Total Maximum Daily Loads
For Sediment, Nutrients, and Ammonia
North Fork Maquoketa River
Dubuque County, Iowa

2007

Iowa Department of Natural Resources
Watershed Improvement Section

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1. Summary

Table 1. North Fork Maquoketa River summary.

Waterbody Name	North Fork Maquoketa River
County	Dubuque and Delaware
Use Designation Class	B(WW-2) (aquatic life)
Major River Basin	Maquoketa River Basin
Pollutants	Sediment (sheet, rill, and bank erosion) Nutrients (phosphorous limited algae) Ammonia (toxicity and oxygen demand)
Pollutant Sources	Sediment – Nonpoint sources Nutrients – Point and nonpoint sources Ammonia – Episodic nonpoint sources
Impaired Use	B(WW-2) (aquatic life)
2002 303d Priority	Low
Watershed Area	28,252 acres
Impaired Stream Length	19.5 miles
Sediment TMDL	
Target	Reduce stream bed siltation from 39% to 9% bottom coverage
Load Capacity (annual avg.)	20,200 tons per year
Existing Load (annual avg.)	87,500 tons per year
Reduction to Achieve Target (annual avg.)	67,300 tons per year
Load Allocation (annual avg.)	20,200 tons per year
Existing load (max. daily, see #7, p. 5)	51,000 tons per day (2yr. 24 hr. event)
Load Reduction (max. daily, see #7, p. 5)	39,300 tons per day (2yr. 24 hr. event)
Load Allocation (max. daily, see #7, p. 5)	11,700 tons per day (2yr. 24 hr. event)
Wasteload Allocation	No sediment point sources
Margin of Safety	Implicit - conservative assumptions
Nutrient TMDL (Phosphorous)	
Targets	Reduce diurnal DO swings to 10 mg/l or less, reduce bottom algae by 33%, maintain a minimum DO concentration of 5.0 mg/l
Load Capacity	6.64 lb/day total phosphorous (TP)
Existing Load	21.04 lb/day TP
Load Reduction to Achieve Target	14.40 lb/day TP
Load Allocation	5.40 lb/day TP
Wasteload Allocation	1.24 lb/day TP (existing daily load)
Margin of Safety	Implicit – conservative assumptions
Maximum daily load	6.64 lb/d TP
Ammonia TMDL (Episodic Toxicity)	
Target (simulated 24 hr. discharge at pH = 9.0 and temp. = 20C, flow = 10 L/sec)	Water Quality Standards Acute Criterion for Total Ammonia
Load Capacity (10 mg/l ammonia)	1.92 lb/d total ammonia
Existing Load (45 mg/l ammonia)	8.63 lb/d total ammonia
Load Reduction to Achieve Target	6.71 lb/d total ammonia
Wasteload Allocation	No episodic point sources.
Load Allocation	1.92 lb/d total ammonia
Margin of Safety	0.13 mg/l total ammonia (10 % of 1.32 mg/l WQS concentration criterion)

The Federal Clean Water Act requires the Iowa Department of Natural Resources (IDNR) to develop a total maximum daily load (TMDL) for waters that have been identified on the state's 303(d) list as impaired by a pollutant. North Fork Maquoketa River (NFMR) has been identified as impaired by sediment, nutrients, and episodic slugs of ammonia. The purpose of these TMDLs for North Fork Maquoketa River is to calculate the maximum allowable sediment, total phosphorus, and ammonia loads for the stream so that water quality standards are maintained.

Because the cause (stressor) of the biological impairment in 1998 was unknown, a method called Stressor Identification (SI) was used to determine the existing stressors on the biotic community of North Fork Maquoketa River. The process involves "critically reviewing available information, forming possible stressor scenarios that might explain the impairment, analyzing those scenarios, and producing conclusions about which stressor or stressors are causing the impairment."

Phasing TMDLs is an iterative approach to managing water quality that becomes necessary when the origin, nature, or sources of water quality impairments are not well understood. This TMDL will have two phases. Phase 1 will consist of setting specific and quantifiable targets for sediment, oxygen demand, total phosphorus, and ammonia loads to the creek. Phase 2 will consist of implementing the monitoring plan, evaluating collected data, and readjusting target values if needed and as resources are available.

In Phase 1, the waterbody load capacity, existing pollutant load in excess of this capacity, and the source load allocations are estimated based on available information. As resources become available, a monitoring plan will be used to determine if prescribed load reductions result in attainment of water quality standards and whether or not the target values are sufficient to meet designated uses.

Monitoring activities may include routine sampling and analysis, biological assessment, fisheries studies, and watershed and/or waterbody modeling. Monitoring is important for watershed TMDL plans to:

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

Any additional data will be used in Phase 2 to determine if the implemented TMDL and watershed management plan have been effective in addressing the water quality impairments. The data and information can also be used to determine if the TMDLs have accurately identified the required components, i.e., assimilative capacity, load and wasteload allocations, in-stream response to pollutant loads, etc., and if revisions are appropriate.

This TMDL has been prepared in compliance with the current regulations for TMDL development that were promulgated in 1992 as 40 CFR Part 130.7. These regulations and consequent TMDL development are summarized below:

1. **Name and geographic location of the impaired or threatened waterbody for which the TMDL is being established:** North Fork Maquoketa River, S31, T89N, R2W, Dubuque County at Dyersville.

2. **Identification of the pollutant and applicable water quality standards:** The pollutants causing the water quality impairments are sediment, phosphorous limited benthic algae, and episodic ammonia loads. The designated use for North Fork Maquoketa River is Aquatic Life Class B(WW-2). Excess sediment, phosphorus and ammonia have impaired the aquatic life designated use criteria as described in the Iowa Water Quality Standards.

3. **Quantification of the pollutant load that may be present in the waterbody and still allow attainment and maintenance of water quality standards:** The target of this TMDL is a reduction of sediment, benthic algae productivity and respiration, ammonia and oxygen demand loadings that allows the biological community to meet regional reference criteria. Biological targets are based on the Fish Index of Biotic Integrity (FIBI) and Benthic Macroinvertebrate Index of Biotic Integrity (BMIBI). Stream segments having FIBI or BMIBI scores below the 25th percentile of reference sites are considered impaired.

   In order to meet the biological targets, secondary targets are set for delivered sediment, phosphorous, and ammonia. Measurements from the monitored NFMR stream segments are compared to stream reference sites within the same ecological region. These biotic index targets are set for scores equaling or exceeding the 25th percentile of regional reference sites.

4. **Quantification of the amount or degree by which the current pollutant load in the waterbody, including the pollutant from upstream sources that is being accounted for as background loading, deviates from the pollutant load needed to attain and maintain water quality standards:** The existing FIBI and BMIBI scores based on 1999, 2001 and 2005 bioassessment sampling and the ecoregion reference scores are shown in Table 6. Based on comparisons to regional reference sites, reductions are needed for sediment, phosphorous limited benthic algae, and episodic ammonia loads to meet the ecoregion targets and protect beneficial aquatic life use.

5. **Identification of pollution source categories:** Both point and nonpoint pollutants have been identified as sources of impairments to North Fork Maquoketa River. Point sources include municipal wastewater treatment facilities. Nonpoint sources include runoff from both urban and agricultural land uses.

6. **Wasteload allocations (WLA) for pollutants from point sources:** There are no point sources in the watershed that are significant sources of sediment and therefore there are no wasteload allocations for sediment. The total phosphorous WLA for the New Vienna wastewater treatment plant is based on the existing estimated average daily load. It is 564 gram/d (1.24 lb/d) or the

monitored daily load when this data becomes available. Ammonia limits are the same as in the WLA developed during planning for the recently constructed aerated lagoon.

7. **Load allocations for pollutants from nonpoint sources:** The load allocation for sediment is set as both a long term annual average and a maximum daily load for the 2 year 24 hour storm event (3 inches). The long-term annual average load allocation is set at 20,200 tons/year delivered to the stream based on the Revised Universal Soil Loss Equation (RUSLE) model. The maximum daily load was estimated using the Modified USLE model and a 2-year return 24-hour storm event (3 inches over 24 hours). The maximum daily load allocation is set at 11,700 tons per day. The total phosphorus daily load allocation is set at 5.40 pounds per day. The total ammonia load allocation for a slug discharge to the stream over 24 hours is 1.9 pounds per day, i.e., 10 mg/l total ammonia concentration in a 1000 gal/hour discharge to the stream.

8. **A margin of safety:** The margin of safety for this TMDL is provided by the conservative assumptions made during its development. Some of these assumptions were:
   - That there are no management practices in the watershed that reduce delivered sediment to the stream when in fact there are several of these BMPs, such as riparian buffer strips and sediment control basins in place.
   - The median for the reference conditions used as a target puts the goal well above the 25th percentile of the IQR that is the threshold for determining impairment.

   Additionally, an explicit 10 % MOS was applied to the total ammonia toxicity criterion for episodic ammonia slug loads to the stream.

9. **Consideration of seasonal variation:** This TMDL was developed based on the average annual and daily maximum sediment load and the critical conditions in late summer for daily maximum dissolved oxygen fluctuations and episodic ammonia loads.

10. **Allowance for reasonably foreseeable increases in pollutant loads:** An allowance for increased sediment and phosphorus loading was not included in this TMDL. The City of New Vienna's population is stable and is expected to remain so. The watershed landuses are expected to remain predominantly agricultural. The addition or deletion of animal feeding operations within the watershed could increase or decrease nutrient and ammonia loading. An allowance for potential increases in agricultural loads is not included because such increases are not predictable.

11. **Implementation plan:** Although not required by the current regulations, an implementation plan is outlined in Section 4 of this report.

2. North Fork Maquoketa River, Description and History

2.1 The Stream

The North Fork Maquoketa River (NFMR) runs generally south and east from its headwaters near the City of Luxemburg in Dubuque County to its confluence with the Maquoketa River in Jackson County near the City of Maquoketa. The impaired NFMR segment starts near the headwaters and flows 19.5 miles to Dyersville.

Table 2. North Fork Maquoketa River features.

Waterbody Name:	North Fork Maquoketa River;
Hydrologic Unit Code:	HUC10 0706000603
IDNR Waterbody ID:	IA 01-NMQ-0020_2;
Location:	Section 31 T89N R2W; Section 21 T89N R2W
Latitude:	42° 29' N
Longitude:	91° 7' W
Water Quality Standards Designated Uses:	Aquatic Life Support, B(WW-2)
Tributaries:	Coffee Creek
Receiving Waterbody:	Maquoketa River
Stream Segment Lengths:	19.5 miles
Watershed Area:	28,252 acres

Hydrology

The NFMR impaired segment flows near the cities of Holy Cross and Luxemburg, through the City of New Vienna, and continues through the City of Dyersville. Its basin consists of a single HUC 12 sub watershed and its tributaries are Coffee Creek and several smaller unnamed streams. The segment ends in the City of Dyersville. Approximately 70 miles downstream of Dyersville, the North Fork Maquoketa River joins the Maquoketa River at the City of Maquoketa.

2.2 The Watershed

Land Use

The watershed of the impaired segment of the North Fork Maquoketa River has an area of 28,252 acres. Landuse data is based on 2002 statewide land covers derived from satellite imagery. Watershed landuses and areas are shown in Table 3. Figure A-2 in Appendix A is a map showing the distribution of land uses.

The watershed contributing to flow in the NFMR upstream from Dyersville, Iowa (Segment No. IA 01 NMQ-0020_2) is a transitional area that is divided between two ecological regions of Iowa (Figure 1). Roughly half of the lower portion of the watershed is located in the Iowan Surface of the Western Corn Belt Plains, and the upper one-half of the watershed is located in the Paleozoic Plateau (Driftless Area) ecoregion.

Table 3. 2002 landuses in the North Fork Maquoketa watershed

Land cover	**Area, acres**	**% of total**
Corn	11,817	41.8
Ungrazed and CRP grassland	6,427	22.7
Soybeans	4,629	16.4
Alfalfa	2,000	7.1
Roads, barren, unknown	864	3.1
Forest	804	2.8
Grazed grassland	769	2.7
Commercial industrial	405	1.4
Other rowcrop	372	1.3
Residential	128	0.5
Water and wetlands	38	0.1
Total	28,252	100

Estimated livestock in the watershed includes 7,200 cattle and 13,250 hogs held in pastures, feedlots, and CAFOs. These estimates are based on the 2002 Census of Agriculture. Although livestock inventory varies throughout the year depending on sale and slaughter rates, it is assumed that the Census number is representative of the average population for the year. The county level data was reduced by calculating the percentage of the county that is part of the watershed, assuming an even distribution of livestock

CAFOs are animal feeding operations in which animals are confined to areas that are totally roofed. CAFOs typically utilize earthen or concrete structures to contain and store manure prior to land application. Pollutants from CAFOs are delivered to a receiving stream via runoff from land-applied manure or from leaking/failing storage structures.

Open feedlots are unroofed or partially roofed animal feeding operations in which no crop, vegetation, or forage growth or residue cover is maintained during the period that animals are confined in the operation. Runoff from open feedlots can deliver substantial quantities of nutrients, oxygen demanding pollutants, and ammonia to streams dependent upon factors such as proximity to a water surface, number and type of livestock and manure controls.

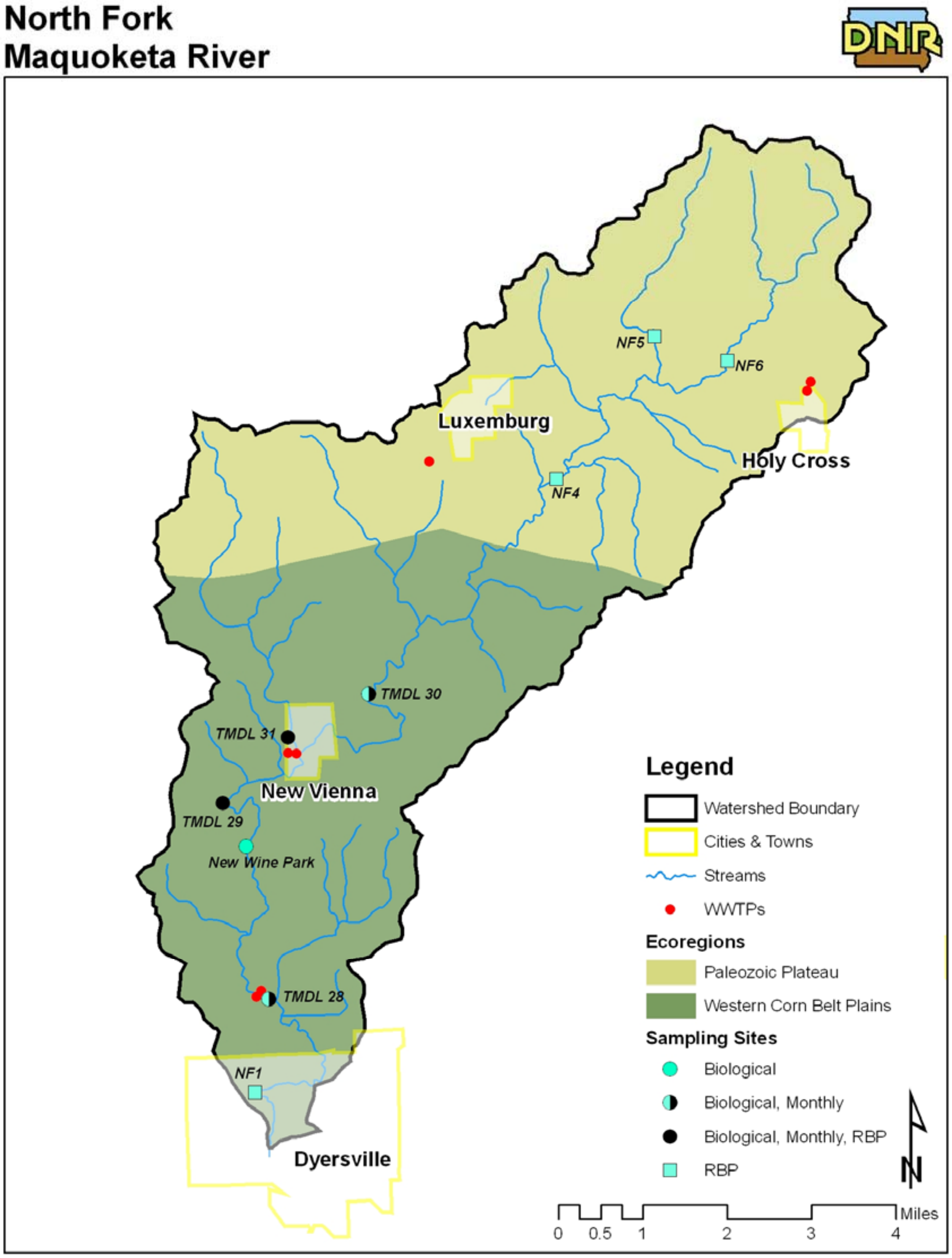


Figure 1 The North Fork Maquoketa River impaired segment and its watershed

Geology, Topography, and Soils

The watershed contributing to flow in the NFMR upstream from Dyersville, Iowa (Segment No. IA 01 NMQ-0020_2) is a transitional area that is divided between two ecological regions of Iowa (Figure 1). Roughly two-thirds of the lower portion of the watershed is located in the Iowan Surface of the Western Corn Belt Plains, and the upper one-third of the watershed is located in the Paleozoic Plateau (Driftless Area) ecoregion.

