Water Quality Improvement Plan for

Dry Run Creek

Black Hawk County, Iowa

Total Maximum Daily Load
for Connected Impervious Surface

Prepared By: Jason Palmer and Mindy Buyck

Iowa Department of Natural Resources
Watershed Improvement Section
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General Report Summary

What is the purpose of this report?

This Water Quality Improvement Plan serves multiple purposes. First, it is a resource for guiding locally-driven water quality improvements in Dry Run Creek (DRC). Second, it satisfies the Federal Clean Water Act requirement to develop a Total Maximum Daily Load (TMDL) report for all federally impaired waterbodies. As an impaired waterbody, Dry Run Creek is eligible for financial assistance to improve water quality. This document is meant to help guide watershed improvement efforts to remove Dry Run Creek from the federal 303(d) list of impaired waters.

What's wrong with Dry Run Creek?

Dry Run Creek has an impairment of its biological uses. This impairment is based on data from biological sampling at two sites along the stream (Segment No. IA 02-CED-0390). The biological data collected at the sampling sites included fish species richness, abundance and health that were used to develop a Fish Index of Biotic Integrity (FIBI) and benthic macroinvertebrate species richness and abundance data that were used to develop a Benthic Macroinvertebrate Index of Biotic Integrity (BMIBI). The 2005 FIBI scores from DRC watershed sites 1 & 4 (**Table G-1**) were significantly lower than the FIBI reference biological impairment criterion (BIC) used to determine aquatic life use support status (**Table G-1**). Benthic macroinvertebrate sampling at the same sites also uncovered a community with BMIBI scores well below the ecoregion BMIBI BIC.

Table G-1 Index of Biotic Integrity scores for benthic macroinvertebrates (BMIBI) and fish (FIBI) from the DRC watershed

Site	Year	BMIBI	BMIBI Biological Impairment Criterion (BIC)	FIBI	FIBI Biological Impairment Criterion (BIC)
DRC 1	1999	48	70	50	44
DRC 1	2005	42	70	44	44
DRC 4	2005	38	70	38	65

In general the benthicmacroinvertebrate community in DRC is comprised of pollution tolerant organisms, no sensitive taxa and very few EPT taxa were collected in the biological sampling. The benthicmacroinvertebrate community is a good indicator of overall stream health/quality. In the case of DRC it is used as an integrator of overall stream and water quality. Water quality sampling can often miss spikes in harmful compounds, especially in flashy, event driven systems. Using the invertebrate community as a stream quality indicator indicates that the DRC watershed has chronic water quality and stream habitat problems which have a negative impact on overall stream health.

What is causing the problem?

Despite some data limitations, the evidence was sufficient to identify the following primary stressors, all of them are capable of causing a biological impairment in the DRC watershed:

- Elevated levels of bedded sediments
- Reduced macro and micro habitat availability
- Excessive storm water inputs and hydrologic alterations

All three of these primary stressors are tied to the hydrologic alterations and pollutant delivery from increased urban stormwater inputs to the stream system. The increased frequency and magnitude of storm water flow from urbanized sections of the DRC watershed have significant impacts, direct and indirect, on stream biota. Increases in stream flow velocities directly impact biota through increased hydraulic scour of benthic surfaces. Organisms exposed to these shear forces may be dislodged and transported downstream, experience stresses that reduce reproduction and feeding efficiency, or may suffer from direct mortality. Increased in-stream velocities also have indirect impacts on stream biota. Large increases in stream velocity can scour periphyton, which mainly grows on the upper surfaces of benthic substrate, reducing food available for organisms in the scraper feeding guild.

Rapid increases in stream velocities can exert pressures on more than just the biota in the stream system. Increases in peak velocity will result in changes in channel geomorphology. Typical reactions include channel incision (bed degradation) followed by channel widening (streambank sloughing/erosion). These channel adjustments are a direct response to increased flow and are predictable and constant across landscapes (Lane, 1955; Schumm, 1999; Simon, 1989). Channel and floodplain modification and changes in discharge caused by changes in watershed land use may alter physical features of the stream network. This includes, peak discharge, lateral and longitudinal connectivity, sediment transport characteristics, and the retention and accumulation of woody debris and organic materials. Additionally alterations to the stream (channelization) preformed in order to increase the drainage capacity of this system will have long lasting impacts on the system. Stream channelization removes stream meanders, increases stream gradient, shortens stream length, and decreases in-channel water and sediment storage capacity. The result of this activity is a channel that conveys water downstream in an extremely efficient manner, placing further hydrologic pressures on in-stream features downstream of the reach.

Impacts associated with storm water runoff are not limited to direct hydrologic effects. Increased storm water runoff is consistently associated with an increase in pollutant loads. Storm water pollutant loading is likely impacting the biological community in DRC. The degree to which the impairment can be attributed to storm water pollutant loading cannot be determined. Neither the additive nor synergistic impacts of the array of chemicals present in DRC can be quantified. The complicated web of interactions that occur among and between metals and chemicals, and the organisms in DRC cannot be untangled. It is likely that the combined effects of the pesticides, metals and other chemicals are having an adverse impact on biota attempting to inhabit this system.

Depending upon the causal mechanism, primary stressors can manifest as short-term acute impacts or long-term chronic impacts to aquatic biota. To restore the biological condition of the stream to unimpaired status, the TMDL and implementation plans need to address each of the primary stressors and multiple causal pathways that occur in the watershed.

What can be done to improve Dry Run Creek?

The existing loads, loading targets, a general listing of BMPs needed to improve water quality, and a monitoring plan to assess progress are established in this TMDL. Ideally, the TMDL would be followed by the development of a watershed management plan. The watershed management plan should include more comprehensive and detailed strategies to better guide the implementation of specific BMPs. Other ongoing tasks required to obtain real and significant water quality improvements include continued monitoring, assessment of water quality trends, assessment of WQS (biological community) attainment, and adjustment of proposed BMP types, locations, and implementation schedule based on measured results. A full discussion of this can be found in Section 4 of this document.

Who is responsible for a cleaner Dry Run Creek?

Everyone who lives, works, or plays in the Dry Run Creek watershed has a role in water quality improvement. Due to the nature of the problem and the complicated issues at play in tracking and isolating pollutants and pollution related to storm water discharges in DRC it is not likely that the management of individual point sources will have much impact on DRC. Because of this, success in DRC may only be achieved when all municipal, and university departments responsible for storm water regulation, design and maintenance come together with development companies, commercial and industrial interest groups, and community based watershed interest groups to organize all current and future storm water regulation, design, improvement and public education into one centrally focused plan. Everyone in the watershed has a roll to play, from the home owner spraying herbicide on their yard to the facilities manager responsible for the maintenance of dozens of parking lots. Everyone must pay attention to what makes it into the storm water system and how that water is handled.

Technical Elements of the TMDL

Name and geographic location of the impaired or threatened waterbody for which the TMDL is being established:	Dry Run Creek located in Black Hawk County Hydrologic Unit Code: HUC 12 070802050401 IDNR Waterbody ID: IA 02-CED-0390 Section 18 T89N R13W (Mouth) Section 23 T89N R14W (confluence with Unnamed tributary)
Surface water classification and designated uses:	Class A1 Primary Contact Recreation Class B (WW-2) Aquatic Life
Impaired beneficial uses:	Class A1 Primary Contact Recreation Class B (WW-2) Aquatic Life
Identification of the pollutant and applicable water quality standards:	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. Measurements from the monitored Dry Run Creek 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.
Quantification of the pollutant load that may be present in the waterbody and still allow attainment and maintenance of water quality standards:	The TMDL is based on attaining Connected Impervious Surface of less than 10%.
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:	See table 3.1 in document
Identification of pollution source categories:	Increased frequency and magnitude of stream flow due to increased connected impervious surface area
Wasteload allocations for pollutants from point sources:	Since the TMDL is targeting CIS and the resulting storm runoff flows associated with CIS, there is no WLA assigned.

Load allocations for pollutants from nonpoint sources:	See table 3.2 in document
A margin of safety:	Explicit MOS of 10%
Consideration of seasonal variation:	None
Reasonable assurance that load and wasteload allocations will be met:	Availability of technical and financial assistance for conservation practices and watershed improvement grants. Funding made available to local stakeholder groups on an annual basis provides an opportunity for local citizens and landowners to seek their own solutions with technical guidance from state and local government agencies
Allowance for reasonably foreseeable increases in pollutant loads:	None
Implementation plan:	Although not required by the Clean Water Act, a general Implementation Plan is included in this report to assist managers in removing this stream from the 303(d) Impaired Waters List

1. Introduction

The Federal Clean Water Act requires all states to develop lists of impaired waterbodies that are not meeting water quality standards (WQS) and designated uses. This list of impaired waterbodies is referred to as the state's 303(d) list. In addition to developing the 303(d) list, a Water Quality Improvement Plan, or Total Maximum Daily Load (TMDL) report, must also be developed for each impaired waterbody included on the list. DRC was first added to the Section 303(d) Impaired Waters List in 2002 following biological sampling in 2000 as part of the Iowa Department of Natural Resources (IDNR) stream biocriteria project. It was determined that the Dry Run Creek biological community was impaired based on assessment of the fish and benthic macroinvertebrate communities. Benthic macroinvertebrates are animals that are larger than 0.5 mm and lack backbones. These animals live on rocks, logs, sediment, debris and aquatic plants during some period in their life. They include crayfish, mussels, snails, aquatic worms, and the immature forms of aquatic insects such as stonefly and mayfly nymphs.

Because the cause (stressor) of the poor condition of the biological community was unknown, a method called Stressor Identification (SI) was used to determine the existing stressors in Dry Run Creek. 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" (U.S. EPA 2000). The SI determined that excess storm water run off from connected impervious surface (CIS) was the cause.

A TMDL is a calculation of the maximum amount of a pollutant a waterbody can receive without exceeding the water quality standards. The TMDL is allocated to permitted point sources (wasteload allocations), nonpoint sources (load allocations), and an allowance for a margin of safety to account for uncertainty in the TMDL calculation. The TMDL calculation is represented by the following general equation:

$$TMDL = LC = \Sigma\, WLA + \Sigma\, LA + MOS$$

Where:
- TMDL = total maximum daily load
- LC = loading capacity
- Σ WLA = sum of wasteload allocations (point sources)
- Σ LA = sum of load allocations (nonpoint sources)
- MOS = margin of safety (to account for uncertainty)

One purpose of this Water Quality Improvement Plan for Dry Run Creek, located in Black Hawk County in central Iowa, is to serve as the TMDL for CIS and the resulting stormflow. The second purpose of the plan is to provide local stakeholders and watershed managers with a tool to promote awareness of water quality issues, guide watershed improvement efforts, and assist the development of a Watershed Management Plan and subsequent funding applications for water quality improvement projects.

