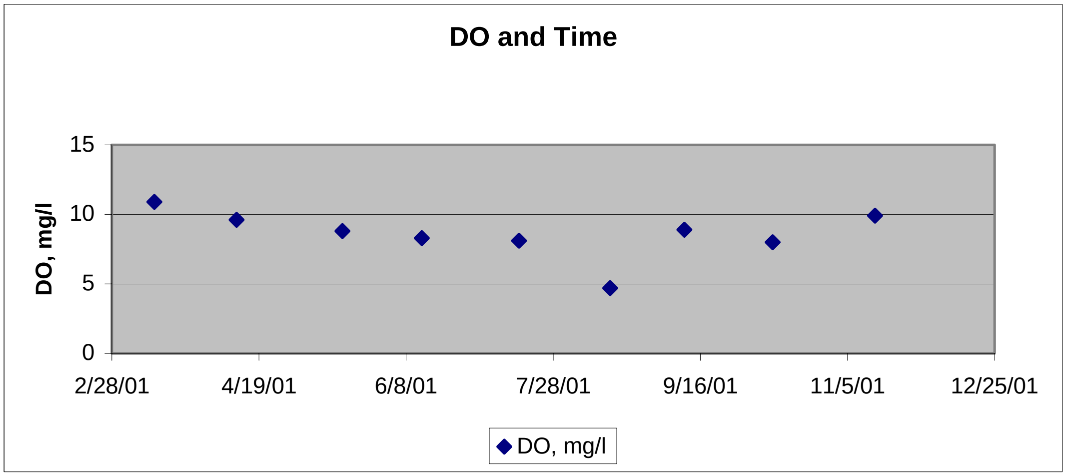
Sampling Site 1



Sampling Site 2



Sampling Site 3



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