The Iowan Surface ecoregion is a geologically complex region located between the bedrock-dominated landforms of the Paleozoic Plateau region and the relatively recent glacial drift landforms of the Des Moines Lobe. The southern and southeastern border of this ecoregion is irregular and crossed by major northwest- to southeast-trending stream valleys. In the northern portion of the region, the glacial deposits are thin, and shallow limestone bedrock creates karst features such as sinkholes and sags. There are no natural lakes of glacial origin in this region, but overflow areas and backwater ponds occur on some of the larger river channels contributing to some diversity of aquatic habitat and a large number of fish species. The NFMR impaired segment is in the northeastern part of the Iowan Surface.

The bedrock-dominated terrain of the Paleozoic Plateau ecoregion is strikingly different from the rest of Iowa. Steep slopes and bluffs, higher relief, sedimentary rock outcrops, dense forests, and unique boreal microhabitats differentiate this ecoregion from the Iowan Surface Western Cornbelt Plains to the west. The Silurian Escarpment, a prominent physiographic feature that helps define the southern and western boundary this ecoregion, separates the mostly cropland area of the west from the mixed land use of the Driftless Area. Dissolution of the limestone and dolomite rocks results in karst features such as sinkholes, caves, and springs, and makes groundwater vulnerable to contamination. The streams in the Iowa portion of this region occupy entrenched valleys, and have cool waters with high gradients flowing over rocky substrates. The fish communities found here reflect this preference for cool clear water with relative consistency of flow.

The North Fork Maquoketa River watershed topography ranges from gently sloping to very steep. The upper portions of the watershed are in well-drained, silty upland soils of the Fayette-Nordness and Downs-Tama associations. These soils are formed primarily from loess.

Near Dyersville, the Chelsea-Sogn-Lamont soil association dominates. This association is characterized as sandy or loamy, excessively drained or well-drained soils on uplands or stream terraces.

3. TMDLs for Sediment, Nutrients, and Ammonia

3.1 Problem Identification

Impaired Beneficial Uses and Applicable Water Quality Standards
The Iowa stream classification document designates the protected aquatic life use for North Fork Maquoketa River as B (WW-2). In 1998, the aquatic life use was assessed as "partially supporting" based on the low diversity of fish as noted in a 1991 stream use assessment. Bioassessments conducted in 1999 and 2001 at four sites in the stream confirmed that the biological community in North Fork Maquoketa River did not meet expectations. The stream was then listed for a biological impairment of undetermined cause based on low Fish Index of Biotic Integrity (FIBI) and Benthic Macroinvertebrate Index of Biotic Integrity (BMIBI) scores. In 2004, the stream was assessed as "not supporting" due to results of biological monitoring that show poor biological integrity.

This headwater segment of the North Fork Maquoketa River is technically defined as the reach from Bear Creek upstream to the headwater. However, the impaired waterbody has been defined by the bioassessment, water quality monitoring and data evaluation as the HUC 12 sub-watershed upstream of the Hewitt Creek. Hewitt Creek is a separate HUC 12 sub-watershed that flows into the NFMR just upstream of Bear Creek at Dyersville and has not been included in this water quality evaluation. A separate TMDL will be developed for Hickory Creek, an impaired stream in the Hewitt Creek HUC 12, and Hewitt Creek will be evaluated at that time.

The FIBI and BMIBI biotic indexes rank the biological integrity of a stream sampling reach on a scale from 0 (min) to 100 (max). Table 4 shows general qualitative scoring guidelines for the two indices.

Table 4 Qualitative scoring guidelines for the BMIBI and FIBI.

Biological Condition Rating	Benthic Macroinvertebrate Index of Biotic Integrity (BMIBI)	Fish Index of Biotic Integrity (FIBI)
Poor	0 - 30	0 -25
Fair	31 - 55	26 - 50
Good	56 - 75	51 - 70
Excellent	76 - 100	71 - 100

The indices from reference streams in the various ecoregions have been used to derive target BMIBI and FIBI scores. The NFMR watershed lies in the two ecoregions shown in Table 5. The reference stream scores for the BMIBI and FIBI shown in this table are the minimum scores for biological integrity for aquatic life use support, below these values a stream is considered not or partially supporting designated uses.

Table 5 Reference criteria for assessing biological integrity

Ecoregion	BMIBI	FIBI
52B Ref. (Paleozoic Plateau)	61	59
47C Ref. (Iowan Surface)	59	71 (riffle), 43 non-riffle*

* FIBI criteria scores vary depending on the presence/absence of riffle habitat. Greater fish diversity and therefore higher FIBI scores are expected from areas with riffles. For the NFMR, only the 1999 sample was taken from a site fitting the description of riffle habitat.

The 1999, 2001 and 2005 FIBI and BMIBI scores for North Fork Maquoketa River and for reference sites are shown in Table 6. BMIBI and FIBI scores from sampling locations in the NFMR watershed generally indicate fair biological condition (Table 4). The shaded columns list the Biological Impairment Criteria (BIC) that are determined from the range of IBI scores sampled from ecoregion reference stream sites. For all sampling locations in all sampling years, the BMIBI and FIBI scores are below the reference condition biological impairment conditions. These results are strong evidence that the biological impairment is consistent across space and time.

Table 6. Index of Biotic Integrity scores for benthic macroinvertebrates (BMIBI) and fish (FIBI) from the NFMR Watershed.

Site (Stream)	**Year**	**BMIBI**	**BMIBI Biological Impairment Criterion (BIC)**	**FIBI**	**FIBI Biological Impairment Criterion (BIC)**
REMAP 147 (NFMR)	2005	42	59	34	UND[1]
TMDL 28 (NFMR)	2001	47	59	29	43
TMDL 28 (NFMR)	2005	26	59	37	43
New Wine Park (NFMR)	1999	N/A[2]	59	32	71[3]
TMDL 29 (NFMR)	2001	47	59	26	43
TMDL 30 (NFMR)	2001	51	59	33	43
TMDL 30 (NFMR)	2005	48	59	37	43
HI2 (Hickory Creek)	1999	53	59	37	71[3]

1. UND – Currently undetermined
2. N/A - Insufficient numbers of organisms for BMIBI calculation
3. Riffle area criterion

IDNR staff followed the Protocol for Stressor Identification (SI) to determine the cause of the North Fork Maquoketa biological impairment. The SI procedure relates impairments described by bioassessments to one or more specific causal agents (pollutants) and also separates water quality (pollutant) impacts from habitat alteration impacts. The SI determined that the primary pollutant related causal factors in the NFMR water quality impairment are sediment, nutrients (specifically phosphorous), and ammonia.

Sources and Interpretation of Monitoring Data

Bioassessment sampling was done at four locations in 1999 and 2001. Monthly water quality samples were collected from two NFMR sites from March through November of 2001 and 2005. The most important data for the development of this document were collected in 2005 at sites 28 and 30. This sampling consisted of two related measuring procedures. In the first, continuous stage data and event samples were collected using ISCO autosamplers and flow estimates were developed from the stage data. The second aspect of the data collection effort used data sondes collecting continuous dissolved oxygen and temperature measurements that were deployed from August 22 to 29.

Background. Evidence of biological impairment in the NFMR dates back to IDNR stream assessments done in 1989 and 1991. The assessment results indicated low diversity in the fish assemblage and fewer species than expected for the ecoregions. Four fish kills documented between June 1995 and July 1998 were cited as additional evidence of aquatic life use impairment leading to its inclusion on the 1998 303(d) impaired waters list. The causes of biological impairment were listed as unknown.

Follow-up sampling was conducted in 1999 to validate the aquatic life use impairment. The 1999 FIBI score from the NFMR at New Wine Park was significantly lower than the reference BIC used to determine aquatic life use support status. Because of the unusually low numbers of organisms collected from standardized sample units, it was not possible to calculate the BMIBI, which requires that at least one of three sample replicates contain 85 or more individual specimens. The three replicates had 70, 25, and 54 specimens.

In 2001, biological sampling was conducted at three locations; sites 28, 29 & 30, to further define the extent of the impairment. Based upon the combined 1999 and 2001 bioassessments, the 2002 and 2004 305(b) water quality reports evaluated the aquatic life designated use status as “not supporting” and the NFMR is currently on the 303(d) list of impaired waters. This assessment was based on low scores on the Fish Index of Biotic Integrity (FIBI) and Benthic Macroinvertebrate Index of Biotic Integrity (BMIBI) from biological monitoring conducted in 1999 and 2001.

Biological sampling was repeated at NFMR TMDL sites 28 & 30 in 2005, and a probabilistic (random) sample site was also sampled in the adjacent downstream segment for the state’s Regional Environmental Monitoring and Assessment Program (REMAP) random survey of perennial rivers and streams. Resulting biotic index scores can be found in Table 6. Also during 2005, biological sampling was conducted using the IDNR Rapid Bioassessment Protocol (RBP) at 13 sites located in the NFMR and Hewitt/Hickory Creek watersheds.

For spatial co-occurrence, stressor indicator data from the NFMR were compared to the inter-quartile ranges (25th to 75th percentile) of indicators for reference sites within the Iowan Surface ecoregion (47c), or when reference data were not available, a comparison was made with a statewide data set from the probabilistic stream survey. In a few cases, the maximum or minimum ecoregion reference value, state water quality standards designed to protect aquatic life, or the mean from random statewide sites are used as benchmarks. A stressor was deemed to be present at a site when the appropriate indicator value exceeded the benchmark value.

Criteria for Assessing Water Quality Standards Attainment

Water quality standards will be considered attained when the reference stream biological targets for ecoregion 47c are met. According to the Methodology for Developing Iowa’s 2004 Section 303(d) List of Impaired Waters, reference stream FIBI and BMIBI scores shown in Table 5 for the two watershed ecoregions are considered ‘supporting’ the aquatic life use.

The following sections on sediment, nutrients, and ammonia describe the procedures used to link the bioassessment scores to causal pollutants. Any of these stressors occurring at levels documented in the stream are capable of causing aquatic life impairment. The SI did not reveal any single stressor that is clearly the dominant cause. The stressors are manifested both as episodic and cumulative impacts.

Sediment Although there are not any specific water quality standards for sediment, excessive sediment can adversely impact aquatic life as demonstrated in the NFMR SI process. The NFMR has been shown to have quantities and coverage of stream bottom silt much higher than found in the reference streams for the relevant ecoregions. This excess sediment adversely affects aquatic life. As shown in Table 7, the measured substrate silt fraction was well outside of the ecoregion inter-quartile range at sites 28 and 30 in both 2001 and 2005.

The embeddedness of the streambed in riffle areas compared to the ecoregion reference values impacts aquatic life use support. The riffle embeddedness rating indicates the fraction of the coarse substrate area that has the interstitial spaces filled by fine sediment. In conjunction with the copious bottom algae, the excess silt alters the physical habitat crowding out benthic macroinvertebrates, changing the available food sources and causing a negative shift in community composition (BMIBI score). The loss of interstitial volume impacts fish reproductive activity and alters the organisms that are available as food (FIBI score).

Table 7. Comparison of altered substrate indicators at sites 28 and 30 to the ecoregion reference sites.

Parameter	Site 28	Site 30	Ecoregion 47c Reference
Substrate silt fraction[1], %	48 (2001), 30 (2005)	55 (2001), 57 (2005)	4 to19 IQR[3], median=9
Embedded riffles[2], %	3.2 (40 to 60%)	3.7 (40 to 70%)	1.74 to 2.53 IQR
TSS, mg/l	15 (5 to 230)	21 (5 to 120)	5 to 15 IQR at baseflow
Turbidity, ntu	7.6 (3.1 to 18)	13 (8 to 43)	4 to 9.5 IQR

1. Bottom fraction that is silt covered as a %. One measurement done in each of two years at each site.
2. Embeddedness is the fraction of coarse substrate area embedded by fine sediment as a %.
3. Reference conditions are measured as the inter-quartile range.

Nutrients Excessive nutrient loads, specifically phosphorous, have increased primary production from bottom algal growth in the NFMR. This growth changes the composition of the basal food source and leads to high nighttime DO respiration rates. When the algal blooms die off, the remaining organic matter also has an oxygen demand that reduces stream dissolved oxygen concentration.

The bottom algae blooms also cause dramatic diurnal swings in dissolved oxygen. As shown in Figure 2, dissolved oxygen concentrations range from 6.1 mg/l to 20.5 mg/l over the course of 12 hours and then drop to 5.3 mg/l in 8 hours. These large fluctuations are stressful to fish and other aquatic life. Phosphorous load reduction in NFMR will improve the BMIBI and FIBI scores by reducing algal photosynthesis and respiration and moderating the amplitude of dissolved oxygen concentration.

Dissolved oxygen measurements taken over an eight day period by the data logger show that oxygen levels fluctuate widely over each 24-hour period, with dissolved oxygen concentrations dipping below 5 mg/l on two nights at site 30. In addition, site 30 monthly grab samples have shown low levels of dissolved oxygen on several occasions. Daytime concentrations were below 5.0 mg/l on one occasion in October of 2001 and at or below 6.0 mg/l on three occasions in both 2001 and 2005.

Diurnal oxygen monitoring conducted in 2005 during base flow stream conditions showed substantial DO fluctuation between day and night caused by photosynthesis and respiration of plants and algae covering the stream bottom. Generally, minimum DO concentration occurs during the dark hours just before sunrise. Despite these large fluctuations, DO concentrations usually remain slightly over the water quality standard during base flow stream conditions. The relatively cool stream temperature mitigates respiratory oxygen demand during dark hours because DO saturation concentration increases with lower water temperature, i.e., DO concentration is higher in cool streams than in warm streams.