The water quality parameters addressed by this plan are CIS and the resulting stormflows, which are adversely affecting the biological community in Dry Run Creek. The plan outlines a phased approach to TMDL development and implementation. A phased approach is helpful when the origin, interaction, and quantification of pollutants contributing to water quality problems are complex and difficult to fully understand and predict.

The TMDL includes an assessment of existing pollutant loads to the stream and a determination of how much of a specific pollutant the stream can tolerate and still meet water quality standards and support its designated uses. The allowable amount of pollutant the stream can receive is the loading capacity, also called the target load. The TMDL also includes a description of potential solutions to the water quality problem. This group of solutions is generally defined as a system of best management practices (BMPs) that will improve water quality in Dry Run Creek with the ultimate goal of supporting all designated uses. These BMPs are outlined in the implementation plan in Chapter 6. A water quality monitoring plan designed to help assess water quality improvement and BMP effectiveness is provided in Chapter 7.

This Water Quality Improvement Plan will be of little value to real water quality improvement unless a Watershed Management Plan is developed and watershed improvement activities and BMPs are implemented. This will require the active engagement of local stakeholders and the collaboration of several state and local agencies. Completion of the TMDL should also be followed by several other actions, including:

- collection of water quality data as part of an ongoing monitoring plan,
- evaluation of collected data, and
- modification of the targets and/or implementation plan (if necessary).

Monitoring is a crucial element in assessing attainment of water quality standards and designated uses, determining if water quality is improving, degrading, or remaining unchanged, and assessing the effectiveness of implementation activities and the possible need for additional BMPs.

2. Description and History of Dry Run Creek (segment No. IA 02-CED-0390)

The surface watershed of DRC is located near the center of the Iowan Surface ecoregion, in western Black Hawk County (**Figure 2-1**). The Iowan Surface (47c) 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 (Prior 1991; Griffith et al., 1994). Dry Run Creek is a third order stream which flows to the Cedar River. At the confluence with the Cedar River in Cedar Falls, DRC receives flow from 15,248 surface acres.

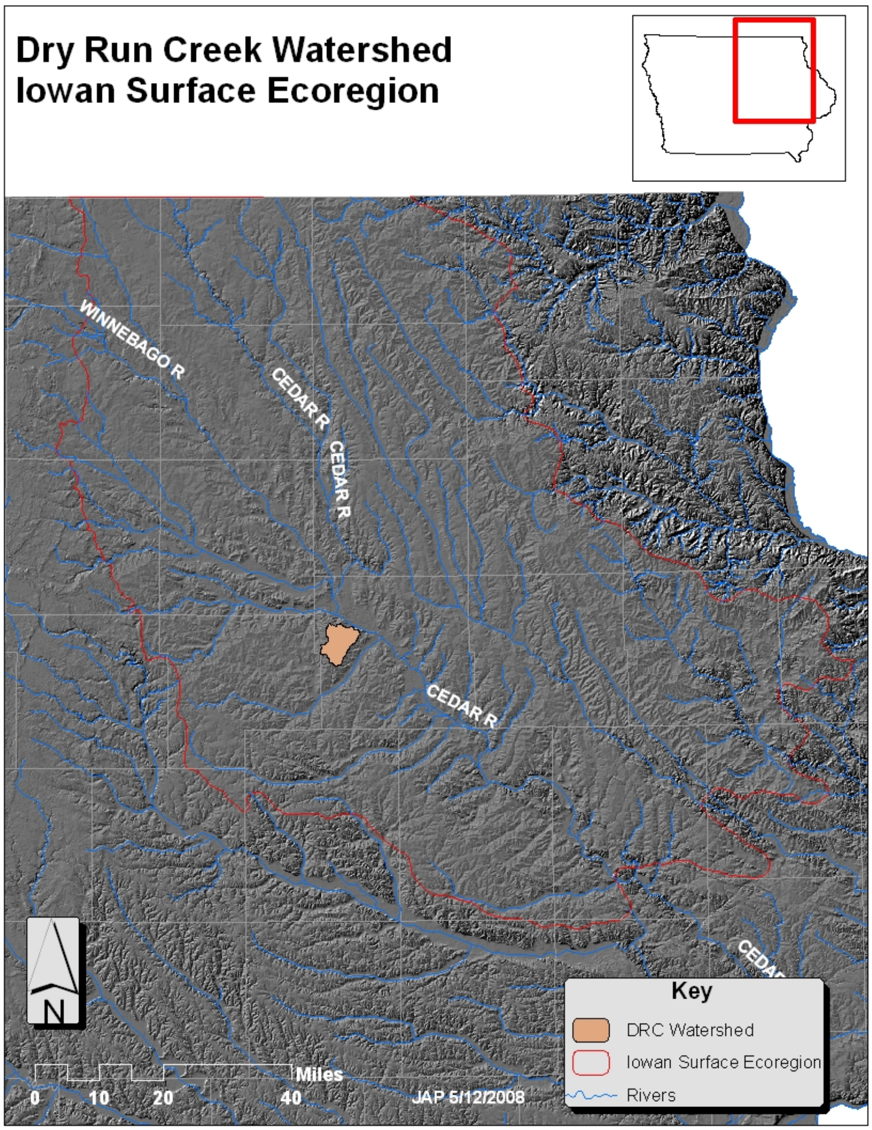

Figure 2-1 The location of the Dry Run Creek Watershed relative to the Iowan Surface Ecoregion

2.1. Dry Run Creek

Hydrology. It is important to examine flow data at several scales to form a complete picture of stream flow within the DRC watershed. Yearly and seasonal trends were determined using the USGS Cedar River gage at Cedar Falls; located near the confluence of DRC with the Cedar River. Stream discharge data from this gage (**Figure 2-2**) illustrates a seasonal pattern for stage height within the Cedar River from January 2003 to December 2007. Similar to many watersheds in Iowa, peak annual flow typically occurs in the spring and summer while lower flows typically occur in the fall and winter. An exception to this trend occurred in 2007 when an abnormally wet late summer, fall and early winter produced flooding. In general this pattern represents a seasonal pattern of spring snow melt and increased precipitation during the spring and summer seasons.

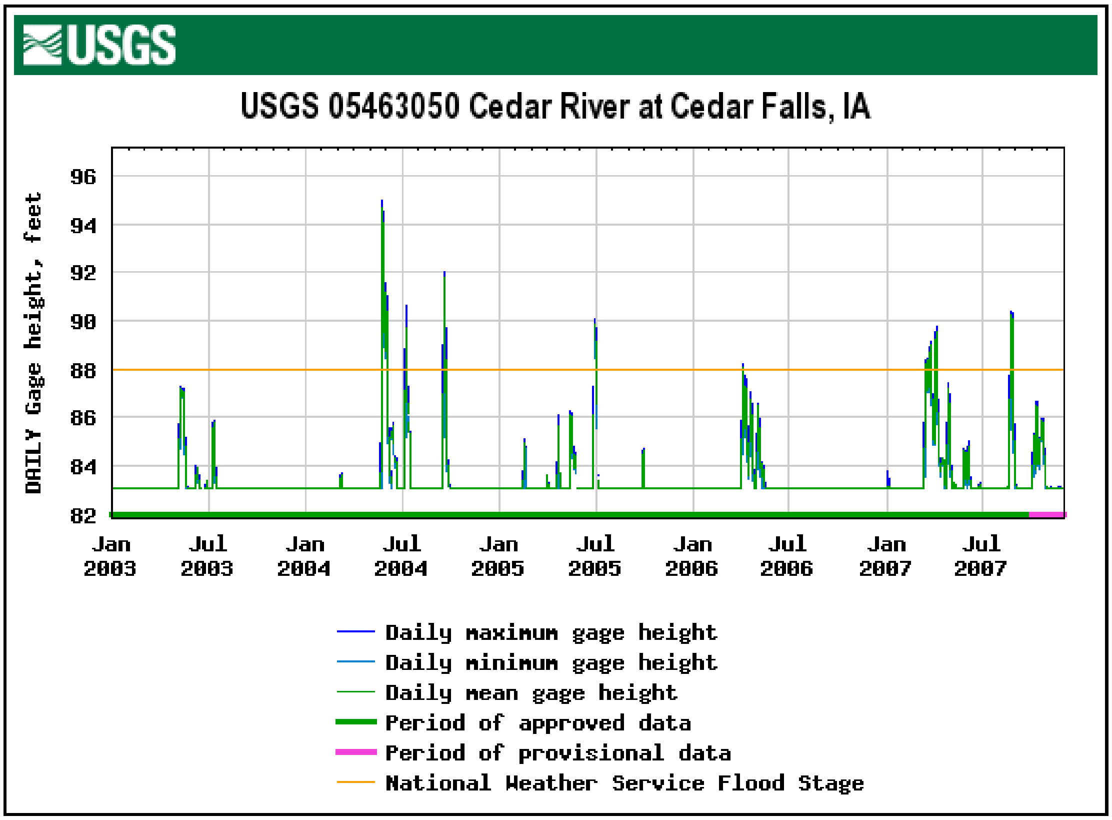

Figure 2-2 Historic stage height of the Cedar River at Cedar Falls depicting a general seasonal trend of wet springs and summers and dry autumns and winters.

The months of September and October 2007 were marked by several large rainfall events as evidenced by changes in flow (**Figure 2-3**) at the upstream end of the impaired segment of DRC (**Figure 2-5**) depicting a very flashy system that peaks and falls to base flow rapidly. The return to steady base flow of approximately 20 cfs indicates a sustained input from the coolant water discharges and ground water flow. During the time period when soil was saturated, even small rain events led to a quick response by the stream, as seen in the comparison of stream discharge to precipitation (**Figure 2-4**). A discussion of the impacts of urbanization on the hydrology of this stream network is located Stressor Identification document (**SI doc location Appendix XX**).