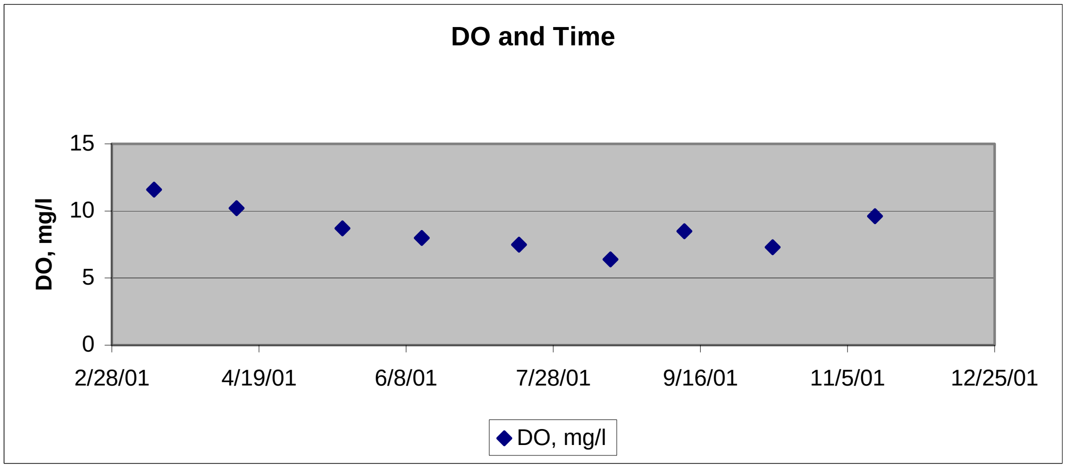
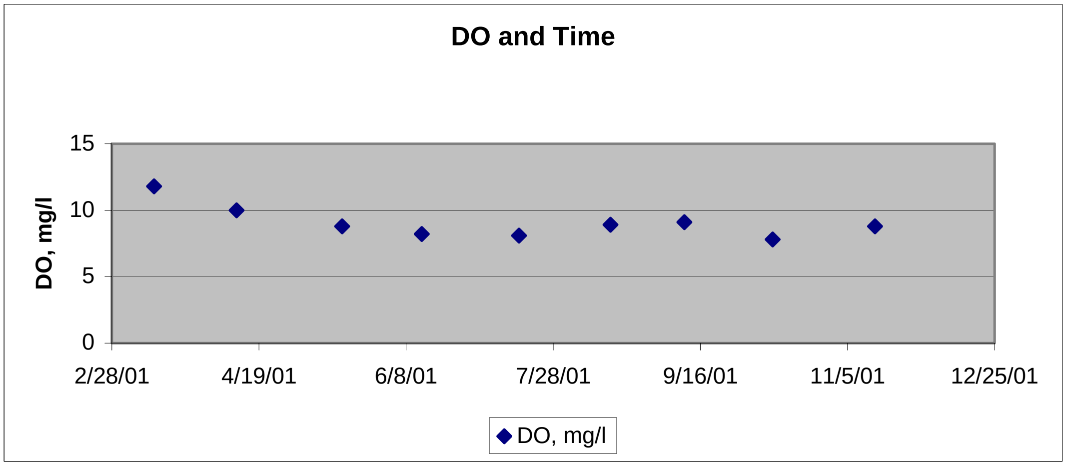
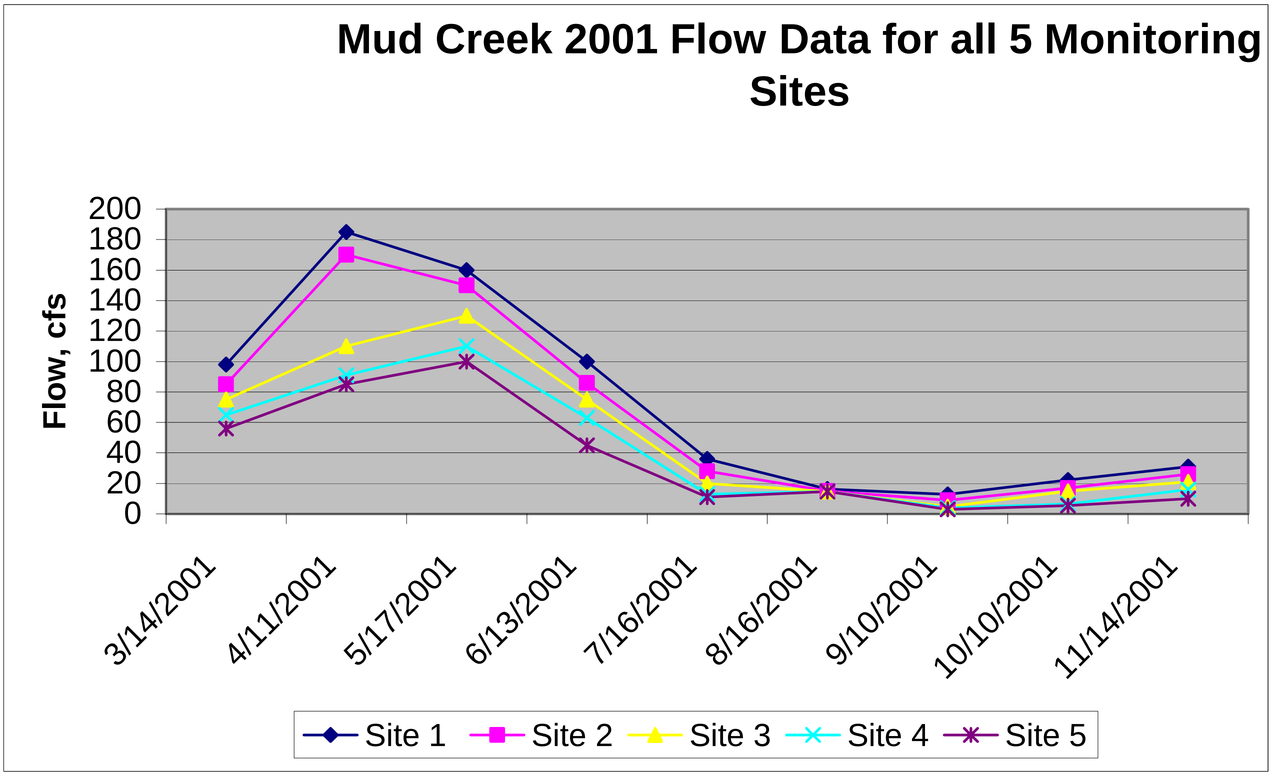