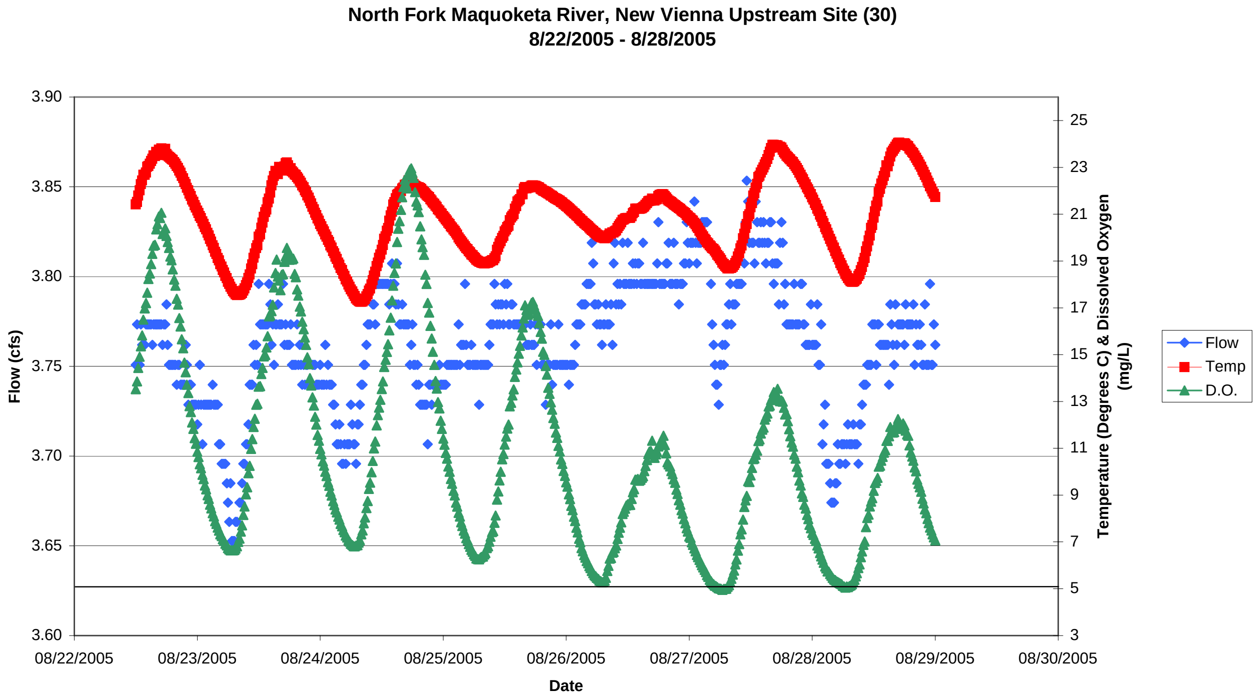


Figure 2 Site 30 continuous DO and temperature

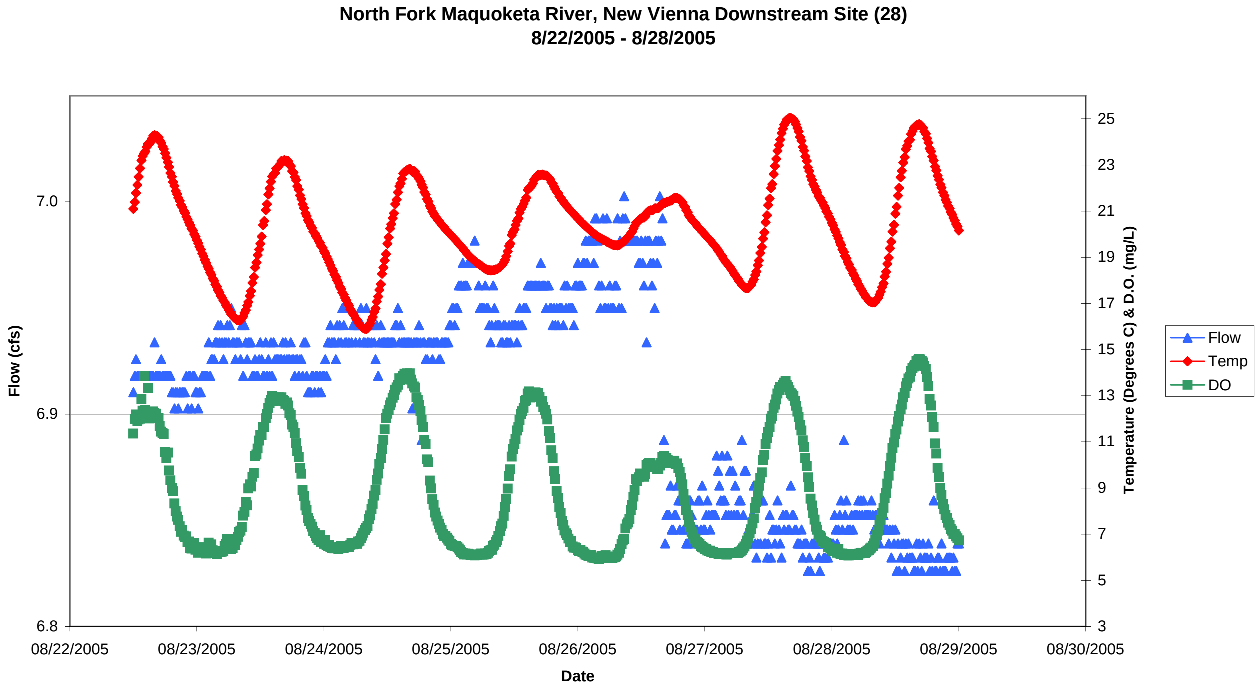
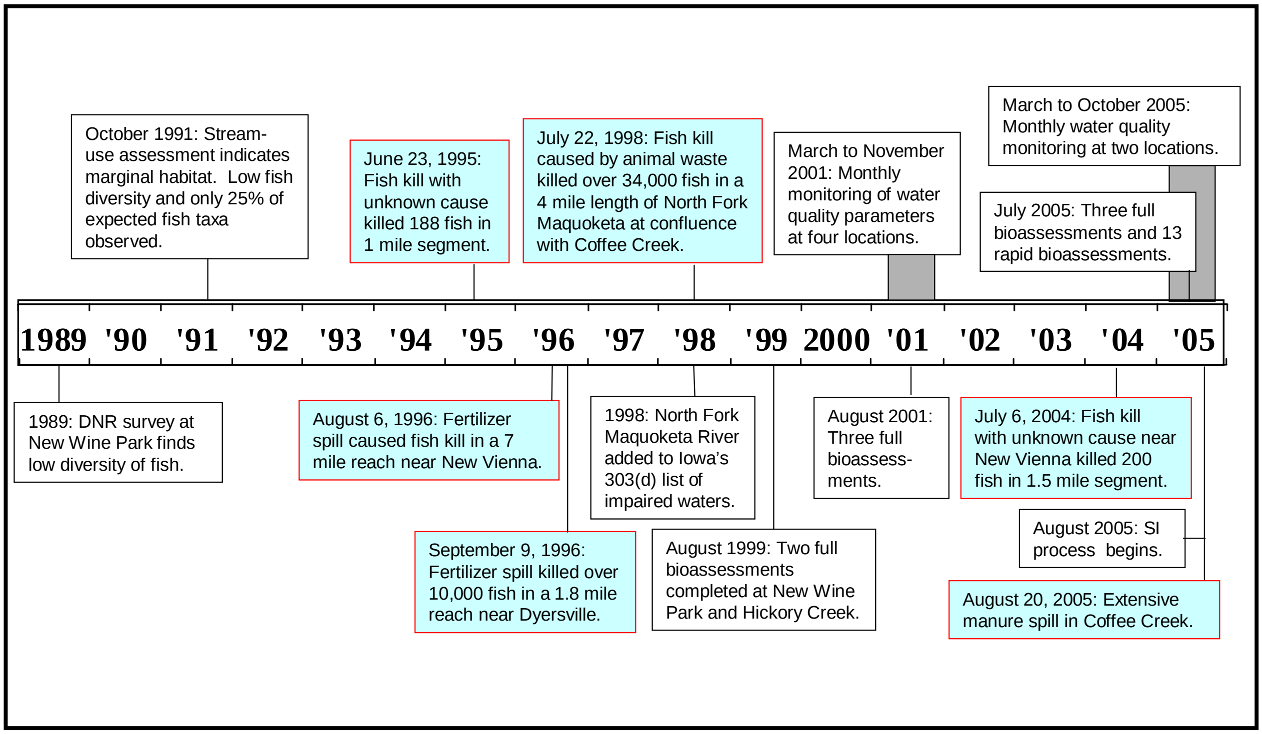


Figure 3 Site 28 continuous DO and temperature

Ammonia High ammonia concentrations in discharges to the NFMR caused by spills and runoff from manure can cause serious water quality problems in two major ways:

1. Ammonia is toxic to all fish even at relatively low concentrations.
2. Ammonia exerts an oxygen demand in streams through nitrification that significantly depletes DO. In addition to ammonia OD, spills and runoff usually have an organic component that becomes an OD from heterotrophic bacteria growth and metabolism.

Spills and runoff problems have been consistently reported for this segment of the NFMR. Figure 4 shows the timeline for monitoring activities and reported spills resulting in fish kills.



October 1991: Stream-use assessment indicates marginal habitat. Low fish diversity and only 25% of expected fish taxa observed.

June 23, 1995: Fish kill with unknown cause killed 188 fish in 1 mile segment.

July 22, 1998: Fish kill caused by animal waste killed over 34,000 fish in a 4 mile length of North Fork Maquoketa at confluence with Coffee Creek.

March to November 2001: Monthly monitoring of water quality parameters at four locations.

March to October 2005: Monthly water quality monitoring at two locations.

July 2005: Three full bioassessments and 13 rapid bioassessments.

1989: DNR survey at New Wine Park finds low diversity of fish.

August 6, 1996: Fertilizer spill caused fish kill in a 7 mile reach near New Vienna.

September 9, 1996: Fertilizer spill killed over 10,000 fish in a 1.8 mile reach near Dyersville.

1998: North Fork Maquoketa River added to Iowa's 303(d) list of impaired waters.

August 1999: Two full bioassessments completed at New Wine Park and Hickory Creek.

August 2001: Three full bioassess-ments.

July 6, 2004: Fish kill with unknown cause near New Vienna killed 200 fish in 1.5 mile segment.

August 2005: SI process begins.

August 20, 2005: Extensive manure spill in Coffee Creek.

Figure 4 Timeline for NFMR monitoring and reported fish kills

Evidence consists of total ammonia levels exceeding the chronic water quality criteria on one occasion in 2001 at 3 monitoring locations on the NFMR. The ammonia violation documented in September 2005 was not known to be associated with a runoff event or spill of animal waste or fertilizer. Ammonia has also been explicitly or implicitly linked to several fish-kill events in the watershed the most recent of which occurred on July 27, 2006 near New Vienna. A fertilizer spill was responsible for one fish kill near Dyersville in September 1996. Runoff of animal waste was responsible for fish kills near New Vienna in July 1998, July 2004 and July 2006.

The segment of NFMR near New Vienna, including the Coffee Creek sub-watershed appears to be particularly susceptible to experiencing acute or chronic ammonia concentrations. It has been suggested that fish kills and other long-term water quality problems have degraded the stream reducing the populations of desirable species. The water quality standards for acute and chronic ammonia toxicity for a range of pH conditions are shown in Table 8.

Table 8 Acute and Chronic WQS Criterion for Total Ammonia at 20C, pH range 8 to 9

PH – standard units	Acute Criterion, mg/l - N	Chronic Criterion, mg/l - N
8.0	8.40	1.71
8.1	6.95	1.47
8.2	5.72	1.26
8.3	4.71	1.07
8.4	3.88	0.906
8.5	3.20	0.765
8.6	2.65	0.646
8.7	2.20	0.547
8.8	1.84	0.464
8.9	1.56	0.397
9.0	1.32	0.342

There is evidence that oxygen concentrations are sometimes below the water quality standard, especially during late summer and early fall runoff events. These episodes are likely to occur in conjunction with toxic ammonia levels resulting from runoff that contains manure and other materials. Both the ammonia and the animal waste organic matter exert an oxygen demand exceeding the stream's capacity to remain above the standard. As the ammonia is oxidized to nitrate and the organic matter decays through microbial processes, oxygen is consumed faster than it can be replenished through re-aeration and algal primary production.

The Iowa Water Quality Standards require that streams classified B(WW-2) meet the DO criteria shown in Table 9. These criteria apply to the impaired segment of the NFMR since it is classified B(WW-2).

Table 9. Criteria for Dissolved Oxygen

Stream Designated Use	B(WW-2)
Minimum value for at least 16 hours of every 24-hour period	5.0
Minimum value at any time during every 24-hour period	4.0

Potential Pollution Sources

Point Sources: There are three NPDES permitted point sources in the North Fork Maquoketa River watershed. These are wastewater treatment plants (wwtp) for the Cities of Luxemburg, Holy Cross, and New Vienna shown in Table 10. The New Vienna wwtp was recently (summer 2006) upgraded to a continuous discharge aerated lagoon.

Table 10. Waste Water Treatment Plants (WWTPs) in the NFMR watershed.

Muncipality	**Luxemburg**	**Holy Cross**	**New Vienna**
IA NPDES #	3158001	3146001	3165001
EPA #	IA0074781	IA0025992	IA0027391
Treatment type	Facultative lagoon[1]	Facultative lagoon[1]	Aerated lagoon[2]
CBOD5[3]	25 mg/l (30-day avg)	25 mg/l (30-day avg)	25 mg/l (30-day avg)
TSS [3]	80 mg/l (30-d avg)	80 mg/l (30-d avg)	80 mg/l (30-d avg)
pH[3]	6.0 to 9.0	6.0 to 9.0	6.0 to 9.0
ADW / AWW[4]	0.075	0.054	0.0278 / 0.0416
Population	331	587	428

1. Facultative lagoons are controlled discharge treatment facilities that provide 180 days of wastewater storage.
2. Aerated lagoons are continuous discharge treatment facilities.
3. These are the NPDES permit limits for these facilities for CBOD5, TSS, and pH.
4. These are the average permit flow limits for the facilities. AWW is 180-day average wet weather flow for the two controlled discharge lagoons. For the New Vienna wwtp where the discharge is continuous, the AWW flow is the 30-day average wet weather flow and ADW is the 30-day average dry weather flow ADW flow is not a consideration for controlled discharge facilities.

The two controlled discharge facilities discharge only in the spring and fall when stream flows are high and not during the design period when base flow conditions prevail, mid to late summer. Therefore, the loads from these two sources are not included in the TMDL. The continuous discharge loads from the New Vienna plant are included in the TMDL analysis and a wasteload allocation for the existing phosphorous load developed. These wastewater treatment plants do not significantly contribute to the delivered sediment load.

Non Point Sources

The potential non-point sources for nutrients, sediment, and ammonia are failed on-site septic tank treatment systems, agricultural activities that add to erosion and nutrient loading, wildlife, and runoff from built-up areas.

Some nonpoint sources in the watershed that add sediment and nutrients to the North Fork Maquoketa River are:

- Cattle in streams may deposit nutrient-rich fecal material directly to the stream and can cause bank erosion releasing sediment attached phosphorus.
- Land in agricultural production can contribute phosphorous through the use of fertilizer and land-applied manure that is delivered to streams in runoff or groundwater.
- Soil erosion from precipitation events.
- Habitat alterations like channelization and removal of riparian vegetation can increase in-stream erosion and sediment delivery from the watershed.
- Runoff from open feedlots that do not have adequate manure management or containment.

Natural Background Conditions

Background conditions are not separated from existing monitored conditions. Potential phosphorus contributions from groundwater influx have not been separated from the total nonpoint source load.

3.2 Sediment TMDL

3.2.1 Sediment TMDL Target

To meet the biological target, a sediment target has been established. Excessive fine sediments reduce the availability of favorable spawning sites for fish and buries desirable habitat for benthic macroinvertebrates, thus reducing BMIBI and FIBI scores. Reducing sediment delivery in the NFMR will improve BMIBI and FIBI scores by reducing streambed silt, reducing the embeddedness in riffle coarse substrates, increasing the size and quality of riffle and pool habitat, and reducing suspended solids and turbidity.

Modeling and Conceptual Approach

The approach used to determine existing and target sediment loads to the NFMR uses the percentage difference between the reference and measured NFMR BMIBI and FIBI scores as the percent reduction needed to attain the target. The existing delivered sediment load was estimated using two different IDNR erosion models to estimate the sediment loads from the watershed. The first model, based on the Revised Universal Soil Loss Equation (RUSLE) and incorporating IDNR ArcView coverages for data, provides long-term average annual sediment loads.

The second model is the Modified Universal Soil Loss Equation (MUSLE) that also uses IDNR ArcView coverages for data but provides erosion output estimates for a single storm event of a selected intensity and duration. The selected storm for the MUSLE modeling was a 2-year return and 24 hour duration event that in this region is a 3-inch rainfall over 24 hours. In sediment erosion estimations, the 2-year return 24-hour event is considered to be the maximum daily load.

The RUSLE model estimates soil erosion rates based on long-term annual averages. The estimated sheet and rill erosion rate in the watershed is 13.21 tons per acre per year, or 373,335 tons per year. The NRCS Erosion and Sediment Delivery procedure estimates the sheet and rill erosion sediment delivery ratio is 18.7%. The estimated sediment delivered to the stream is 69,963 tons per year, as being delivered to the stream. Gully and bed and bank erosion contribute additional sediment to the stream that is estimated to be 25% of the delivered sheet and rill erosion (reference 8). With this additional sediment load the total delivered sediment load is estimated to be 69,963 + 0.25(69,963) = 87,454 tons per year.

The MUSLE model estimates the delivered erosion from the single 2-year return 3-inch event to be 51,000 tons using the following assumptions:

- 2002 IDNR land cover
- No conservation practices (USLE P factor = 1)
- Antecedent moisture conditions set to "average"
- Iowan Surface ecoregion (model only allows one choice)

Waterbody Pollutant Loading Capacity

The target is based upon the biologic indicators. Reducing sediment will improve benthic conditions allowing aquatic species to survive and reproduce. Stream segments having FIBI or BMIBI scores below the 25th percentile of regional reference sites are considered impaired.

The critical metric for sedimentation for the North Fork Maquoketa River is the percent siltation of the streambed. The median percent siltation observed during the stream assessments from 2001 and 2005 for Site 28 was 39% and for Site 30 was 56%. The 75th percentile (upper 25th) bottom siltation for ecoregion 47c reference streams is 19% and the median is 9%. The Site 28 values have been selected as the targets since it is the downstream monitoring site and represents more of the watershed than do the Site 30 values.

The percent siltation in the streambed would need to be reduced from 39% to 9% coverage, a 77% reduction. Assuming a 1:1 relationship between percent silt in the stream and sedimentation, a delivered sediment reduction of 67,300 tons per year is required.

The loading capacity is the amount of silt that can be delivered to the river and still meet the BMIBI and FIBI scores of “fully supporting”. The allowable silt delivery to the North Fork Maquoketa River at the most downstream monitoring site in the impaired segment (Site 28) is 20,200 tons per year. Siltation reduced to this level will improve benthic habitat and allowing aquatic species to survive and reproduce similarly to those in ecoregion reference conditions. The load capacity is 20,200 tons of sediment per year.

3.2.3 Pollution Source Assessment

Existing Load

The existing sediment load was estimated using the RUSLE and NRCS Erosion and Sediment Delivery procedure and estimates for gully and streambank erosion. Existing delivery is approximately 69,963 tons per year or a delivered 365-day average of 192 tons per day. There is an additional load from gully and bed and bank erosion of 17,500 tons per year. The RUSLE sheet and rill erosion map developed using data collected in 2002 is shown in Figure A-3 of Appendix A.

The existing maximum day sediment load as estimated using the MUSLE model is 51,000 tons per day based on the erosion from a 2-year return 24-hour storm.

Departure from Load Capacity

The departure for the maximum daily load has been estimated based on the needed siltation reduction, i.e., 77%. The existing load of 51,000 tons per day would need to be reduced by 39,300 tons per day for the design storm. The load capacity is 11,700 tons per day.

Identification of Pollutant Sources

The sediment originates from sheet and rill erosion from agricultural land, stream banks, and gullies.

Linkage of Sources to Target

Including background sources of sediment, the sources of sediment are entirely from nonpoint sources. The estimated sheet and rill erosion from agricultural land using the RUSLE model and the NRCS Erosion and Sediment Delivery Procedure is 70,000 tons per year plus and an additional 17,500 tons per year for sediment from gully and bed and bank erosion. The delivered sediment load is linked to the biometric scores by the fraction of the NFMR stream bottom that is silted in compared to the siltation fraction for the reference conditions.

3.2.4 Pollutant Allocations

Wasteload Allocation

There are no point sources in the watershed that are significant sources of sediment and therefore there are no wasteload allocations for sediment.

Load Allocation

The sediment load allocation for the watershed of the impaired NFMR segment, has been set as both a long term annual average (from RUSLE modeling) and as a maximum daily load (MUSLE modeling of the two year return 24 hour duration). The load allocations are:

- Maximum daily load allocation = 11,730 tons per day
- Long term annual average load allocation= 20,200 tons per year

Margin of Safety

The margin of safety is provided by two conservative assumptions:

- Even though there are best management practices in the watershed that reduce delivered sediment to the stream, such as riparian buffer strips and sediment control basins, the RUSLE and MUSLE erosion modeling was done with the assumption that there are no installed BMPs.
- The median for the reference siltation conditions used as a target puts the goal well below the 75th percentile (upper 25th) of the percent siltation IQR.