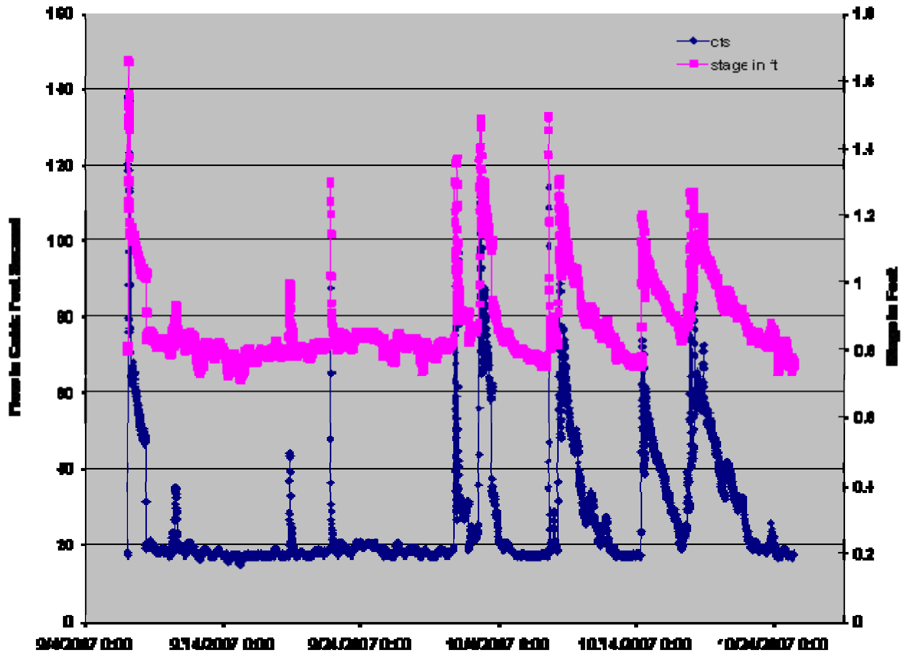

Figure 2-3 Relationship between flow and stage over time

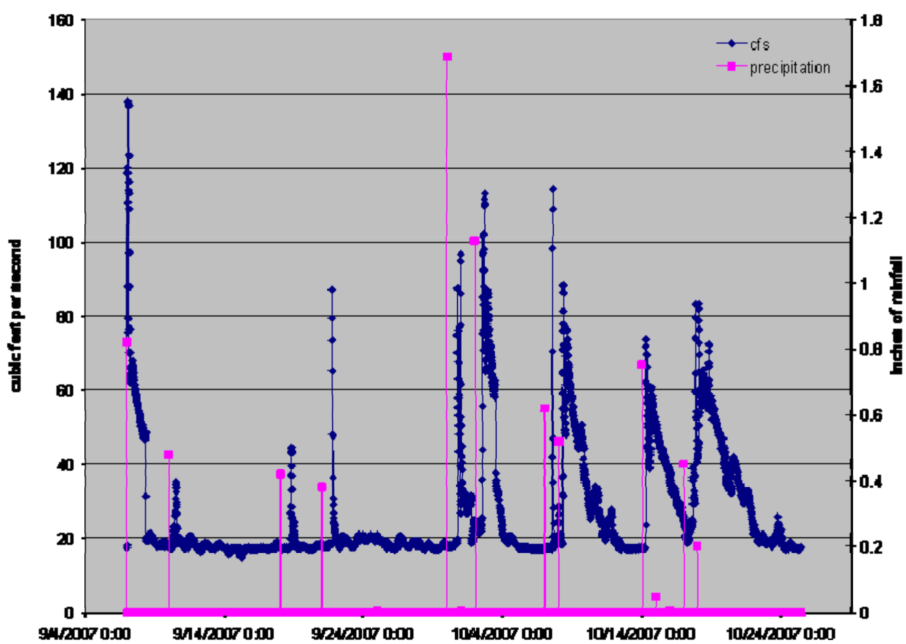

Figure 2-4 Response of stream stage to rain events

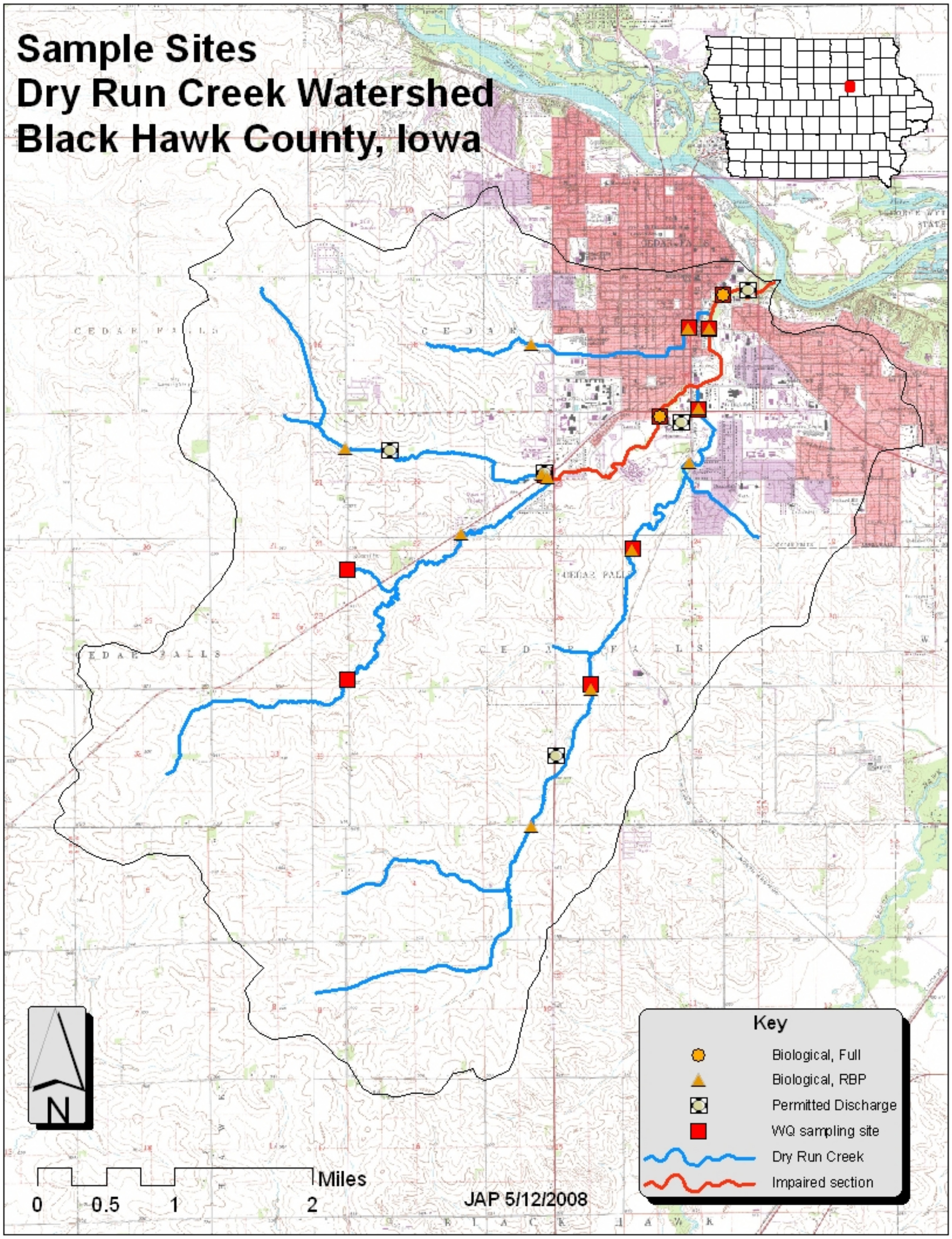

Figure 2-5 Sampling locations and permitted point source dischargers in the Dry Run Creek Watershed

Morphometry & Substrate. Dry Run Creek is a third order watershed with a dendritic drainage pattern (**Figure 2-5**). The total stream length in the DRC watershed is just over 50 miles. The main channel is 22 miles long, has a sinuosity of 1.34 and a slope of 10.2 feet per mile. The DRC basin has a stream density of 1.26 mi/sq mi and an average basin slope of 0.3 percent. Habitat surveys conducted throughout the watershed indicate that the dominant substrate is comprised of sand and silt. The proportion of this depends heavily on the hydrologic variability of the stream segment. Areas subject to frequent scour from storm events tended to be comprised of mostly sand. There are deposits of gravels and small cobble in certain areas of the stream system. These substrates, where present, were observed to be heavily embedded by sand and silt. The channel bottom and banks were observed to be heavily scoured and armored in the lower sections of the watershed, mostly with in urban areas.

2.2. The Dry Run Creek Watershed

Land Use. At the confluence with the Cedar River in Cedar Falls, DRC is a third-order stream draining 15,248 acres in western Black Hawk County (**Figure 2-6**). Current land use in the watershed is a mix of agriculture and urban. Row crop agriculture dominates the landscape in the upper portions of the watershed. Most of the first order tributaries contain agricultural land in the riparian corridor. Roughly 55 percent of the watershed is currently utilized for row crop agriculture and 4 percent is used as grazed grassland. The central and lower portions of the watershed have been urbanized over the past 100 years with the growth of the Cedar Falls area. Based on the 2002 land cover data 22 percent of the watershed is in urban land use and more than 9 percent of the watershed surface is impervious. Urbanization in the central portions of the watershed was especially rapid over the last decade. Urban development in the DRC watershed was determined on a yearly basis utilizing GIS information from the Black Hawk County assessor's office. Information from this analysis indicated that certain areas of the watershed have experienced an increase of over 200 percent in urban land use over the last decade.

Soils, climate, and topography. The surface watershed of DRC is located near the center of the Iowan Surface ecoregion (**Figure 2-1**). The Iowan Surface (47c) 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 (Prior 1991; Griffith et al., 1994). 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, 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, providing diverse aquatic habitat and a large number of fish species.