Sampling Site 5




Mud Creek 2001 Flow Data for all 5 Monitoring Sites
Flow, cfs
200
180
160
140
120
100
80
60
40
20
0
3/14/2001
4/11/2001
5/17/2001
6/13/2001
7/16/2001
8/16/2001
9/10/2001
10/10/2001
11/14/2001
Site 1
Site 2
Site 3
Site 4
Site 5

Appendix B. Discussion of Proposed Two CFS Protected Flow

The basis for these wasteload allocations is a protected flow of 1 cfs as found in the current Iowa Water Quality Standards for Mud Creek. Supported by field notes and other information, IDNR staff have concluded that protected flow should be 2 cfs, not 1 cfs. A rationale and justification for the 2 cfs protected flow is being prepared by state water quality standards staff to initiate state rule making that may amend the Mud Creek WQS protected flow.

The rule revision to the Mud Creek Water Quality Standard is being developed concurrent with TMDL Phase 1 activities. The proposed WQS revision process is following appropriate administrative and technical Water Quality Standards procedures. Meanwhile, tentative endpoints, wasteload allocations, and load allocations have been developed based on the proposed protected flow of 2 cfs. The WLA values in Table B1 and LA values in Table B2 have been estimated using a protected flow of 2 cfs.

Wasteload Allocations

Table B1 shows modeled wasteload allocations at a protected flow of 2 cfs. This may become the water quality standard protected flow for Mud Creek after previously discussed rulemaking is implemented. These wasteload allocations assume a 25% SOD reduction because of the greater dilution available if the protected flow is 2 cfs.

Table B1. TMDL wasteload allocations for Mud Creek permitted discharges, proposed water quality standard protected flow = 2 cfs

Summer (25% SOD Reduction in Reach 22& 23)			
Facility Name	**Design Flows (mgd)**	**NH3-N (mg/l)**	**CBOD5 (mg/l)**
Walcott(N+S)	0.513	7	25
Durant	0.2	8	25
Wilton	0.35	2	25
Winter (No SOD Reduction is needed)			
Facility Name	**Design Flows (mgd)**	**NH3-N (mg/l)**	**CBOD5 (mg/l)**
Walcott(N+S)	0.513	14	25
Durant	0.2	20	25
Wilton	0.35	20	25
Spring/fall (25% SOD Reduction in Reach 22 & 23)			
Facility Name	**Design Flows (mgd)**	**NH3-N (mg/l)**	**CBOD5 (mg/l)**
Walcott(N+S)	0.513	7.5	25
Durant	0.2	10	25
Wilton	0.35	3	25

Load Allocation
Load allocation at a protected flow of 2 cfs with a 25% SOD load reduction required. Total SOD load = 139 lb/d: Needed load reduction = 35 lb/d

Assumes WQS rulemaking protected flow change to 2 cfs

Table B2. TMDL Load Allocations for Mud Creek NPS discharges, proposed WQS protected flow = 2 cfs

Reach NO.	Stream Flow (cfs)	Flow Volume (kcf)	SOD Conc. (mg/l-day)	SOD (lb/day)	No. of Elements	Sub-Total SOD(lb/day)
Reach 22	3.45	6.74	-16.42	-6.9	16	**110**
Reach 23	3.99	8.21	-7.12	-3.6	8	**29**

Load Allocation = 105 lb/d