3.3 Nutrient TMDL

3.3.1 TMDL Targets: Algae, Nutrient and Oxygen Demand

The stressor identification process for the impaired segment of the North Fork Maquoketa River found that excessive benthic algae and low dissolved oxygen were two of the primary stressors in the river. The excessive algae covering the bottom of the river has several negative effects on water quality that depress FIBI and BMIBI scores:

There are large diurnal fluctuations in dissolved oxygen concentration caused by the photosynthesis and respiration of the large quantities of benthic algae. In several recorded instances, DO has gone from 7 to 23 mg/l in less than 12 hours (August 24, 2005) at monitoring site 30. Dissolved oxygen saturation at 20C is 9.1 mg/l. A dissolved oxygen measurement of 23 mg/l is 2.5 times saturation, i.e., a very super-saturated condition. Data shows that there is an impact on FIBI and BMIBI scores when the daily amplitude of the minimum to the maximum DO exceeds 10 to 11 mg/l and when the nighttime DO minima is less than 5.5 mg/l. Very high DO concentrations can also be harmful to aquatic life. Abrupt changes in dissolved oxygen induce stress and subsequently make fish more susceptible to disease.

The filamentous algae growth crowds out other organisms causing a change in the benthic macroinvertebrate assemblage. This change in physical habitat causes a negative shift in community species by loss of interstitial space and alteration of available food resources. This propagates up the food chain to fish resulting in lower FIBI and BMIBI scores.

The targets for algae and associated dissolved oxygen concentrations are:

Target 1 is 200% of saturation concentration. Since the average concentration for the design day is 8.72 mg/l, the daily maximum DO for this TMDL is 17.4 mg/l.

Target 2 is maximum amplitude from daily low to high of 10 mg/l of dissolved oxygen.

Target 3 is a one third reduction in benthic algae and plants.

Target 4 is the Water Quality Standard dissolved oxygen value of 5.0 mg/l or higher for 16 hours a day and 4.0 mg/l daily minimum.

Target 5 is a BMIBI score greater than or equal to 59 and an FIBI score greater than or equal to 43 for non-riffle areas and 71 for riffle areas. This is the overall goal for this TMDL since this index was the tool used to assess the stream as impaired.

Modeling Approach – Linking Targets and Pollutants

The targets and existing conditions for this TMDL have been evaluated using monitoring data and the QUAL2K (Q2K) water quality model. The system hydrology was developed using data from two continuous stage/flow recorders located at sites 28 and 30 (see map) and GIS coverages, infrared aerial photography and 7.5 minute USGS topographic maps. The time of travel, velocity and depth were estimated using the manning equation within Q2K. The stream reaches are defined by the USGS map contour intervals and are shown in Figure A-1 in the Appendix. Figure 5 shows the layout and reference marker system for the modeled NFMR segment.

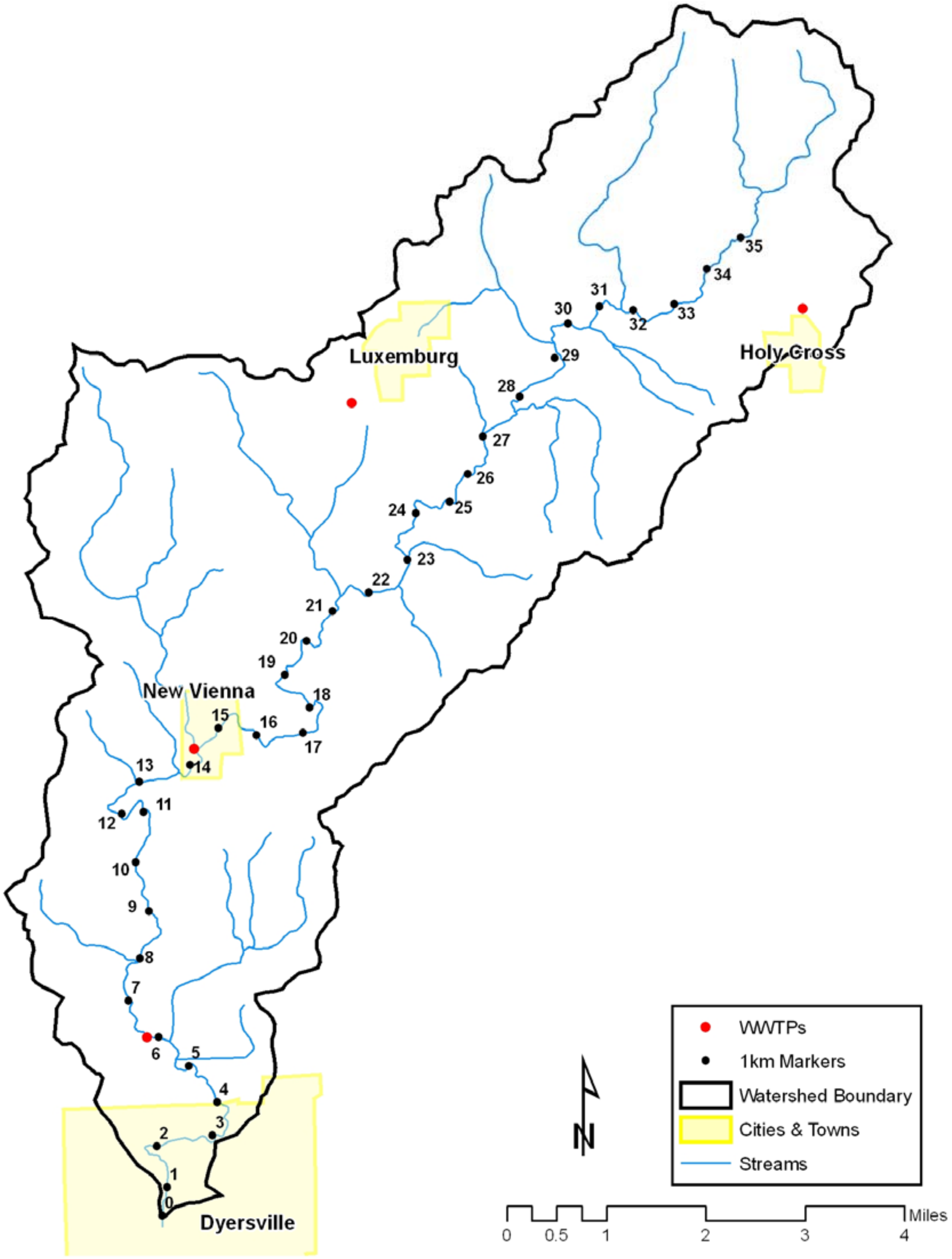


Figure 5 Kilometer reference markers for QUAL2K model

The data used to calibrate the model was continuous temperature and DO measurements (6 minute intervals) provided by data sondes installed at sites 28 and 30 from August 22 to August 29, 2005. The flow during this period was nearly constant at both sites; 3.8 cfs at site 30 and 6.9 cfs at site 28. This constant flow rate made the selection of Q2K a good choice since it is a static flow model.

The Q2K model was run for each 24-hour day (midnight to midnight) that had sonde temperature and DO data available. All variables were held constant except for cloud cover to adjust heat/light to the measured water temperature, sediment oxygen demand (SOD) to adjust to measured DO, and phosphorous to adjust algae biomass and DO. Figures 6 and 7 show the Q2K simulated values for temperature and DO plotted with the measured values for sites 28 and 30.

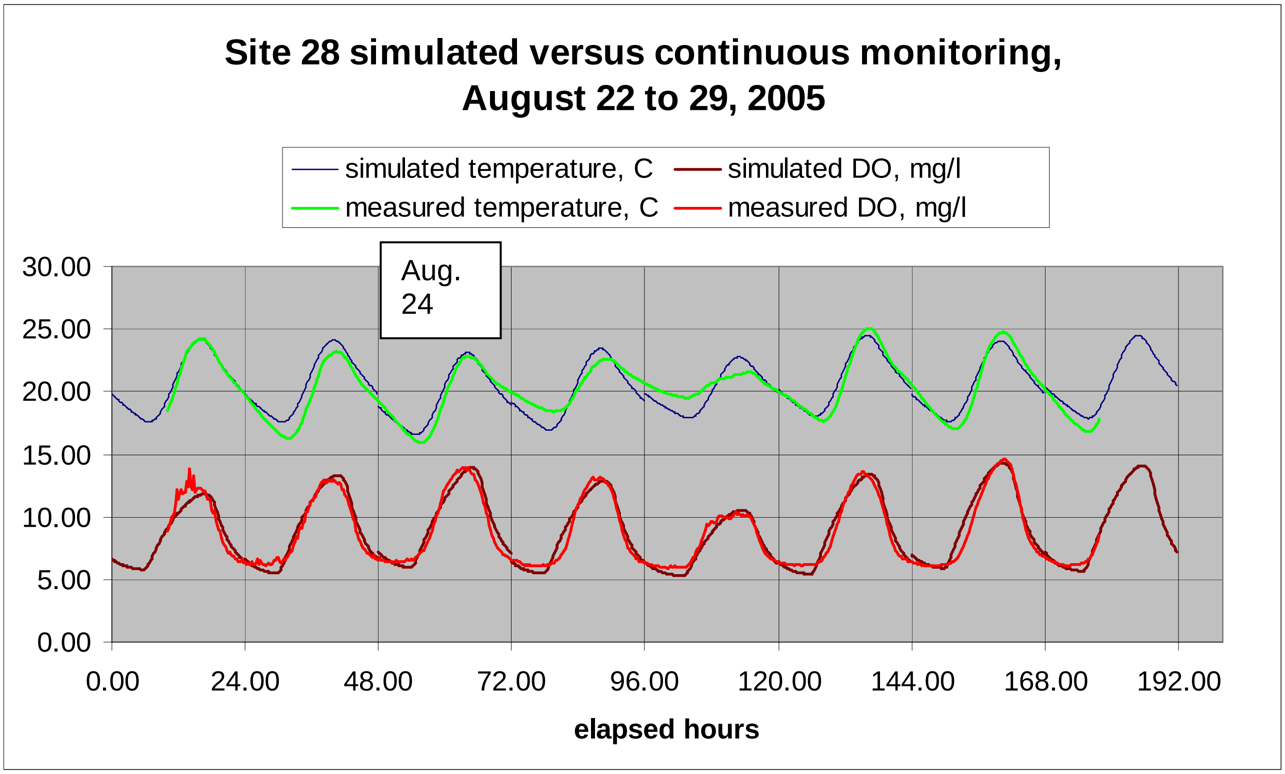


Figure 6 Simulated and measured temperature and DO for Site 28

Figures 6 and 7 also show the very high algal productivity at upstream Site 30 causing pronounced diurnal swings in DO and the less severe but still problematic DO amplitude at Site 28. These charts also show a minor rain event accompanied by a small streamflow increase that occurred August 26 and 27, 2005. This slight flow increase had surprisingly significant impact on DO causing it to decrease at all times of the day for Site 30 and to a lesser degree at Site 28 for peak DO. During the event the DO at Site 30 drops dramatically even dipping below 5 mg/l two nights in a row. This happens because the very supersaturated conditions that exist when it is sunny and the turbidity is lower disappear, reducing daytime photosynthetic oxygen production while the nighttime algal respiration continues depleting the already reduced DO inventory.

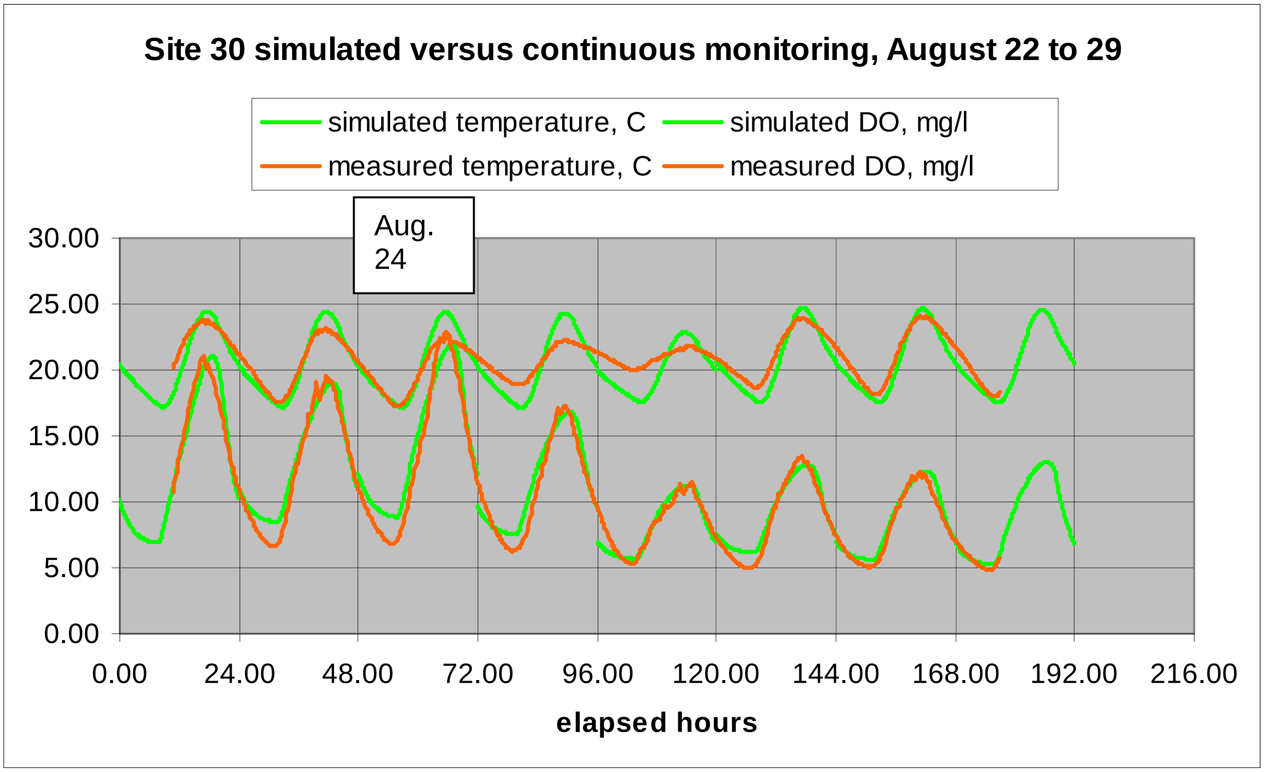


Figure 7 Simulated and measured temperature and DO for Site 30

The Q2K modeling has been performed to demonstrate the following circumstances related to the stream impairment:

- That the excessive mass of photosynthesizing benthic algae and plants creates a system that is overly sensitive to small perturbations and causes diurnal DO amplitudes that lower FIBI and BMIBI scores.
- That the excessive mass of algae and plants and photosynthesis associated DO amplitude can be decreased by a reduction in total phosphorous concentration.
- That chlorophyll (algae/plants) and DO can be estimated along the length of the North Fork Maquoketa for both existing and target conditions and the difference quantified.
- That the impact of a point source in the watershed, the recently constructed New Vienna wastewater treatment facility, can be estimated.
- That the impact from simulated episodic slug loads such as recent manure spills can be described and load reductions estimated.

Design Season and Conditions: After review of flow data and time of the year when an impairment is most likely, the SI shows that the stream is most sensitive to problems at the end of the summer when the algal and plant biomass is at its peak, the temperature is the highest, baseflow is generally the lowest and the risk from episodic loads is the greatest. The continuous sonde temperature and DO data collected in August 2005 is representative of these conditions and the date of August 24, 2005 has been selected as representative of the collected data and the design conditions.

Conceptual setup: The modeled segment of the North Fork Maquoketa runs from a point near the headwaters to Dyersville. It includes the entire impaired segment and consists of a single HUC 12 watershed. The stream model is 35.5 km long and the two monitoring sites, 28 and 30, are located at kilometers 5.42 and 18.40, respectively, going upstream from km zero in Dyersville. The model headwater flow at km 35.5 is based on the ratio of area to flow since there is not any monitoring data available for this location. The flow measured at Site 30 is incrementally added to the headwater flow from km 35.5 to km 18.40. The difference in measured flow between Site 30 downstream to Site 28 (3.11 cfs) is added incrementally from km 18.40 to km 5.42.

The August 24, 2005 diel data for Site 30 was used to establish the temperature and DO conditions upstream from the site to km 35.5 at the end of the modeled segment. The Site 30 values for phosphorous, SOD, and cloud cover for the segment from km 35.5 to km18.40 were then fixed for the August 24, 2005 Site 28 diel data calibration. Consequently, the Site 28 model runs included the results from the Site 30 calibration. This means that the longitudinal profile charts of the parameters and variables in the Site 28 model runs are calibrated for the data from both sites.

Waterbody Pollutant Loading Capacity: The loading capacity of the impaired segment of the North Fork Maquoketa River is the total phosphorous (TP) load that reduces excessive benthic algae and plants. The algae and plants create physical habitat and dissolved oxygen conditions that make significant contributions to depressed FIBI and BMIBI scores indicative of biological impairment.

3.3.2 Pollution Source Assessment

Existing Loads: The existing daily load for the NFMR is shown in Table 11. The existing loads have been distributed as the headwater load, the load from Site 30 upstream to the headwater (diffuse flow 1), the load from Site 28 upstream to Site 30 (diffuse flow 2), and the load from km marker zero in Dyersville upstream to Site 28 (diffuse flow 3). Figure A-4 in Appendix A shows the parts of the watershed drained by each of these model flows. The estimated daily TP load from the New Vienna wastewater treatment plant is also shown.