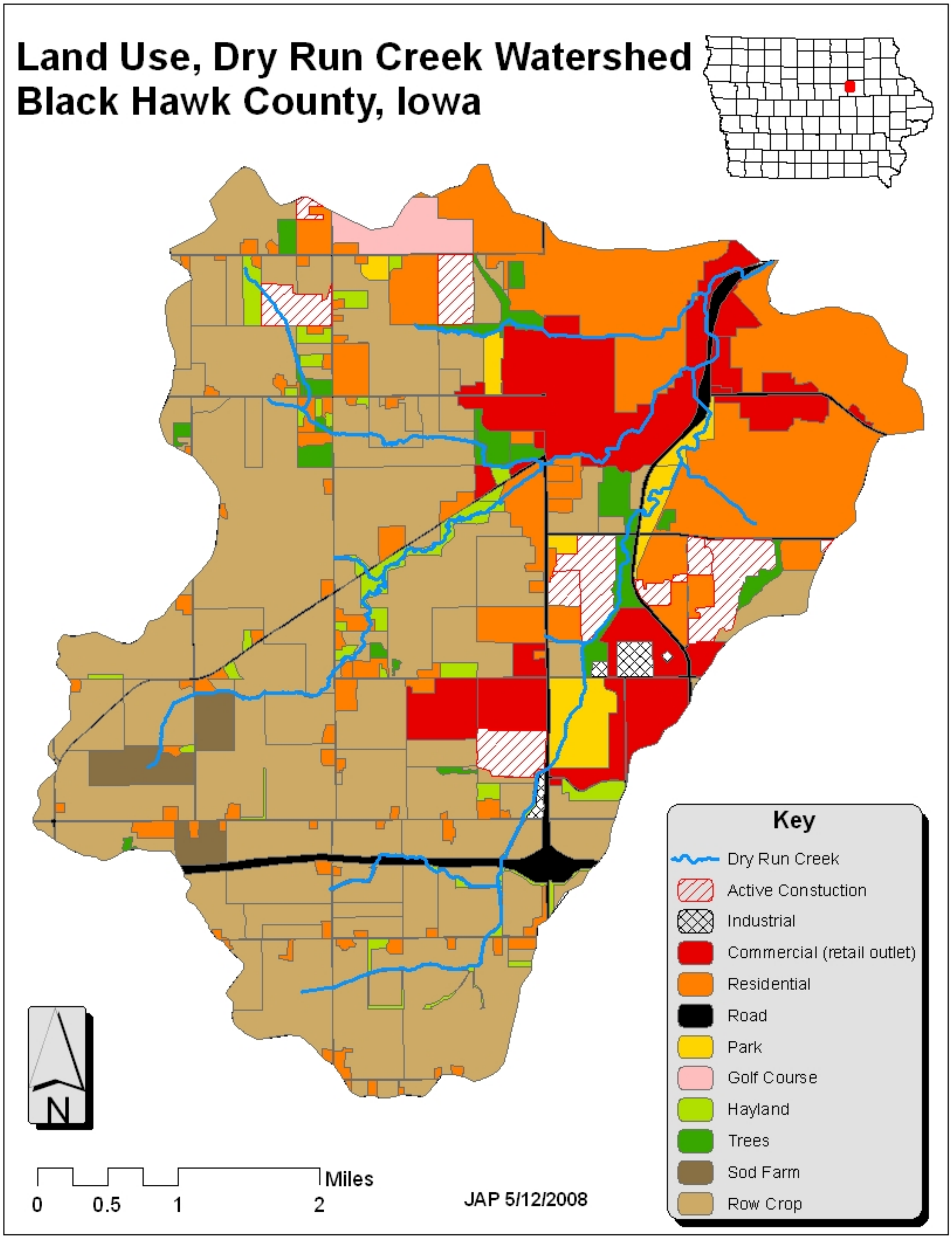

Figure 2-6 Land uses in the Dry Run Creek watershed based on 2006 aerial photography

3. Total Maximum Daily Load (TMDL) for Flow

A Total Maximum Daily Load (TMDL) is required for Dry Run Creek by the Federal Clean Water Act. This chapter will quantify the maximum amount of connected impervious surface (CIS) that Dry Run Creek can tolerate without violating the state's water quality standards.

3.1. Problem Identification

Applicable Water Quality Standards. The Iowa stream classification document designates the protected aquatic life use for Dry Run Creek, Black Hawk County as B (WW-2). Class B (WW2) streams are small warmwater streams which support fish primarily composed of minnows and other nongame species. In 1998, the aquatic life use was assessed as "partially supporting" based on a 1992 stream use assessment. DRC was not biologically assessed again until 1999; however on July 25, 1996 a fish kill was reported which affected 0.3 miles of stream and killed over 60 fish. No data which could identify the cause of the kill was available. Biological assessments conducted in 1999 at one site in the stream confirmed that the biological community in DRC did not meet expectations, so the stream was added to the 2002 303(d) Impaired Waters List as "not supporting" its aquatic life use. Additional biological data was collected at two sites in 2005.

The methods used to determine support of aquatic life use include calculating a series of biological metrics that reflect stream water quality and habitat integrity from the biological sampling data collected. The metrics are based on the numbers and types of benthic macroinvertebrate and fish species that were collected. The biological metrics were combined to make a fish index of biotic integrity (FIBI) and a benthic macroinvertebrate index (BMIBI). The biotic indexes rank the biological integrity of a stream sampling reach on a scale from 0 (minimum) to 100 (maximum). Table 3-1 shows general qualitative scoring guidelines for the two indexes.

Table 3-1. Qualitative scoring guidelines for the BMIBI and FIBI.

Biological Condition Rating	BMIBI	FIBI
Poor	0 - 30	0 -25
Fair	31 - 55	26 - 50
Good	56 - 75	51 - 70
Excellent	76 - 100	71 - 100

Biological sampling from reference streams in Iowa's ecoregions has been used to derive target BMIBI and FIBI scores for each ecoregion (See Section 2, Fig. 2-4). The reference stream BMIBI and FIBI scores shown are the minimum scores for biological integrity that support aquatic life use in ecoregion 52b (Table 3-2). Below these values a stream is considered either partially or not supporting designated uses. The stream is then listed for a biological impairment of undetermined cause based on low FIBI and/or BMIBI scores. The Dry Run Creek BMIBI and FIBI scores are well below the ecoregion 52b biological impairment conditions (Table 3-3).

Table 3-2. Reference criteria for assessing biological integrity.

Ecoregion	BMIBI	FIBI
47c (Iowan Surface	70	44 non-riffle sites 65 riffle sites

IDNR staff followed the SI protocols to determine the cause of the Dry Run Creek biological impairment. The SI procedure relates impairments described by biological assessments to one or more specific causal agents (stressors) and also separates water quality (pollutant) impacts from habitat alteration impacts.

The stressor identification for Dry Run Creek identified increased flow from CIS as the primary cause of the biological impairment. The increased flow causes instability in the substrate that many macroinvertebrates and fish use for breeding and habitat. Additionally, the increased run off from parking lots and construction sites can carry pollutants such as petroleum products (gas and oil), other automobile fluids (antifreeze, power steering fluid, and windshield washer solution), road salts and lawn care chemicals (fertilizers and pesticides). While none of these alone appear to be causing the biological impairment, constant exposure to low levels of several listed pollutants may contribute to an unhealthy macroinvertebrate and fish population. The effects of many of these pollutants in high levels is still unknown much less the effects of constant low level exposure

Problem statement. In 2002, the stream was assessed as "not supporting" because the 1999 monitoring assessment revealed poor biological integrity. The FIBI and BMIBI scores for Dry Run Creek from the 1999 sampling and additional biological sampling in 2005 are shown in Table 3-3. BMIBI and FIBI scores from sampling locations in the Dry Run Creek watershed generally indicate poor to fair biological condition based on the ratings in Table 3-1. The shaded columns list the Biological Impairment Criteria (BIC) that are determined from the range of IBI scores sampled from ecoregion 47c reference stream sites. The Dry Run Creek BMIBI and FIBI scores are below the ecoregion biological impairment conditions, which is strong evidence that the biological impairment is consistent across space and time.

Table 3-3. Index of Biotic Integrity scores for benthic macroinvertebrates (BMIBI) and fish (FIBI) from the Dry Run Creek watershed.

Site	Year	BMIBI	BMIBI Biological Impairment Criterion (BIC)	FIBI	FIBI Biological Impairment Criterion (BIC)
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In general the benthic macroinvertebrate community in Dry Run Creek is comprised of pollution tolerant organisms, no sensitive taxa and very few EPT taxa were collected in the biological sampling. The benthic macroinvertebrate community is a good indicator of overall stream health/quality. In the case of Dry Run Creek it is used as an integrator of overall stream and water quality. Water quality sampling can often miss spikes in harmful compounds, especially in flashy, event driven systems. Using the invertebrate community as a stream quality indicator indicates that the DRC watershed has chronic water quality and stream habitat problems which have a negative impact on overall stream health.

Data sources. Full biological sampling was performed at one location in 1999 (Site DRC1) and two locations in 2005 (Sites DRC1 and DRC4), with rapid bioassessment protocol (RBP) sampling at eleven additional sites in 2005. Stream physical habitat was also assessed at all biosampling sites. Water quality samples were collected from ten Dry Run Creek sites from June through December 2005, March through December 2006, and February through September 2007 (Appendix E).

Interpreting Dry Run Creek data. 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 3-2 for the watershed ecoregion are considered 'supporting' the aquatic life use. Dry Run Creek will be considered no longer impaired when the ecoregion 47c BICs are met/

The primary stressors determined by the Stressor Identification process are tied to the hydrologic alterations and pollutant delivery from increased urban stormwater inputs to the stream system. The increased frequency and magnitude of storm water flow from urbanized sections of the DRC watershed have significant impacts, direct and indirect, on stream biota. Increases in stream flow velocities directly impact biota through increased hydraulic scour of benthic surfaces. Organisms exposed to these shear forces may be dislodged and transported downstream, experience stresses that reduce reproduction and feeding efficiency, or may suffer from direct mortality. Increased in-stream velocities also have indirect impacts on stream biota. Large increases in stream velocity can scour periphyton, which mainly grows on the upper surfaces of benthic substrate, reducing food available for organisms in the scraper feeding guild.