Table 11 Existing TP loads for the NFMR

Flow name	flow, L/d	TP existing conc., ug/l	TP existing load, lb/day
headwater	2,332,800	320	1.65
diffuse flow 1	6,972,480	540	8.30
diffuse flow 2	7,594,560	415	6.95
diffuse flow 3	3,170,880	415	2.90
total	20,070,720		19.80
New Vienna wwtp	129,600	4340[1]	1.24

1. Estimated from typical wwtp effluent (about 5 mg/l), no monitoring data available.

The chart shown in Figure 8 shows the modeled longitudinal profiles for daily maximum, mean, and minimum DO along the NFMR from the headwater to Dyersville. DO saturation is also shown.

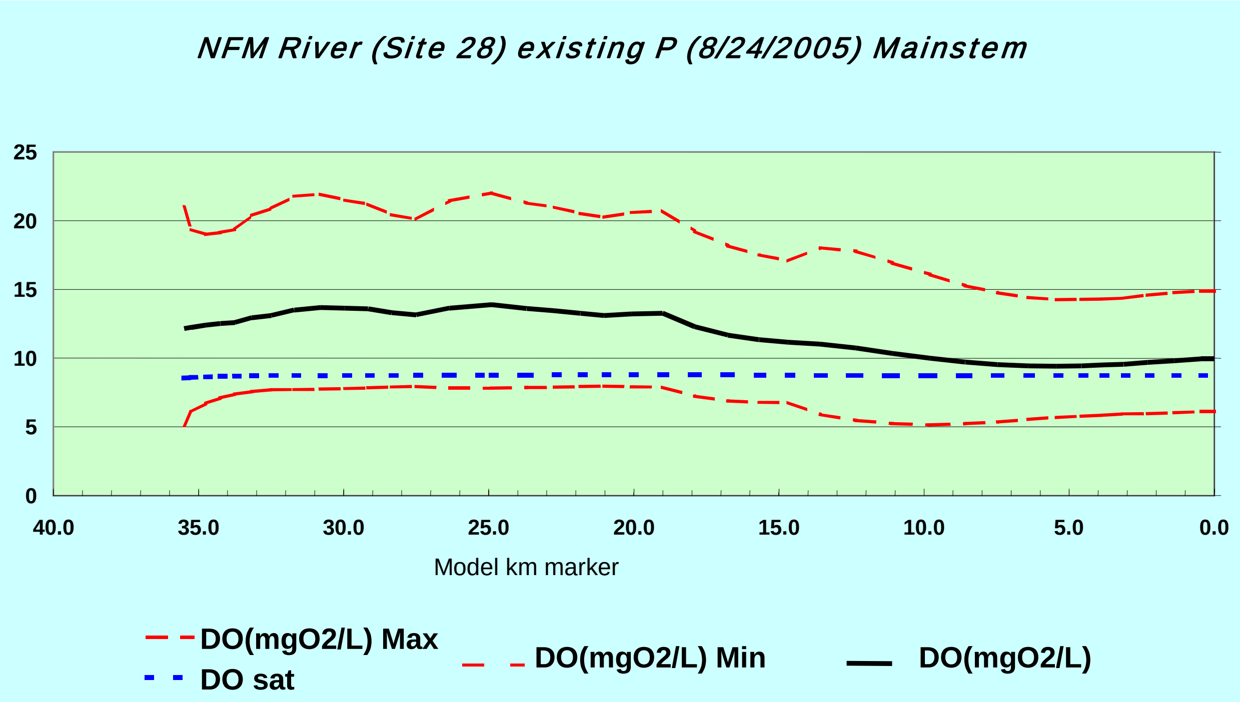


Figure 8 NFMR modeled longitudinal existing DO profile, length units are km

The important locations along the profile are:

- Headwater - 35.50 km
- Site 30 - 18.40 km
- New Vienna wwtp - 13.94 km
- Site 28 - 05.42 km
- Dyersville - 00.00 km

Figure 8 shows that for existing conditions:

- Maximum DO is well above saturation in the upper half of the stream and is 250 % of saturation upstream of Site 30 as shown by the maximum DO curve.
- The difference between max and min DO (amplitude) is greater than the target value of ten.
- The estimated load from the New Vienna wwtp treatment plant has a noticeable affect on the DO profile downstream from it.
- Going downstream the values for minimum DO decrease, dropping as low as 5.1 mg/l in the early morning as shown by the minimum DO curve in Figure 8 at km marker 10.

Figure 9 shows the modeled benthic algae corresponding to the DO in Figure 8. The algae are represented by the amount of benthic chlorophyll required to provide the oxygen production actually measured at Sites 30 and 28. The large mass of filamentous algae represented here affects benthic physical habitat and available food sources for other aquatic life depressing NFMR FIBI and BMIBI scores.

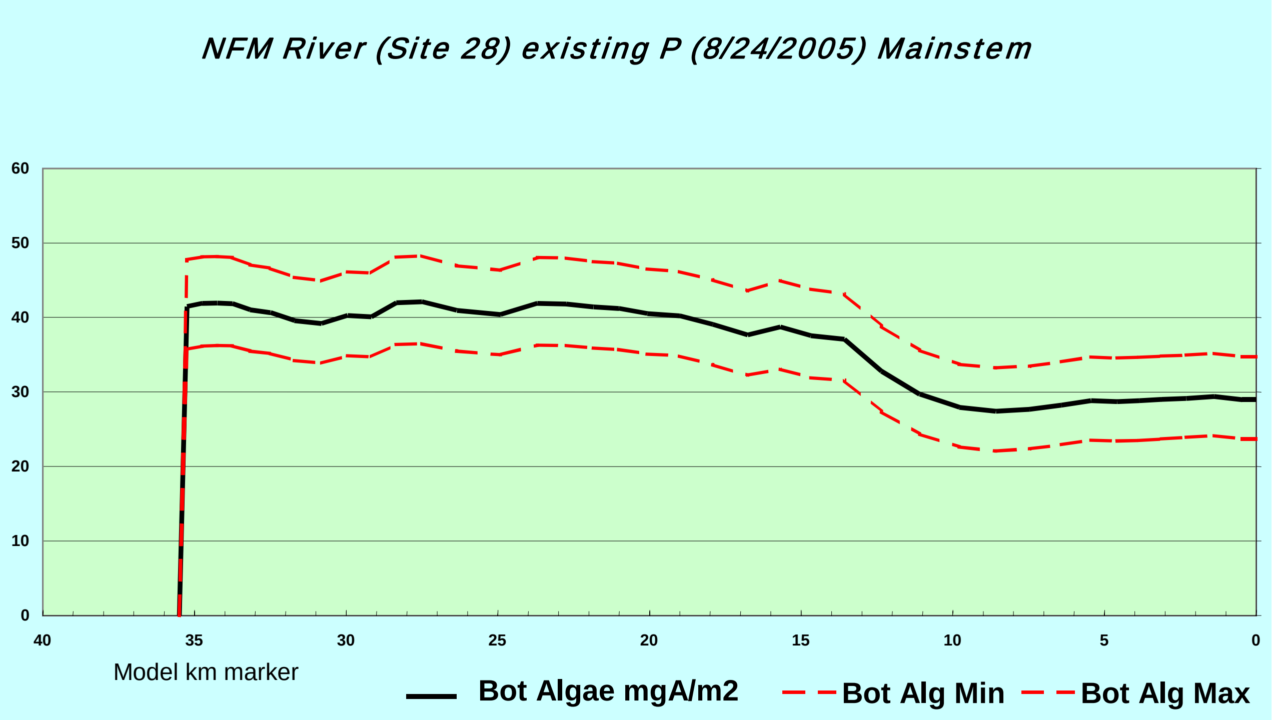


Figure 9 Modeled existing benthic algae longitudinal profile - as chlorophyll

Identification of Pollutant Sources

Most phosphorous is delivered to the stream from watershed non-point sources. Figure 10 shows the annual total phosphorous (TP) loads estimated by both the EPA and WILMS Export Loading Coefficients for the watershed landuses. It also shows the estimated TP from open feedlots estimated by the acres of feedlot in the watershed multiplied by an export coefficient for this use. As can be seen, most nonpoint source TP is from row crop landuses and open feedlot runoff. Besides row crop uses and other agriculturally related TP sources there are septic tank systems, and wildlife and pet feces. These are relatively small contributors with less impact than agricultural loads.

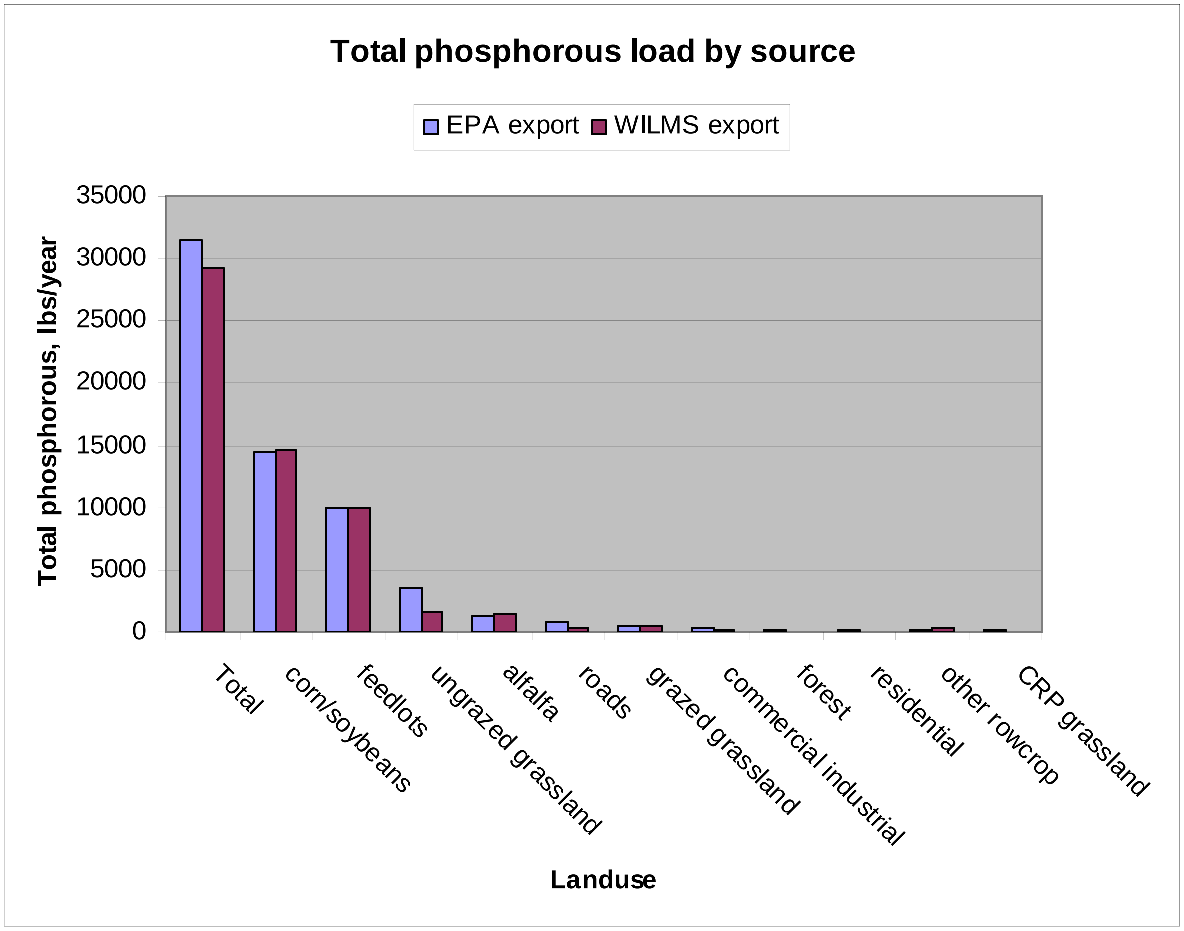


Figure 10 Total phosphorous sources by landuse and export coefficients

Departure from Load Capacity

The Q2K model was repeatedly run with all variables except for phosphorous held constant from the model runs used to calibrate to existing conditions. Phosphorous was reduced until the daily DO amplitude was less than 10 mg/l, the minimum night-time DO was 5.5 mg/l, and the algae/plant chlorophyll was reduced by one-third along the modeled NFMR segment. The results from this modeling are shown in Figures 11 and 12.

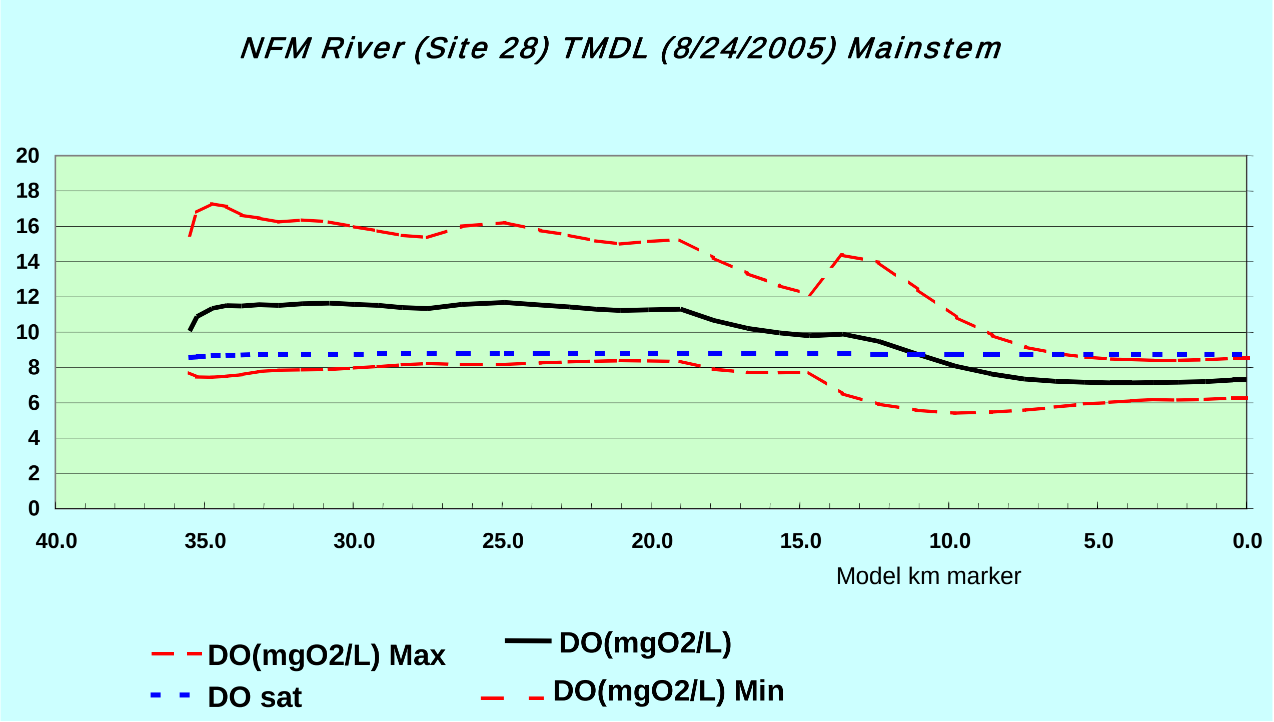


Figure 11 NFMR modeled longitudinal <u>target</u> DO profile; length units are km

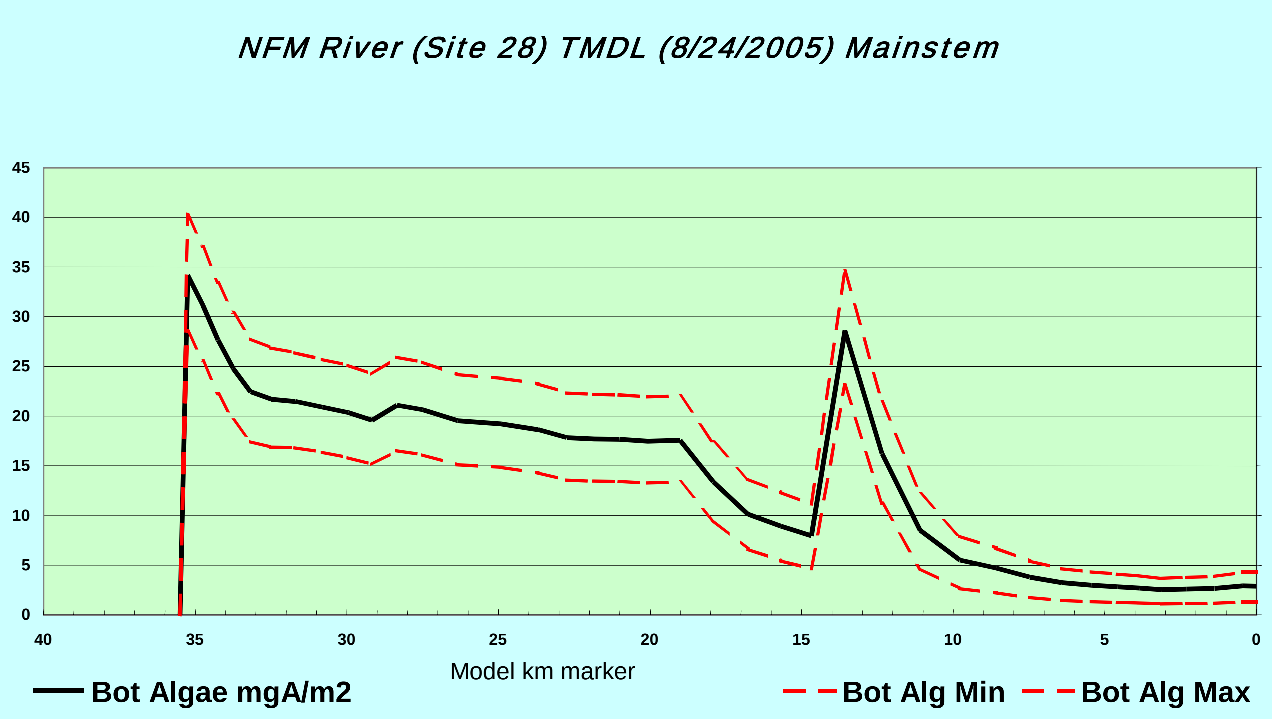


Figure 12 Modeled <u>target</u> benthic algae longitudinal profile - as chlorophyll

The target daily load for the NFMR is shown in Table 12. As with the existing loads in Table 11, the target loads have been distributed as the headwater load, the load from Site 30 upstream to the headwater (diffuse flow 1), the load from Site 28 upstream to Site 30 (diffuse flow 2), and the load from km zero in Dyersville upstream to Site 28 (diffuse flow 3). The last column in this table shows the difference between the existing phosphorous load and the target phosphorous load in pounds per day for the modeled sub-segments as well as the total for the entire HUC 12 watershed.