Rapid increases in stream velocities can exert pressures on more than just the biota in the stream system. Increases in peak velocity will result in changes in channel geomorphology. Typical reactions include channel incision (bed degradation) followed by channel widening (streambank sloughing/erosion). These channel adjustments are a direct response to increased flow and are predictable and constant across landscapes (Lane, 1955; Simon, 1989; Schumm, 1999). Channel and floodplain modification and changes in discharge caused by changes in watershed land use may alter physical features of the stream network. This includes, peak discharge, lateral and longitudinal connectivity, sediment transport characteristics, and the retention and accumulation of woody debris and organic materials. Additionally alterations to the stream (channelization) preformed in order to increase the drainage capacity of this system will have long lasting impacts on the system. Stream channelization removes stream meanders, increases stream gradient, shortens stream length, and decreases in-channel water and sediment storage capacity. The result of this activity is a channel that conveys water downstream in an extremely efficient manner, placing further hydrologic pressures on in-stream features downstream of the reach.

Impacts associated with storm water runoff are not limited to direct hydrologic effects. Increased storm water runoff is consistently associated with an increase in pollutant loads. Storm water pollutant loading is likely impacting the biological community in DRC. The degree to which the impairment can be attributed to storm water pollutant loading cannot be determined. Neither the additive nor synergistic impacts of the array of chemicals present in DRC can be quantified. The complicated web of interactions that occur among and between metals and chemicals, and the organisms in DRC cannot be untangled. It is likely that the combined effects of the pesticides, metals and other chemicals are having an adverse impact on biota attempting to inhabit this system.

3.2. TMDL Target

General description of the pollutant. Multiple studies have shown a linkage between increased urbanization and alterations in community composition, reduced taxa richness and diversity, and an increase in pollution tolerant taxa in macroinvertebrate communities (Stepenuck *et al*. 2002; Booth and Jackson, 1997; Jones and Clark, 1987). Studies conducted on 43 southern Wisconsin streams showed that levels of connected impervious surfaces between 8 and 12 percent represented a threshold where minor increases in urbanization were associated with sharp declines in macroinvertebrate communities (Stepenuck *et.al*. 2002). Additional studies in the same streams showed that number of fish species per site and fish IBI scores were consistently low in watersheds with greater than 10 percent connected impervious surfaces (Wang *et. al.* 2000).

Selection of environmental conditions. Urbanization in the central portions of the watershed has increased significantly over the last decade. Data on urban development in the DRC watershed, determined on a yearly basis utilizing GIS information from the Black Hawk County assessor’s office, showed that certain areas of the watershed have experienced a 200 percent increase in urban land use over the last decade. Sub-watersheds 4 and 8 along the southeastern branch of DRC had the highest percent increase in the watershed over the past decade (Figure 2-6).

The increased frequency and magnitude of storm water flow from urbanized sections of the DRC watershed have significant impacts, direct and indirect, on stream biota. Increases in stream flow velocities directly impact biota through increased hydraulic scour of benthic surfaces. Organisms exposed to these shear forces may be dislodged and transported downstream, experience stresses that reduce reproduction and feeding efficiency, or may suffer from direct mortality. Increased in-stream velocities also have indirect impacts on stream biota. Large increases in stream velocity can scour periphyton, which mainly grows on the upper surfaces of benthic substrate, reducing food available for organisms in the scraper feeding guild. Increases in magnitude and frequency of peak velocities can destabilize the stream bed resulting in frequent mobilization of benthic surfaces. This reduces colonization potential and in extreme cases may result in the direct burial of organisms.

Water body pollutant loading capacity (TMDL). The goal for DRC is to decrease storm event runoff associated with CIS, which is based on attaining CIS of less than 10 percent. The reductions are based on different magnitude storm events with various return periods (or recurrence intervals) that coincide with different stormwater management BMPs.

Decision criteria for water quality standards attainment. The decision criteria for water quality standards attainment in Dry Run Creek are based on meeting biological conditions typical of healthy reference streams for this ecoregion.

3.3. Pollutant Source Assessment

Existing load. The SI conducted in Dry Run Creek identified increased stormwater run-off and its associated pollutants as the most probable cause of the biological impairment. Since the impairment cannot be tied to one specific pollutant, the use of CIS as a surrogate measure has been targeted. The use of a surrogate in TMDLs is supported by Federal Regulation 40 CFR § 130.2-(i) which states "TMDLs can be expressed in terms of either mass per time, toxicity, or other appropriate measure." Research has indicated a strong relationship between increased CIS and declining macroinvertebrates and fish populations.

Water Quality Target. The TMDL was developed using CIS as a surrogate for increased stormwater runoff and the array of pollutants associated with the runoff. To quantify the effects of CIS on stormwater flows, a SWAT model was developed and ran for existing conditions and for the target of 10% CIS in subwatersheds with higher percentage of CIS. The resulting flows were compared for 24-hour Water Quality storm event (as provided by the Iowa Stormwater Management Manual available at http://www.ctre.iastate.edu/PUBS/stormwater/documents/2C-2RainfallandRunoffAnalysis.pdf) and the target was based on the resulting decrease in flow from current conditions to 10% CIS. The flows associated with these storm events (plus or minus 10 percent to provide a more robust data set) were acquired by identifying storms of this magnitude within the weather data set and comparing resulting model flows for the current land management and a scenario of 10% CIS applied across the watershed for those given 24 hour periods.

Identification of sources. The source of the increased storm runoff in Dry Run Creek is the increase of CIS as urbanization continues to expand.

Allowance for increases in pollutant loads. There are no allowances for increases in as the implementation plan calls for all new construction to put BMPs in place to allow for infiltration.

Table 3.1 Reductions in flow based on revised CIS percentages

Date	Recorded Rainfall (inches)	Flow Current CIS (CFS)	Flow 10% CIS (CFS)
6/12/1994	1.14	57.02	17.07
7/4/1994	1.26	71.93	32.57
7/13/1994	1.18	70.28	36.54
8/12/1994	1.14	66.36	32.64
6/28/1995	1.30	130.45	93.14
8/29/1995	1.34	84.77	37.28
10/29/1996	1.18	61.81	24.97
9/22/1997	1.18	66.92	31.49
5/23/1998	1.22	93.49	55.48
6/20/1998	1.30	254.07	249.06
6/24/1998	1.34	258.44	251.51
8/17/1998	1.22	112.28	84.91
10/4/1998	1.26	106.30	70.67
4/22/1999	1.34	144.69	114.24
5/12/1999	1.18	119.49	92.44
7/26/1999	1.14	118.06	93.66
11/23/1999	1.18	59.96	17.99
6/23/2000	1.26	140.28	119.18
7/4/2002	1.14	68.43	31.48
5/8/2003	1.18	81.41	48.62
8/3/2004	1.26	78.54	34.00
8/26/2004	1.30	70.84	26.74
4/22/2005	1.14	61.39	23.72
5/12/2005	1.18	73.01	30.75
8/11/2005	1.18	72.49	36.58
7/11/2006	1.14	63.98	27.03
6/21/2007	1.18	97.72	65.45
6/22/2007	1.26	148.16	114.10
7/18/2007	1.18	90.55	52.61
8/18/2007	1.14	76.90	47.29
8/20/2007	1.26	361.55	362.95
8/24/2007	1.18	300.72	320.46
10/2/2007	1.14	172.45	154.14
Average Flows (CFS)		**116.20**	**85.77**
Resulting Reduction		**26.18**	**percent**

3.4. Pollutant Allocation

Wasteload allocation. The WLA is set at 10% CIS and the resulting flow reductions for a 24-hour Water Quality storm event

Load allocation. Since stormwater is considered a point source under MS4 permitting, the LA is zero.

Margin of safety. An explicit 10% margin of safety was applied.

3.5. Reasonable Assurance

Reasonable assurance for the reduction of nonpoint source loading is given by the availability of technical and financial assistance for conservation practices and watershed improvement grants. Funding made available to local stakeholder groups on an annual basis provides an opportunity for local citizens and landowners to seek their own solutions with technical guidance from state and local government agencies.

3.6. TMDL Summary

The following equation represents the Total Maximum Daily Load (TMDL) and its components for Dry Run Creek:

$$TMDL = LC = \Sigma\ WLA + \Sigma\ LA + MOS$$

Where:
- TMDL = total maximum daily load
- LC = loading capacity
- Σ WLA = sum of wasteload allocations (point sources)
- Σ LA = sum of load allocations (nonpoint sources)
- MOS = margin of safety (to account for uncertainty)

Table 3.2 TMDL LA calculations for specified storm event

Return Period	LA (CFS)	MOS (CFS)	TMDL (CFS)
24 hour (1.25 in)	77.19	8.58	85.77

4. Implementation Plan

This implementation plan is not a requirement of the Federal Clean Water Act. However, the Iowa Department of Natural Resources recognizes that technical guidance and support are critical to achieving the goals outlined in this TMDL. Therefore, this plan is included to be used by local professionals, watershed managers, and citizens for decision-making support and planning purposes. The best management practices (BMPs) listed below represent a comprehensive list of tools that may help achieve water quality goals if applied in an appropriate manner; however, it is up to land managers, citizens, and local conservation technicians to determine exactly how best to implement them.

4.1. General Approach & Reasonable Timeline

Initiative and action by local landowners and citizens are crucial to improving the overall health of any watershed. This is especially true of the Dry Run Creek watershed because most of the land is a combination of privately and publicly owned land. Watershed work and improvements to the creek should proceed in conjunction with a comprehensive monitoring system that will adequately characterize daily, seasonal, and annual pollutant loadings in the creek as improvements to the watershed are made.

General approach. The existing loads, loading targets, a general listing of BMPs needed to improve water quality, and a monitoring plan to assess progress are established in this TMDL. Ideally, the TMDL would be followed by the development of a watershed management plan. The watershed management plan should include more comprehensive and detailed strategies to better guide the implementation of specific BMPs. Other ongoing tasks required to obtain real and significant water quality improvements include continued monitoring, assessment of water quality trends, assessment of WQS (biological community) attainment, and adjustment of proposed BMP types, locations, and implementation schedule based on measured results.

Timeline. Development of a comprehensive watershed management plan takes time—perhaps as long as one to three years. Implementation of watershed BMPs could take upwards of five to ten years, depending on funding, willingness of landowner participation, and time needed for design and construction of any structural BMPs. Realization and documentation of water quality benefits and improvement in the biological community may take 10 years or longer, depending on weather patterns, amount of data collected, and the successful location, design, construction, and maintenance of BMPs. Utilization of the monitoring plan as outlined in Chapter 5 should begin immediately to establish baseline conditions, and should continue throughout implementation of BMPs and beyond.