Table 12 Target TP loads for the NFMR

Flow name	Flow, L/d	TP target conc., ug/l	TP target load, lb/day	TP departure from capacity, lb/day[1]
headwater	2,332,800	100	0.51	1.13
diffuse flow 1	6,972,480	125	1.92	6.38
diffuse flow 2	7,594,560	125	2.09	4.86
diffuse flow 3	3,170,880	125	0.87	2.03
New Vienna wwtp	129,000	NA	1.24	0.0
Watershed total	20,070,720	NA	6.64	14.40

1. This is the mass phosphorous reduction needed to achieve the TMDL targets for daily DO amplitude, DO minimum, and decreased benthic algal mass.

3.3.3 Pollutant Allocations

Wasteload Allocations

The New Vienna wwtp is the only permitted point source in the watershed that discharges continuously to the NFMR. To evaluate the downstream impact of the wwtp TP loads the Q2K model was run both with and without estimated plant loads for both existing and target stream conditions. The daily peak and minimum DO concentrations were estimated 2 km downstream of the wastewater treatment plant discharge (model km marker 11.74). Table 13 shows the modeled impact of the wwtp TP load for existing and target conditions.

Table 13 New Vienna wwtp TP impacts on downstream DO amplitude

Model Output Condition and Figure Number	**NV wwtp TP load as a % of the total**	**Peak DO, mg/l**	**Minimum DO, mg/l**	**24 hour DO amplitude, mg/l, (target = 10 mg/l)**
Existing conditions, Figures 8 and 9	1.24 lb/day, 6% of load	16.95	5.23	11.72
Target conditions, with wwtp TP load, Figures 11 and 12	1,24 lb/day, 18% of load	12.38	5.58	6.80
Target conditions without wwtp TP loads, Figures 13 and 14	NA	11.37	7.87	3.50

The DO amplitude target is 10 mg/l and it is exceeded at this location in existing conditions but not at target conditions either with or without the wwtp load. For bottom algae the target is a one third reduction. The modeled algae reduction at the 2 km downstream location is over 50% from existing conditions to the target conditions with existing wwtp loads. Also, the estimated wwtp TP load is only 6% of the total watershed load (total load = 21.04 lb/day) and was estimated as the potential maximum that could be discharged from the wwtp, i.e., it was conservatively assumed that there would be no TP removal in the treatment process.

There are not any monitoring records for phosphorous from the old New Vienna trickling filter plant or for the aerated lagoon that recently replaced it in 2006. The TP loads have been estimated from typical per capita values as well as typical effluent concentrations from wastewater treatment plants. Most phosphorous discharged in plant effluent is soluble (inorganic in the model) and it has been assumed that the soluble fraction is 80%. The plant phosphorous calculation is as follows:

Effluent TP per capita = 1.5 gram/day
Population = 376
Total daily load = 564 grams/d = 1.24 lb/day
Daily plant flow = 34,400 gal/d = 130,000 l/d
Effluent concentration = 4.34 mg TP/L

The assumed phosphorous effluent concentration for the Q2K modeling is 5 mg/l with 4 mg/l as soluble (inorganic in the model) and 1 mg/l as particulate (organic in the model) phosphorous. The modeling charts showing the differences between existing DO and algae conditions and target DO and algae conditions demonstrate that the impact from wwtp loads for existing conditions is minimal due to the high NPS loads but that it is much more apparent with the reduced target loads.

The wwtp effluent total phosphorous will need to be monitored to establish the actual daily load. The total phosphorous WLA for the New Vienna wastewater treatment plant is based on the existing estimated average daily load. It is 564 grams/d (1.24 lb/d) or the monitored daily load when this data becomes available.

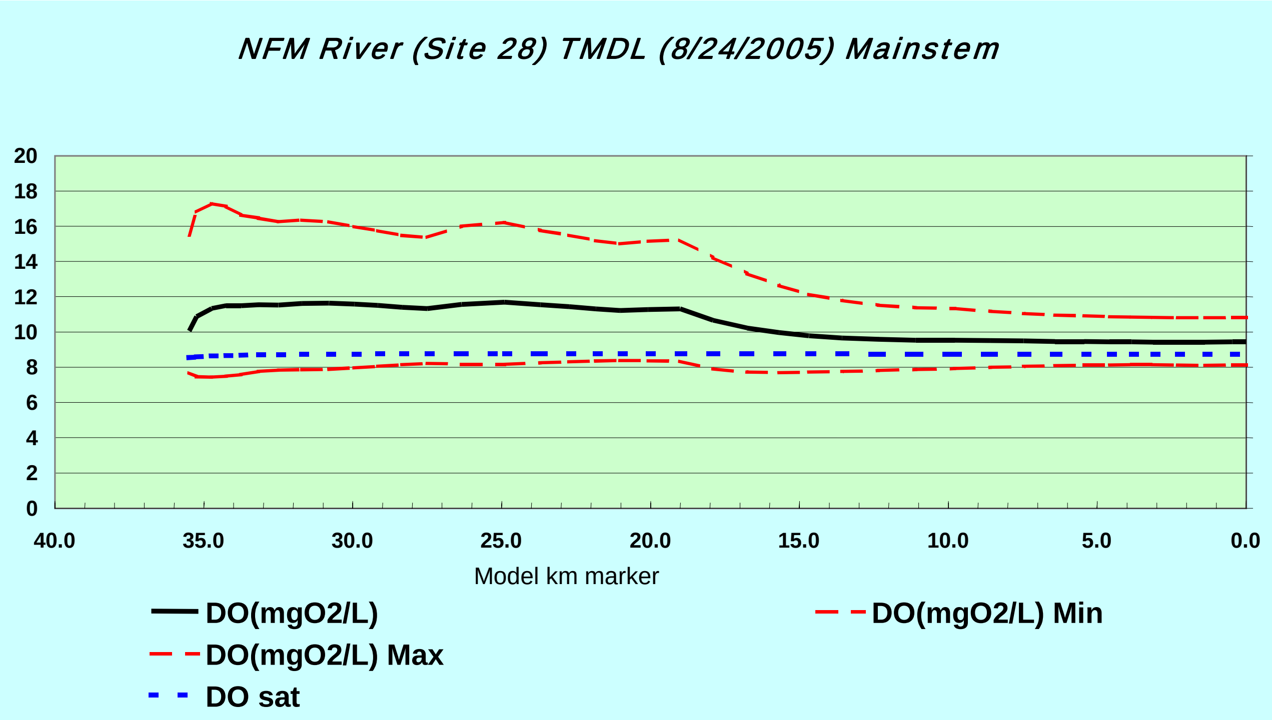


Figure 13 Modeled longitudinal <u>target</u> DO profile without the New Vienna wwtp

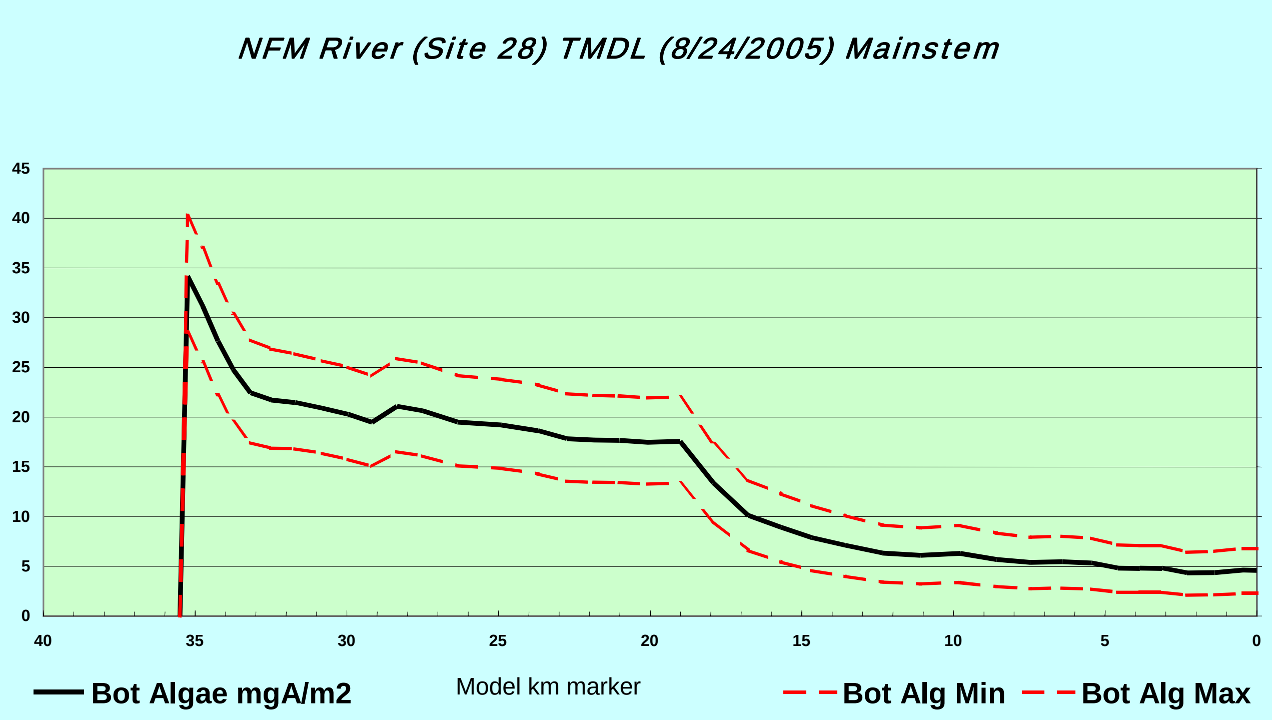


Figure 14 Modeled <u>target</u> benthic algae longitudinal profile <u>without</u> the NV wwtp

Load Allocations

The non-point source phosphorous load allocations for this TMDL, shown in Table 13, are the target loads from Table 12.

Table 14 NFMR Phosphorous Load Allocations

Flow/Load Name	Non-Point Source Load Allocations, pounds/day
headwater	0.51
diffuse flow 1	1.92
diffuse flow 2	2.09
diffuse flow 3	0.87
Watershed total	5.40

Margin of Safety

The margin of safety for this nutrient TMDL is implicit in that conservative assumptions have been made throughout the Q2K modeling and that the modeled values for the load allocations produce DO and algae estimates that are at least 10% lower than the target values.

3.2.4 TMDL Equation - Total Phosphorous

TMDL = LA + WLA + MOS = 5.40 lb/d + 1.24 lb/d = 6.64 lb/d Total Phosphorous

3.2.5 Reasonable Assurance

Reasonable assurance means a demonstration that the wasteload and load allocations will be realized through regulatory or voluntary actions. For waterbodies impaired by both point and non-point sources, such as the impaired segment of the NFMR that these TMDLs have been developed for, wasteload allocations may reflect anticipated or expected reductions of total phosphorous from other sources if those anticipated or expected reductions are supported by a reasonable assurance that they will occur (CFR 40-130.2g).

The TMDL wasteload allocation for the NPDES permitted point source in the NFMR watershed is set to the existing total phosphorous discharge and says that the new facility should begin monitoring effluent total phosphorous to determine the actual impact on the NFMR. This wasteload allocation will be implemented through the Iowa NPDES permitting procedure following rules in the Iowa Administrative Code (567-64). Further TP reductions below the wasteload allocations in this document cannot improve NFMR ability to comply with the water quality standards.

Reasonable assurance for non-point sources will be accomplished through methods and projects that reduce the impacts of row crop and livestock as described in the Section 4 Implementation Plan.

3.4 Ammonia TMDL

3.4.1 TMDL Target

The stressor identification process for the impaired segment of the North Fork Maquoketa River found that excessive ammonia causing toxic conditions for fish and a depleted dissolved oxygen condition was a primary stressor in the river that depresses FIBI scores. The targets for ammonia toxicity and dissolved oxygen concentration are those found in the Iowa water quality standards described in Section 3.1 and listed in Tables 8 and 9. Because of the episodic nature of the discharges that caused these fish kills, the total ammonia target for this pollutant is the acute criterion (at pH=9.0 and temperature = 20C) of 1.32 mg/l. The target for dissolved oxygen is the WQS minimum of 4.0 mg/l where the oxygen sag from the slug load is lowest, at model km marker 11.

Modeling and Conceptual Approach

Manure spills from storage facilities and runoff from open feedlots and fields have been identified as some of the biggest water quality issues in the NFMR watershed. There have been several instances in which there were severe violations of the water quality standards, generally for ammonia toxicity, caused by spills and runoff that led to fish kills. State and federal programs that regulate manure application and open feedlots are meant to alleviate these problems. Spills and runoff that cause fish kills can lead to enforcement and fines. The following approach is not meant to suggest that spills and runoff are acceptable conditions, but to define loads that would not necessarily cause impairments and to show that these non-violating loads are quite low, much lower than for an actual manure spill or runoff incident.

The approach used to establish existing conditions and the ammonia concentration that would not cause a violation of the acute WQS was to simulate a spill in the NFMR with high concentrations of ammonia and BOD. To do this, the Q2K model developed for the nutrient TMDL oxygen dynamics simulation was used in conjunction with an ammonia slug load discharge to the stream at model km marker 20. The simulated discharge flow would be equivalent to the runoff from a quarter acre in a 2-year return 24-hour rain (3 inches). The total ammonia concentration in the discharge was set at 45 mg/l, about the same as in untreated wastewater. Since there would also be an organic heterotrophic oxygen demand in the runoff, a CBOD concentration of 100 mg/l was also included in the slug load. The organic load was reduced to 25 mg/l CBOD to calculate the ammonia concentration that does not violate the acute WQS.

To obtain the maximum daily load, the ammonia concentration in the discharge to the stream was reduced in model runs until it was at least 10% less than the WQS acute criterion of 1.32 mg/l along the entire length of the stream below the discharge. Ten percent is the margin of safety. The 45-mg/l total ammonia concentration was reduced in the simulation to 10 mg/l. At this discharge concentration, the total ammonia was low enough and the DO concentration was high enough to meet the water quality standards along the impaired segment downstream of the discharge. The model results and the WQS targets are shown in Figures 15 and 17 for total ammonia and dissolved oxygen.

Figure 15 shows the results of modeling these two discharges for the length of the impaired segment and compares them to the acute and chronic WQS values at a pH of 9.0 and a temperature of 20C. Ammonia also causes an oxygen demand through the process of nitrification. Figure 16 shows the DO along the length of the impaired segment. From this model output it can be seen that the lowest point of the downstream oxygen sag is at Model km marker 11. The modeled 24 hour simulation at the km marker 11 DO sag low point is shown in Figure 17 for both the 45 mg/l and the 10 mg/l concentrations used to generate the ammonia slug loads.