4.2 Best Management Practices

Recently, there has been growing interest in utilizing BMPs that are not only effective but also aesthetically pleasing. Each practice is limited in how much runoff it can reduce, placement and cost. It will require effective planning on the part of watershed improvement groups to research these BMPs and decide on a case by case basis which one is most effective. Table 4.1 provides average runoff reductions for each practice as compiled by the Center for Watershed Protection and Chesapeake Stormwater Network. The following is a list of defined practices that might be of use in the Dry Run Creek watershed.

Green Roofs: the roof of a building that is partially or completely covered with vegetation and soil, or a growing medium, planted over a waterproofing membrane. It may also include additional layers such as a root barrier and drainage and irrigation systems.

Rain tanks and Cisterns: rain capturing devices and systems. The water can then be used as grey water or outdoor irrigation.

Permeable Pavement: Porous pavement is a permeable pavement surface with or without an underlying reservoir that temporarily stores surface runoff before infiltrating into the subsoil. This porous surface replaces traditional pavement, allowing parking lot runoff to infiltrate directly into the soil. There are several pavement options, including porous asphalt, pervious concrete, and grass pavers. Porous asphalt and pervious concrete appear the same as traditional pavement from the surface, but are manufactured without "fine" materials, and incorporate void spaces to allow infiltration. Grass pavers are concrete interlocking blocks or synthetic fibrous grid systems with open areas designed to allow grass to grow.

Bioretention: Bioretention utilizes soils and plants to remove pollutants from storm water runoff. Runoff is conveyed as sheet flow to the treatment area, which consists of a grass buffer strip, sand bed, ponding area, organic or mulch layer, planting soil, and plants. Runoff passes first over or through a sand bed, which slows the runoff's velocity and distributes it evenly along the length of the ponding area, which consists of a surface organic layer and/or ground cover and the underlying planting soil.

Dry Swales: Dry swales are essentially bioretention cells that are shallower, configured as linear channels, and covered with turf or other surface material (other than mulch and plants). The dry swale is a soil filter system that temporarily stores and then filters the desired volume. Dry swales rely on a pre-mixed soil media filter below the channel that is similar to that used for bioretention. If soils are extremely permeable, runoff infiltrates into underlying soils. In most cases, however, the runoff treated by the soil media flows into an underdrain, which conveys treated runoff back to the conveyance system further downstream. The underdrain system consists of a perforated pipe within a gravel layer on the bottom of the swale.

Table 4.1 Average runoff reductions for each practice as compiled by the Center for Watershed Protection and Chesapeake Stormwater Network.

Practice	Average Runoff Reduction
Green Roofs	46 to 60%
Rain tanks and Cisterns	40%
Permeable Pavement	45 to 75%
Bioretention	40 to 80%
Dry Swales	40 to 60%

5. Future Monitoring

Water quality monitoring is a critical element in assessing the current status of water resources and historical trends. Furthermore, monitoring is necessary to track the effectiveness of water quality improvements made in the watershed and document the status of the waterbody in terms of achieving total maximum daily loads. Also, because the impaired use is for aquatic life, biological sampling is critical to document any improvement in the biological community that may result from implementation efforts within the watershed.

Future water quality monitoring in the Dry Run Creek watershed can be agency-led, volunteer-based, or a combination of both. The Iowa Department of Natural Resources (IDNR) Watershed Monitoring and Assessment Section administers a water quality monitoring program that provides training to interested volunteers. This program is called IOWATER. More information can be found at the program web site: http://www.iowater.net/Default.htm.

Biological monitoring should be conducted by a professional organization such as the University of Iowa Hygienic Lab (UHL) to ensure accuracy and consistency of methods

5.1. Monitoring Plan to Track TMDL Effectiveness

Currently, due to resource limitations, there are no plans for water quality monitoring or biological sampling in the Dry Run Creek watershed.

5.2. Idealized Plan for Future Watershed Projects

The ideal monitoring plan for Dry Run Creek would involve water chemistry sampling, biological sampling, habitat sampling, and continuous sampling for storm peak flow (Table 5-1) at select sites in the watershed.

Table 5-1. Idealized monitoring plan for Dry Run Creek.

Component	Sample Frequency	Parameters/Details
Water chemistry sampling*	Bi-weekly- March to October Monthly- November to February	All common parameters listed in Appendix A of the Iowa Water Monitoring Plan 2000 http://www.igsb.uiowa.edu/wqm/publications/plan2000.htm
Benthic Macroinvertebrate and Fish sampling*	Annually	Should be done to track improvement in benthic macroinvertebrates and fish and evaluate changes in species susceptible to ammonia toxicity and low DO.
Habitat sampling*	Annually	Concurrently with the biological sampling, habitat assessment should take place according to IDNR protocols. Will track improvement in habitat conditions that may be contributing to the impairment such as sedimentation and substrate embeddedness.
Storm Peak Flow*	From June to October	Autosampler deployment according to UHL protocols (15 minute intervals)

*Sampling locations should be consistent with those used during SI process found in figure 2-5.

While resources may not currently be available to implement this type of monitoring plan, this strategy should be incorporated into the Dry Run Creek Watershed Management Plan discussed in Section 4. Then, as funding becomes available to support watershed improvement efforts, this monitoring plan can be implemented by the local watershed group(s).

6. Public Participation

Public involvement is important in the TMDL process since it is the land owners, tenants, and citizens who directly manage land and live in the watershed that determine the water quality in Dry Run Creek. During the development of this TMDL, every effort was made to ensure that local stakeholders were involved in the decision-making process to agree on feasible and achievable goals for the water quality in Dry Run Creek.

6.1. Public Meetings

A public meeting was held on Thursday, Oct. 19, 2010. The meeting was from 6 to 8 p.m. at Lantz Auditorium (room 137) in McCollum Science Hall on the campus of the University of Northern Iowa in Cedar Falls.

6.2. Written Comments

No comments were received during the comment period.

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Appendix A --- Glossary of Terms and Acronyms

303(d) list: Refers to section 303(d) of the Federal Clean Water Act, which requires a listing of all public surface water bodies (creeks, rivers, wetlands, and lakes) that do not support their general and/or designated uses. Also called the state's "Impaired Waters List."

305(b) assessment: Refers to section 305(b) of the Federal Clean Water Act, it is a comprehensive assessment of the state's public water bodies ability to support their general and designated uses. Those bodies of water which are found to be not supporting or just partially supporting their uses are placed on the 303(d) list.

319: Refers to Section 319 of the Federal Clean Water Act, the Nonpoint Source Management Program. Under this amendment, States receive grant money from EPA to provide technical & financial assistance, education, & monitoring to implement local nonpoint source water quality projects.

AFO: Animal Feeding Operation. A livestock operation, either open or confined, where animals are kept in small areas (unlike pastures) allowing manure and feed become concentrated.

Base flow: The fraction of discharge (flow) in a river which comes from ground water.

BMIBI: Benthic Macroinvertebrate Index of Biotic Integrity. An index-based scoring method for assessing the biological health of streams and rivers (scale of 0-100) based on characteristics of bottom-dwelling invertebrates.

BMP: Best Management Practice. A general term for any structural or upland soil or water conservation practice. For example terraces, grass waterways, sediment retention ponds, reduced tillage systems, etc.

CAFO: Confinement Animal Feeding Operation. An animal feeding operation in which livestock are confined and totally covered by a roof, and not allowed to discharge manure to a water of the state.

Credible data law: Refers to 455B.193 of the Iowa Administrative Code, which ensures that water quality data used for all purposes of the Federal Clean Water Act are sufficiently up-to-date and accurate.

Cyanobacteria (blue-green algae): Members of the phytoplankton community that are not true algae but can photosynthesize. Some species can be toxic to humans and pets.

Designated use(s): Refer to the type of economic, social, or ecologic activities that a specific water body is intended to support. See Appendix B for a description of all general and designated uses.

DNR (or IDNR): Iowa Department of Natural Resources.

Ecoregion: A system used to classify geographic areas based on similar physical characteristics such as soils and geologic material, terrain, and drainage features.

EPA (or USEPA): United States Environmental Protection Agency.

FIBI: Fish Index of Biotic Integrity. An index-based scoring method for assessing the biological health of streams and rivers (scale of 0-100) based on characteristics of fish species.

FSA: Farm Service Agency (United States Department of Agriculture). Federal agency responsible for implementing farm policy, commodity, and conservation programs.

General use(s): Refer to narrative water quality criteria that all public water bodies must meet to satisfy public needs and expectations. See Appendix B for a description of all general and designated uses.

GIS: Geographic Information System(s). A collection of map-based data and tools for creating, managing, and analyzing spatial information.

Gully erosion: Soil movement (loss) that occurs in defined upland channels and ravines that are typically too wide and deep to fill in with traditional tillage methods.

HEL: Highly Erodible Land. Defined by the USDA Natural Resources Conservation Service (NRCS), it is land which has the potential for long term annual soil losses to exceed the tolerable amount by eight times for a given agricultural field.

Integrated report: Refers to a comprehensive document which combines the 305(b) assessment with the 303(d) list, as well as narratives and discussion of overall water quality trends in the state's public water bodies. The Iowa Department of Natural Resources submits an integrated report to the EPA biennially in even numbered years.

LA: Load Allocation. The fraction of the total pollutant load of a water body which is assigned to all combined *nonpoint sources* in a watershed. (The total pollutant load is the sum of the waste load and load allocations.)

Load: The total amount (mass) of a particular pollutant in a waterbody.

MOS: Margin of Safety. In a total maximum daily load (TMDL) report, it is a set-aside amount of a pollutant load to allow for any uncertainties in the data or modeling.

MS4 Permit: Municipal Separate Storm Sewer System Permit. An NPDES license required for some cities and universities which obligates them to ensure adequate water quality and monitoring of runoff from urban storm water and construction sites, as well as public participation and outreach.

Nonpoint source pollution: A collective term for contaminants which originate from a diffuse source.

NPDES: National Pollution Discharge Elimination System, which allows a facility (e.g. an industry, or a wastewater treatment plant) to discharge to a water of the United States under regulated conditions.

NRCS: Natural Resources Conservation Service (United States Department of Agriculture). Federal agency which provides technical assistance for the conservation and enhancement of natural resources.

Periphyton: Algae that are attached to substrates (rocks, sediment, wood, and other living organisms).

Phytoplankton: Collective term for all self-feeding (photosynthetic) organisms which provide the basis for the aquatic food chain. Includes many types of algae and cyanobacteria.

Point source pollution:	A collective term for contaminants which originate from a specific point, such as an outfall pipe. Point sources are generally regulated by an NPDES permit.
PPB:	Parts per Billion. A measure of concentration which is the same as micrograms per liter (µg/l).
PPM:	Parts per Million. A measure of concentration which is the same as milligrams per liter (mg/l).
Riparian:	Refers to site conditions that occur near water, including specific physical, chemical, and biological characteristics that differ from upland (dry) sites.
RUSLE:	Revised Universal Soil Loss Equation. An empirical model for estimating long term, average annual soil losses due to sheet and rill erosion.
Secchi disk:	A device used to measure transparency in water bodies. The greater the secchi depth (measured in meters), the more transparent the water.
Sediment delivery ratio:	A value, expressed as a percent, which is used to describe the fraction of gross soil erosion which actually reaches a water body of concern.
Seston:	All particulate matter (organic and inorganic) in the water column.
Sheet & rill erosion	Soil loss which occurs diffusely over large, generally flat areas of land.
SI:	Stressor Identification. A process by which the specific cause(s) of a biological impairment to a water body can be determined from cause-and-effect relationships.
Storm flow (or stormwater):	The fraction of discharge (flow) in a river which arrived as surface runoff directly caused by a precipitation event. *Storm water* generally refers to runoff which is routed through some artificial channel or structure, often in urban areas.
STP:	Sewage Treatment Plant. General term for a facility that processes municipal sewage into effluent suitable for release to public waters.

SWCD:	Soil and Water Conservation District. Agency which provides local assistance for soil conservation and water quality project implementation, with support from the Iowa Department of Agriculture and Land Stewardship.
TMDL:	Total Maximum Daily Load. As required by the Federal Clean Water Act, a comprehensive analysis and quantification of the maximum amount of a particular pollutant that a water body can tolerate while still meeting its general and designated uses.
TSI (or Carlson's TSI):	Trophic State Index. A standardized scoring system (scale of 0-100) used to characterize the amount of algal biomass in a lake or wetland.
TSS:	Total Suspended Solids. The quantitative measure of seston, all materials, organic and inorganic, which are held in the water column.
Turbidity:	The degree of cloudiness or murkiness of water caused by suspended particles.
UAA:	Use Attainability Analysis. A protocol used to determine which (if any) designated uses apply to a particular water body. (See Appendix B for a description of all general and designated uses.)
UHL:	University Hygienic Laboratory (University of Iowa). Provides physical, biological, and chemical sampling for water quality purposes in support of beach monitoring and impaired water assessments.
USGS:	United States Geologic Survey (United States Department of the Interior). Federal agency responsible for implementation and maintenance of discharge (flow) gauging stations on the nation's water bodies.
Watershed:	The land (measured in units of surface area) which drains water to a particular body of water or outlet.
WLA:	Waste Load Allocation. The fraction of waterbody loading capacity assigned to point sources in a watershed. Alternatively, the allowable pollutant load that an NPDES permitted facility may discharge without exceeding water quality standards.

WQS: Water Quality Standards. Defined in Chapter 61 of Environmental Protection Commission [567] of the Iowa Administrative Code, they are the specific criteria by which water quality is gaged in Iowa.

WWTP: Waste Water Treatment Plant. General term for a facility which processes municipal, industrial, or agricultural waste into effluent suitable for release to public waters or land application.

Zooplankton: Collective term for all animal plankton which serve as secondary producers in the aquatic food chain and the primary food source for larger aquatic organisms.

Appendix B --- General and Designated Uses of Iowa's Waters

Introduction

Iowa's water quality standards (Environmental Protection Commission [567], Chapter 61 of the Iowa Administrative Code) provide the narrative and numerical criteria by which water bodies are judged when determining the health and quality of our aquatic ecosystems. These standards vary depending on the type of water body (lakes vs. rivers) and the assigned uses (general use vs. designated uses) of the water body that is being dealt with. This appendix is intended to provide information about how Iowa's water bodies are classified and what the use designations mean, hopefully providing a better general understanding for the reader.

All public surface waters in the state are protected for certain beneficial uses, such as livestock and wildlife watering, aquatic life, non-contact recreation, crop irrigation, and other incidental uses (e.g. withdrawal for industry and agriculture). However, certain rivers and lakes warrant a greater degree of protection because they provide enhanced recreational, economical, or ecological opportunities. Thus, all public bodies of surface water in Iowa are divided into two main categories: *general* use segments and *designated* use segments. This is an important classification because it means that not all of the criteria in the state's water quality standards apply to all water ways; rather, the criteria which apply depend on the use designation & classification of the water body.

General Use Segments

A general use segment water body is one which does not maintain perennial (year-round) flow of water or pools of water in most years (i.e. ephemeral or intermittent waterways). In other words, stream channels or basins which consistently dry up year after year would be classified as general use segments. Exceptions are made for years of extreme drought or floods. For the full definition of a general use water body, consult section 61.3(1) in the state's published water quality standards, which became effective on March 22, 2006 (Environmental Protection Commission [567], Chapter 61 of the Iowa Administrative Code).

General use waters are protected for the beneficial uses listed above, which are: livestock and wildlife watering, aquatic life, non-contact recreation, crop irrigation, and industrial, agricultural, domestic and other incidental water withdrawal uses. The criteria used to ensure protection of these uses are described in section 61.3(2) in the state's published water quality standards, which became effective on March 22, 2006 (Environmental Protection Commission [567], Chapter 61 of the Iowa Administrative Code).

Designated Use Segments

Designated use segments are water bodies which maintain flow throughout the year, or at least hold pools of water which are sufficient to support a viable aquatic community (i.e. perennial waterways). In addition to being protected for the same beneficial uses as the general use segments, these perennial waters are protected for more specific activities such as primary contact recreation, drinking water sources, or cold-water fisheries. There are a total of thirteen different designated use classes (Table B-1) which may apply, and a water body may have more than one designated use. For definitions of the use classes and more detailed descriptions, consult section 61.3(1) in the state's published water quality standards, which became effective on March 22, 2006 (Environmental Protection Commission [567], Chapter 61 of the Iowa Administrative Code).

Table B-1. Designated use classes for Iowa water bodies.

Class prefix	Class	Designated use	Brief comments
A	A1	Primary contact recreation	Supports swimming, water skiing, etc.
	A2	Secondary contact recreation	Limited/incidental contact occurs, such as boating
	A3	Children's contact recreation	Urban/residential waters that are attractive to children
B	B(CW1)	Cold water aquatic life – Type 2	Able to support coldwater fish (e.g. trout) populations
	B(CW2)	Cold water aquatic life – Type 2	Typically unable to support consistent trout populations
	B(WW-1)	Warm water aquatic life – Type 1	Suitable for game and nongame fish populations
	B(WW-2)	Warm water aquatic life – Type 2	Smaller streams where game fish populations are limited by physical conditions & flow
	B(WW-3)	Warm water aquatic life – Type 3	Streams that only hold small perennial pools which extremely limit aquatic life
	B(LW)	Warm water aquatic life – Lakes and Wetlands	Artificial and natural impoundments with "lake-like" conditions
C	C	Drinking water supply	Used for raw potable water
Other	HQ	High quality water	Waters with exceptional water quality
	HQR	High quality resource	Waters with unique or outstanding features
	HH	Human health	Fish are routinely harvested for human consumption

Appendix C --- Modeling Equations and Methodology

The Soil and Water Assessment Tool (SWAT) is a hydrologic and water quality model developed by the U.S. Department of Agriculture (USDA) Agricultural Research Service (ARS) (Arnold et al., 1998 Arnold and Fohrer, 2005; Gassman et al., 2005). It is a long-term, continuous, watershed-scale, simulation model that operates on a daily time step and is designed to assess the impact of land use and different land management practices on water, nutrient and bacteria yields. The model is physically based and includes major components of weather, hydrology, soil temperature, crop growth, nutrients, bacteria and land management. SWAT was later adapted to run within the Global Information Systems (GIS) platform in a version called ARCSWAT.

C.1 Model Set-up and Development

Model Development . It is standard practice to calibrate SWAT model flow output to USGS gauging stations within the watershed of interest. However in the case of Dry Run Creek, the gage at the confluence of Dry Run Creek and the Cedar River collects only stage data. There is a further complication in that at this gage flow gets backed up and floods upstream into Dry Run Creek. Therefore, this gage is not a point that can be calibrated to. The ideal solution would have been to choose a watershed with the same landuses as seen in Dry Run Creek that could be calibrated to a gage, find the appropriate curve numbers to calibrate the secondary watershed and apply those to Dry Run Creek. However, Dry Run Creek, with its amount of urban landuse is unique to the Iowan Surface. Therefore, the next option was to use an adjacent watershed, calibrate it to a corresponding USGS gage, use the curve numbers for all non-urban landuses within the Dry Run Creek model and then use standard urban curve numbers as cited within the SWAT model literature. The Beaver Creek watershed is directly north of the Dry Run Creek watershed. This is a typical Iowan Surface watershed with over 80 percent of the land in corn and soybean rotations. Additionally, this model had an advantage of already being in development for a grant research project through the EPA Region 7 TMDL program by the Center for Agricultural and Rural Development (CARD) at Iowa State University.

Model Inputs The ARCSWAT interface requires several major input files including: Digital Elevation Map (DEM) at 30 foot resolution, SURGO or STATSGO soils maps, and a landuse cover. A 2007 landuse cover was used which updated the 2002 landuse cover for new construction. The SURGO soils data was used. The model also requires weather data for precipitation and high/low temperature data. This data was acquired from the environmental Mesonet from the Waterloo station.