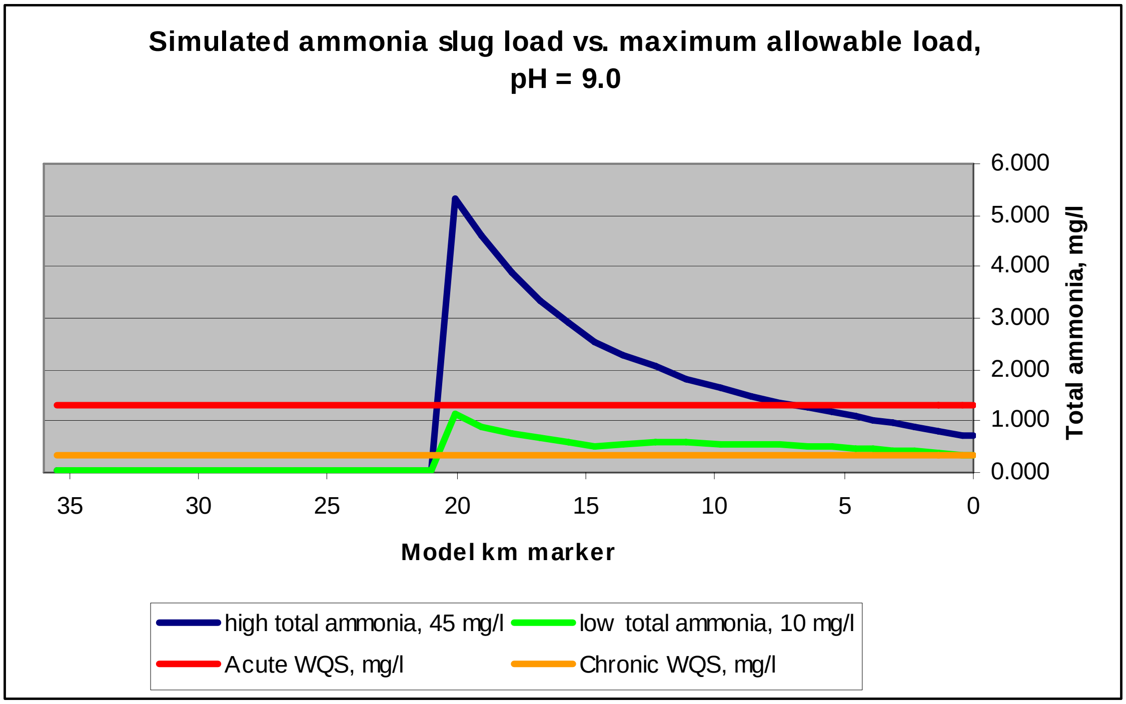


Figure 15 Simulated ammonia slug discharge at Model km marker 20

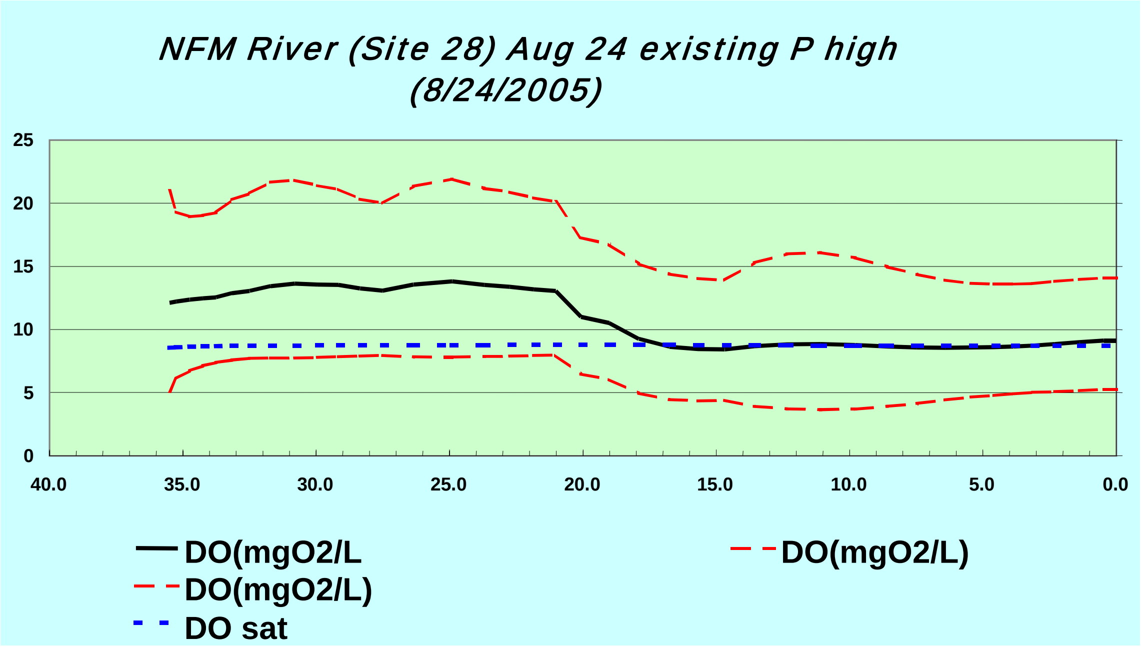


Figure 16 DO profile for simulated ammonia slug discharge at Model km marker 20

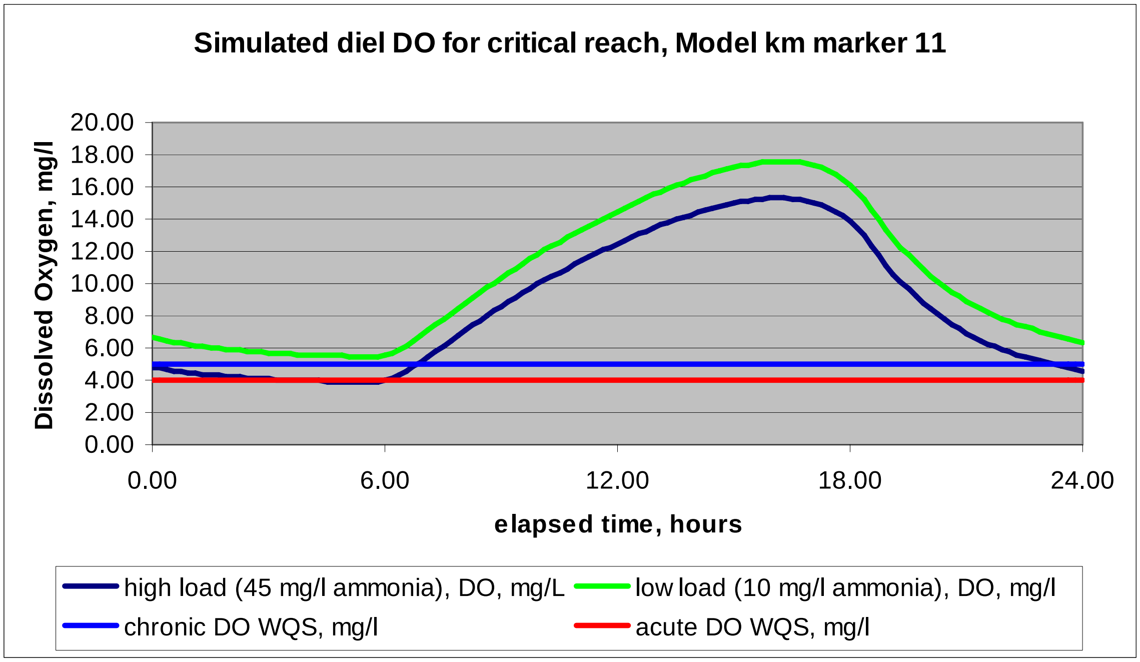


Figure 17 Diel DO cross-section at the oxygen sag low point, Model km marker 11 (See Figure 16).

For a high ammonia slug load, Figure 17 shows that the DO concentration dips below the 4.0 mg/l WQS criterion in the early AM and then rises quickly with algal productivity. When the ammonia concentration is reduced to 10 mg/l, the DO remains above 5.0 mg/l at all times of the day, well above all WQS DO criteria.

Waterbody Pollutant Loading Capacity

The ammonia toxicity loading capacity of the NFMR is defined by the table of ammonia concentrations and pH in the water quality standards (Table 8) for a given stream flow or volume. The oxygen demand loading capacity is defined by the minimums in the water quality standards (Table 9).

3.4.2 Pollution Source Assessment

The slug discharges that have caused reported fish kills in the impaired segment of the NFMR have been from manure related runoff or fertilizer spills in the middle third of the stream. There are at least 66 open feedlots of varying size in the watershed, some on sloping ground, near NFMR tributaries, and with minimal containment.

Existing Load

The existing load is that from the slug of ammonia in the simulated spill. The simulated ammonia concentration is 45 mg/l at a 24-hour flow of 23,000 gpd (10 l/s). The total daily load from this flow and concentration is 9 lb ammonia/day. Figure 18 shows the impact of the simulated ammonia load on the NFMR for the design model conditions. As can be seen, the total ammonia concentration immediately peaks and then gradually drops downstream from the point of discharge.

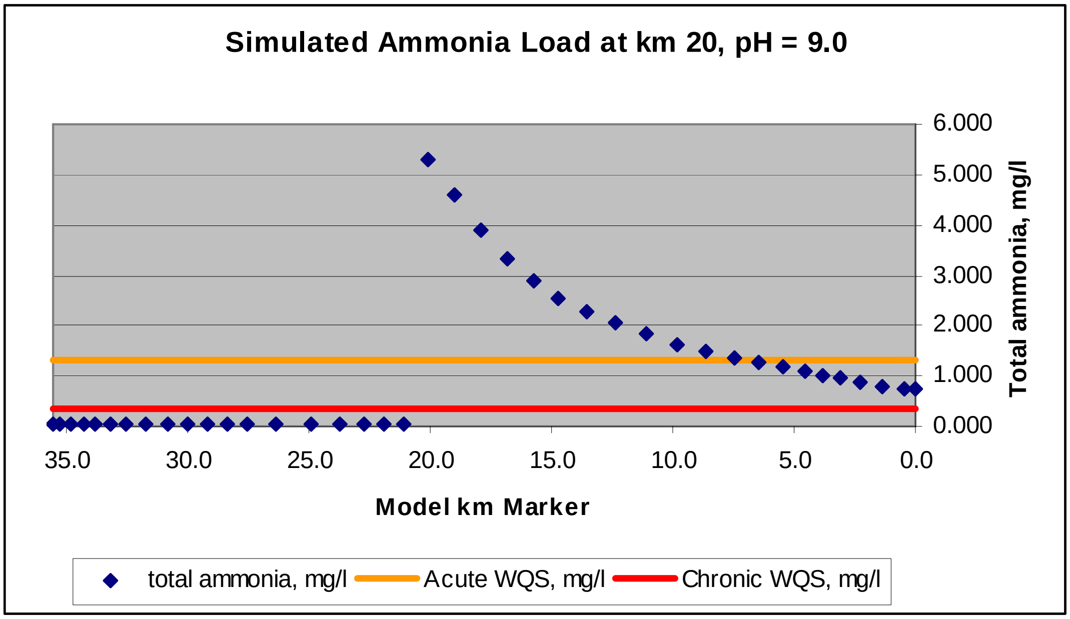


Figure 18 Simulated Ammonia Slug Load, "Existing Conditions"

Departure from Loading Capacity

The total ammonia load capacity for the impaired NFMR segment is the load that does not cause a condition that exceeds the acute WQS for the simulated design conditions. Figure 19 shows the simulated total ammonia concentration along the length in the stream when the discharge concentration is 10 mg/l. The departure from loading capacity is the difference between the loads at the 45 and the 10-mg/l ammonia concentrations calculated as a mass/day for the 23,000-gpd discharges, i.e., 8.63 - 1.92 = 6.71 pounds total ammonia per day.

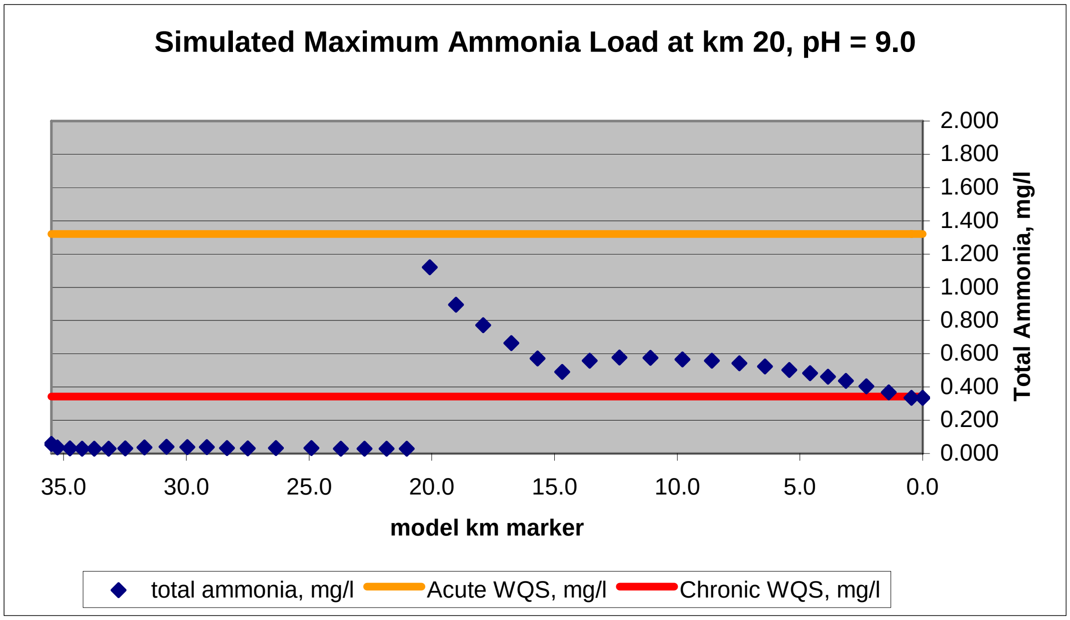


Figure 19 Simulated Ammonia Load reduced to meet acute total ammonia WQS

3.4.3 Pollutant Allocations

Wasteload Allocation
There are no point sources in the watershed that are significant sources of episodic slug ammonia discharges and, therefore, there are no wasteload allocations for episodic slug ammonia loads.

Load Allocation
The load allocation for ammonia is the slug ammonia load that will meet the water quality standard numeric limits for ammonia toxicity and dissolved oxygen along the entire length of the impaired segment of the NFMR. For the simulated discharge of 23,000 gallons per day to the stream the load allocation would be for a concentration of 10-mg/l total ammonia or a daily load of 1.9 pounds of ammonia.

Margin of Safety
The margin of safety for slug ammonia loads to the impaired segment of the NFMR is an explicit ten percent of the WQS acute criterion for total ammonia at pH = 9.0 and temperature = 20C. The criterion is 1.32 mg/l and 10% MOS is 0.13 mg/l.

4. Implementation Plan

The following implementation plan is not a required component of a Total Maximum Daily Load but provides department staff, partners, and watershed stakeholders with a framework for improving NFMR water quality. Currently there is an EPA funded assessment project called the Upper North Fork Maquoketa River Watershed Comprehensive Plan, headed by the Limestone Bluffs RC & D, that includes the impaired segment covered by these TMDLs.

The stressor identification process for the impaired segment of the North Fork Maquoketa River identified three pollutants and associated stream conditions as the causes of the biological impairments. The three pollutants are streambed silt, high phosphorous concentrations that cause excessive algae growth, and ammonia concentrations that are toxic to aquatic life and cause dissolved oxygen depletion. The associated conditions are suspended solids, embeddedness of coarse streambed materials, large diurnal DO amplitude caused by excessive bottom algae, and episodic fish kills. Reducing the loads from these three pollutants will improve the biological condition of the stream.

The reductions in watershed loads of both sediment and phosphorus will require land management changes that take time to implement. Reducing erosion would also significantly reduce total phosphorous.

A detailed field assessment of the NFMR watershed that would identify and locate existing erosion controls has not yet been performed. Therefore, the erosion modeling shown in Appendix A, Figure A-3, does not include controls that may already be in place. Nonetheless, the Figure A-3 sediment delivery map does show the areas where the potential for sediment delivery is the greatest. These are also the locations where erosion controls would have the most impact if they have not already been constructed.

Funding is needed for administration and producer implementation. A program of no-till plus nitrogen, phosphorous and manure management coupled with sediment management may very well be needed. This will require farm operator education, involvement and funding. Therefore, the watershed may need to be designated a priority watershed by the Soil and Water Conservation District. Funding for manure storage and other feedlot runoff controls may also be needed as a priority in the watershed.

If erosion reduction goals are to be realized, specific objectives and a schedule to reach them can provide a framework for understanding the nature and extent of the erosion management problem. Below is a basic example of a timetable and long-term annual average erosion reduction targets:

- The current loading of sediment is 87,500 tons per year.
- Reduce loading of sediment to 65,000 tons per year by 2015, a reduction of 25% from the current load estimate.
- Reduce loading of sediment to 42,500 tons per year by 2020, a reduction of 35% from the year 2015 load estimate.
- Reduce loading of sediment to 20,200 tons per year by 2025 a reduction of 52% from the year 2020 load estimate.

The reduction to 20,200 tons per year, the TMDL target, is a total decrease of 77% from the current average annual loading of 87,500 tons per year.

4.1 Sediment

Channel erosion: Channel erosion has been identified as a sediment source. Areas of severe channel erosion should be identified and targeted for restoration activities. Suggested controls are:

- Installation of structures to reduce peak flows during runoff events.

- Exclusion of livestock from the stream to increase bed and bank stability.
- Installation of stream bank protection measures such as vegetation and graded rock.
- Stabilization of stream banks by shaping and removing overhangs unless there are indications that the bank has been stabilized by dense tree or sod root systems.

Overland sheet and rill erosion: Erosion control activities, including the maintenance of installed structures, need to continue in the watershed. The watershed should be periodically evaluated and erosion control activities focused on identified and targeted sediment contributors. Suggested controls are:

- Agricultural management practices such as no-till farming that will increase crop residue.
- Construction of terraces and grassed waterways.
- Installation of riparian buffers along stream corridors.
- Construction of grade stabilization structures.
- Implementation and enforcement of erosion control measures at development sites.

4.2 Nutrients

Best management practices to reduce nutrient delivery, particularly phosphorus, should be emphasized in the NFMR watershed. Many of these practices involve erosion control and would be applicable for sediment reduction as well. For agricultural land uses, these practices include the following:

- Nutrient management on production agriculture ground to achieve the optimum soil test category. This soil test category is the most profitable for producers to sustain in the long term.
- Incorporate or subsurface apply phosphorus (manure and commercial fertilizer) while controlling soil erosion. Incorporation will physically separate the phosphorus from surface runoff.
- Continue encouraging the adoption of reduced tillage systems, specifically no till and strip tillage.
- Initiate an incentive program for fall-seeded cover such as hairy vetch or fall rye. The incentives should be directed at fields with low residue producing crops such as soybeans or low residue crops after harvest such as corn silage fields. This practice increases residue cover on the soil surface and improves water infiltration.
- Fencing of livestock from the stream, alternative water sources, and buffer strips along the stream corridor.
- Improvements in manure containment and management for open feedlots.

Best Management Practices (BMPs) for controlling nutrient delivery associated with residential and commercial runoff are also important. These practices include:

- Addition of landscape diversity to reduce runoff volume and/or velocity through the strategic location of filter strips, rain gardens, swales, and grass waterways.

- Installation of terraces, ponds, or other erosion and water control structures at appropriate locations within the watershed to control erosion and reduce delivery of sediment and phosphorus to the stream.
- Use of low or no-phosphorus fertilizers on residential and commercial lawns.
- Use of appropriate erosion controls on construction sites to reduce delivery of sediment and phosphorus to the stream.

4.3 Episodic Ammonia Toxicity

As previously noted in this report, accidental manure spills from storage facilities and open feedlots and precipitation event runoff from manure applied to fields and from open feedlots have caused water quality violations. These violations have led to fish kills (see Figure 4) in the impaired segment of the NFMR. The most immediate threat to aquatic life from a spill or runoff to the stream is from un-ionized ammonia followed by oxygen demand.

Preventing accidental spills from stored manure requires increased vigilance by producers and manure application contractors to the condition of their manure handling equipment and storage structures. It also requires preparedness to control accidental spills should they occur.

Control of open feedlots means that there should not be any contaminated runoff. Precipitation runoff carrying manure must be contained in structures at the site. Runoff from areas upland of open feedlots needs to be diverted around them. Open feedlots with greater than 1,000 cattle are required to obtain NPDES discharge permits that limit discharges to zero.

5. Monitoring

The Upper North Fork Maquoketa River Watershed Comprehensive Plan assessment project by the Limestone Bluffs RC & D, including the impaired segment covered by this group of TMDLs, continues. Part of this watershed assessment effort should include water quality monitoring.

The existing ambient monitoring being done by the IDNR ambient monitoring provides only minimal information for water quality assessment and evaluation of the effectiveness of watershed best management practices. To further evaluate NFMR pollutant problems, effectively manage their impact, and design solutions through improvements to controls, additional targeted monitoring is needed.

A plan for future water quality monitoring should include the following to enhance hydrologic and water quality modeling and evaluation of the problems in this segment of the NFMR:

- Install two autosamplers with stage measurement at the same locations, sites 28 and 30 from April to November in conjunction with continuous dissolved oxygen and temperature data collection. This will provide refined calibration for the Q2K modeling for total phosphorous and algae.

- Install an autosampler with stage measurement upstream of site 30 from April to November in conjunction with continuous dissolved oxygen and temperature data collection. This will provide additional data on the locations and nature of upstream pollutant sources and more refined data on the headwaters component in the water quality model. .

- Install an autosampler with stage measurement on Coffee Creek just upstream of its confluence with NFMR from April to November in conjunction with continuous dissolved oxygen and temperature data collection. The Coffee Creek sub-watershed is fairly large and it would be useful to separate loads from it from those in other parts of the watershed.

- Install an autosampler with stage measurement just upstream of Hewitt Creek from April to November in conjunction with continuous dissolved oxygen and temperature data collection. This will provide data for the target watershed separate from the Hewitt Creek watershed.

- More frequent sampling at the autosampler sites during a wider range of flow conditions, especially at high flows during the rising part of the hydrograph. This would provide a more accurate picture of what the actual loads are from non-point sources.

- In addition to QUAL2K, use other water quality models and analytical methods to evaluate existing and new data to provide further insight into the nature of the NFMR water quality problems.

- Perform annual follow-up biological assessments near locations where autosamplers are installed.

- Get actual flow and concentration data from manure runoff and the stream during accidental releases to improve ammonia and oxygen demand impact modeling.

- Perform an annual trend analysis on the load estimates to provide information on the effectiveness of implemented BMPs. This could be part of an ongoing data analysis program that includes a statistical design for the number of samples required to achieve desired confidence in the results.

Phasing TMDLs is an iterative approach to managing water quality that is used when the origin, nature and sources of water quality impairments are not completely understood. In the first phase, the waterbody load capacity, existing pollutant load in excess of this capacity, and the source load allocations are estimated based on the resources and information available.

This report contains specific and quantified targets for reducing pollutant concentrations in the river and allocates allowable loads to all sources. These three TMDLs represent a first phase in the development of NFM River water quality improvements. The value of these evaluations and the effectiveness of their follow-ups are dependent on local activities to improve conditions in the watershed. Without the efforts of watershed citizens, implementation of practices that will remedy the NFMR impairment may not occur. What is needed in follow-up activities are stakeholder driven solutions and more effective management practices. Implementing targeted monitoring will determine what management practices result in load reductions and the attainment of water quality standards. Summarizing, renewed targeted monitoring will:

- Assess the future beneficial use status;
- Determine if water quality is improving, getting worse, or staying the same;
- Evaluate the effectiveness of implemented best management practices.

6. Public Participation

TMDL staff held a public meeting in New Vienna on May 18, 2005, to describe the Stressor Identification process and to request local knowledge on past and present conditions in North Fork Maquoketa River. The 25 attendees at this meeting included farmers, city residents, officials from the Cities of New Vienna and Holy Cross.

A draft of the TMDL was presented at a second local public meeting in New Vienna at 7:00 PM on December 4, 2006. Among the thirty attendees were farmers, city officials, and representatives from Iowa State University Extension and the Iowa Department of Agriculture and Land Stewardship Division of Soil Conservation. Comments received were reviewed and given consideration and, where appropriate, incorporated into the TMDL.

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11. Upper North Fork Maquoketa River Watershed Comprehensive Plan, Assessment and Management Strategies, Draft Version, prepared by the Limestone Bluffs RC&D with assistance from Northeast Iowa RC&D. Draft, October 2006

Appendix A – Watershed Maps

This appendix contains several maps of the impaired segment of the North Fork Maquoketa River watershed that show the ten foot elevation changes along the stream segment model, land use, estimates of erosion potential, and modeled sub-basins.

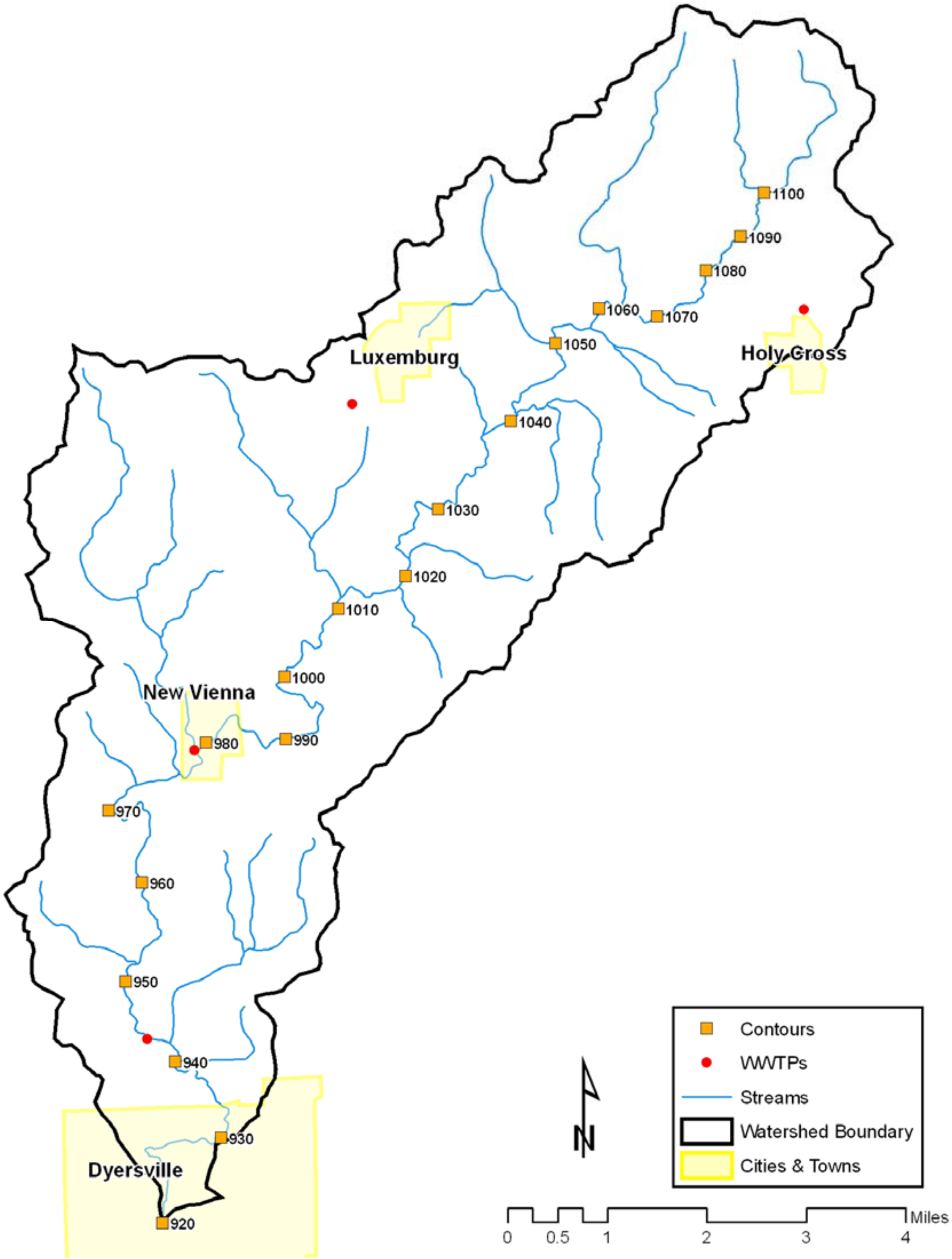

Figure A-1 Elevation contours used to define Q2K model reaches.

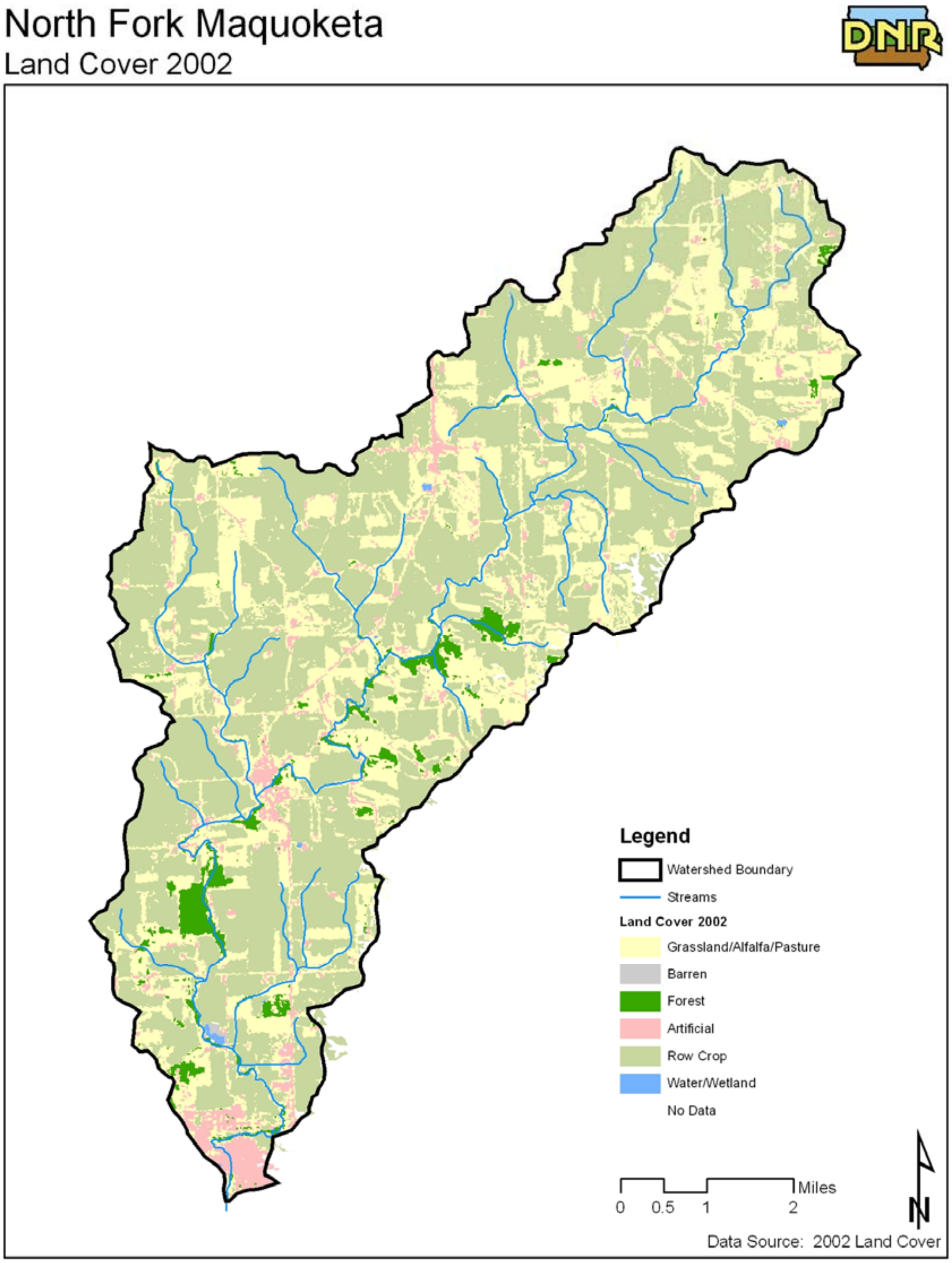

Figure A-2. North Fork Maquoketa River watershed 2002 Land uses from the IDNR Coverage.

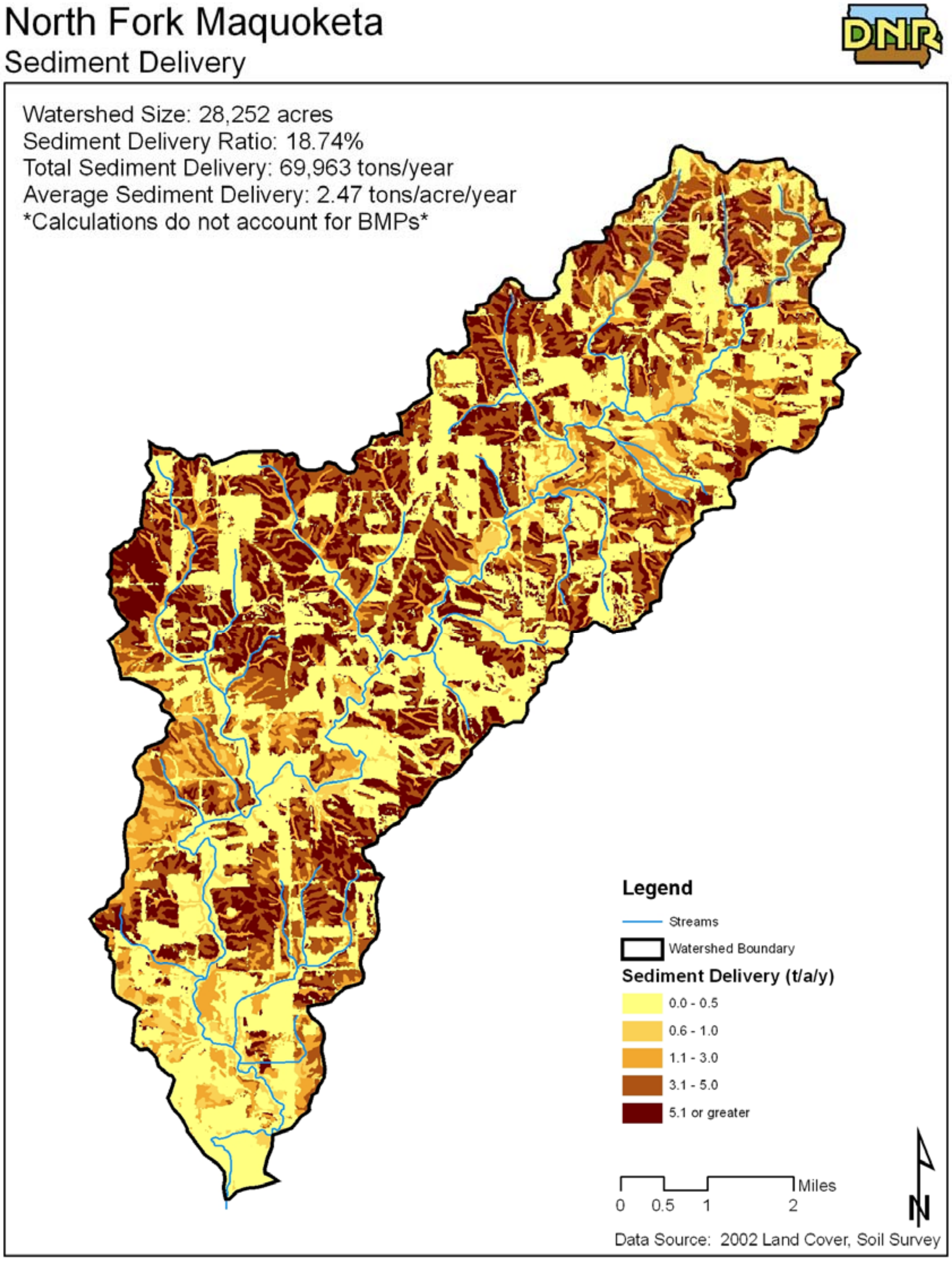

Figure A-3 This map shows sheet and rill erosion for the watershed that incorporates the estimated sediment delivery ratio. Watershed practices that reduce sediment erosion and delivery to the stream have not been included in the evaluation.

Figure A-4 Modeled Sub-basins based on the locations of the monitoring sites and the data generated from these sites. The sub-basins are labeled using the corresponding monitoring site name.