Once the initial data was loaded, the models were set up. During the watershed delineation process, outlets were removed and added in order to create subwatersheds that are similar in size but encompassed either an area dominated by rural landuse or urban landuse. The resulting subbasins for both the Beaver Creek and Dry Run Creek models are provided in figures C-1 and C-2. This was done in an effort to make later comparisons between major landuse categories easier. Slope was divided into five classes

(0-2, 2-5, 5-7, 7-9, and 9-9999). During the HRU definition thresholds were set at 10% for landuse, soils and slope classes. However, the landuse of forest and pastures were retained outside of the filter. The model was run for a weather period of 1990-2008.

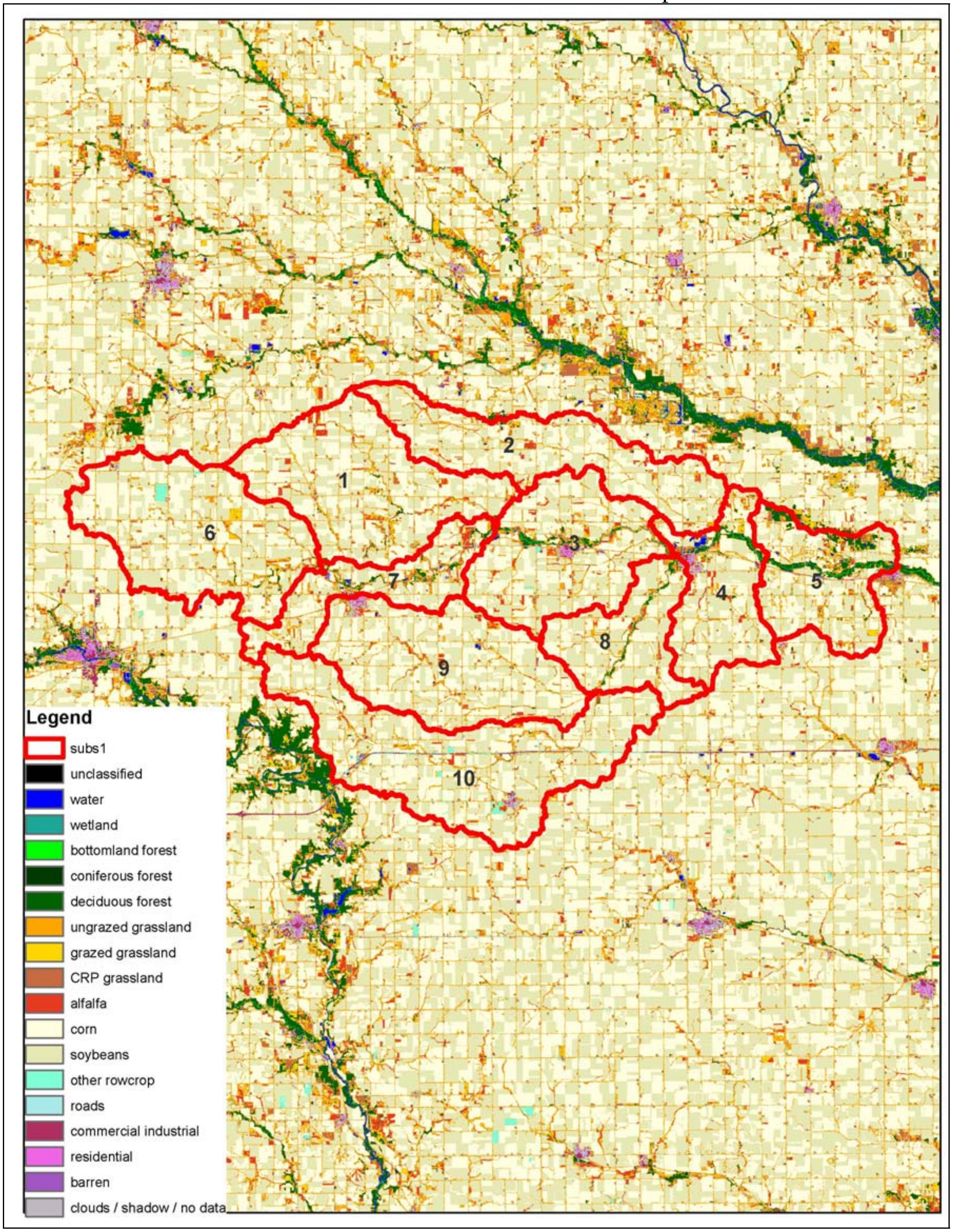

Figure C-1. SWAT subbasin delineation for the Beaver Creek Watershed.

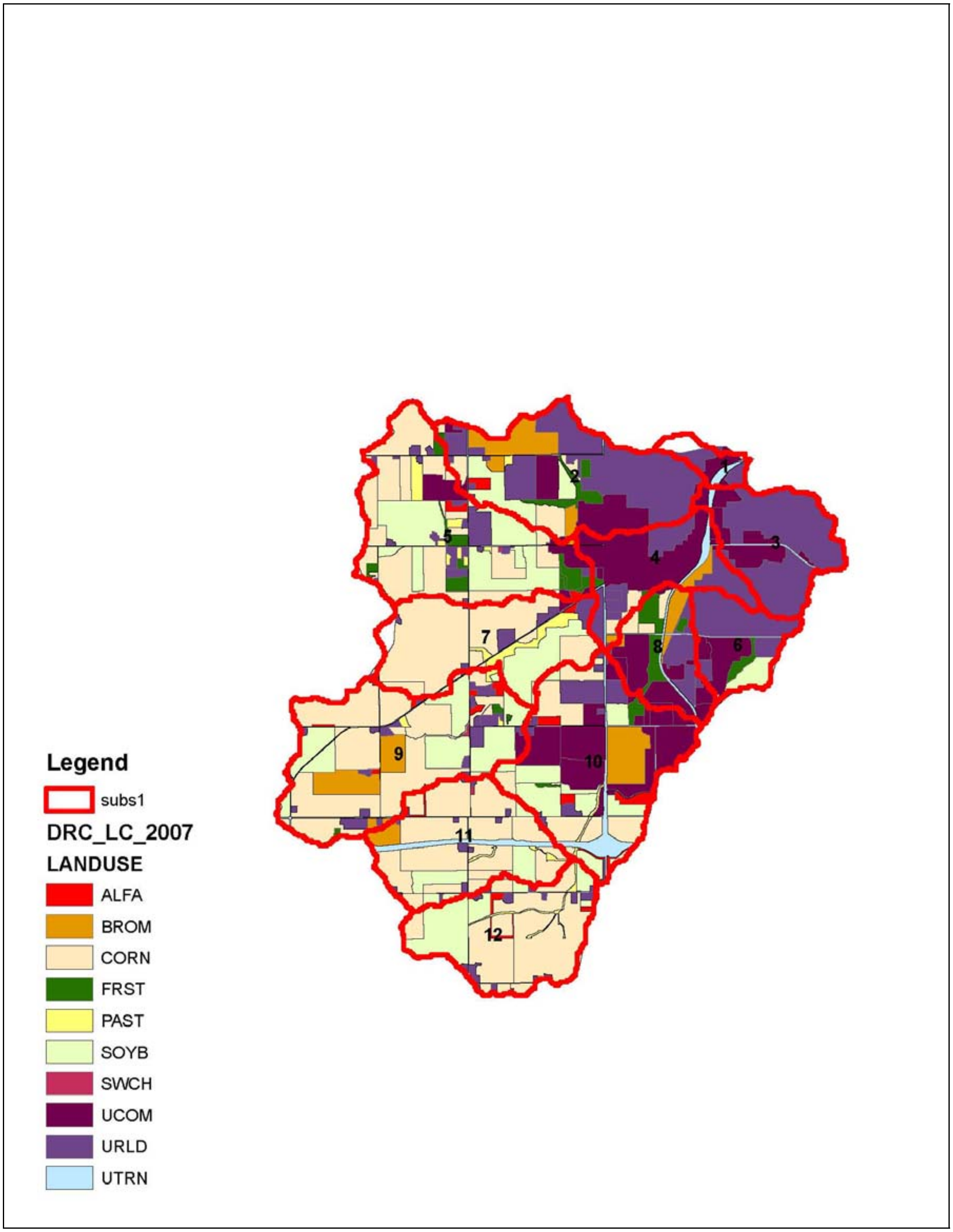

Figure C-2. SWAT subbasin delineation for Dry Run Creek Watershed.

Calibration. The Beaver Creek model was calibrated to the USGS gage station 0546300 at New Hartford, Ia. The model was run for the years 1990-2008 and model output from 1994-2008 was used in calibration. It is suggested by the developers of the SWAT model to skip at least the first 3 years of data to allow then model to converge. In this case the first 4 years were used. This approach provided a 15 year output data set. The model was calibrated to yearly and monthly flows. The final calibrated values are listed in Table C-1. The r-square values for these calibrations are provided in figures C-3 and C-4. A Nash-Sutcliffe statistical analysis was also ran for the yearly and monthly Beaver Creek models and resulted in values of 0.76 and 0.79 respectively.

Table C-1 SWAT parameter and final calibration value

Model Input	Parameter	Calibrated Value
Streamflow	Curve Number	
	Corn	67
	Soybean	68
	Grasses	59
	Alfalfa	59
	Forest	66
	Surface Runoff Lag	4 days
	Soil Evaporation Compensation Coeff.	0.95
	Groundwater Delay	30 days
	Alpha Baseflow Factor	0.048 days
	Soil ET method	
Nitrate	Ammonia Fertilizer Rate	152 lbs/ac
	Di-ammonium Phosphate Fertilizer Rate	156 lbs/ac
	Nitrogen Percolation Coeff.	0.8

Once the Beaver Creek model was developed the Dry Run Creek model was also assigned the same curve numbers with the exception of expansion of the urban numbers. Because runoff from impervious surface was chosen as the surrogate pollutant and this would be what was targeted for future BMPs, a higher level of resolution was needed. SWAT allows for several parameters of urban landuse (transportation, commercial, residential, ect.) to be used that create better resolution. The main categories of urban landuse for Dry Run Creek were: transportation, commercial and residential (low, medium and high). The standard curve numbers provided by the SWAT model were used since these are well documented in literature.

Upon a review of the Beaver Creek model it was found slopes were inaccurately calculated. Slopes were recalculated via a re-delineation of the model. However, this resulted in little to no change to subbasin water yields. Since the model was used strictly for determining curve numbers and the resulting curve numbers matched other modeling efforts in the ecoregion, there were no resulting changes made to the Dry Run Creek model.

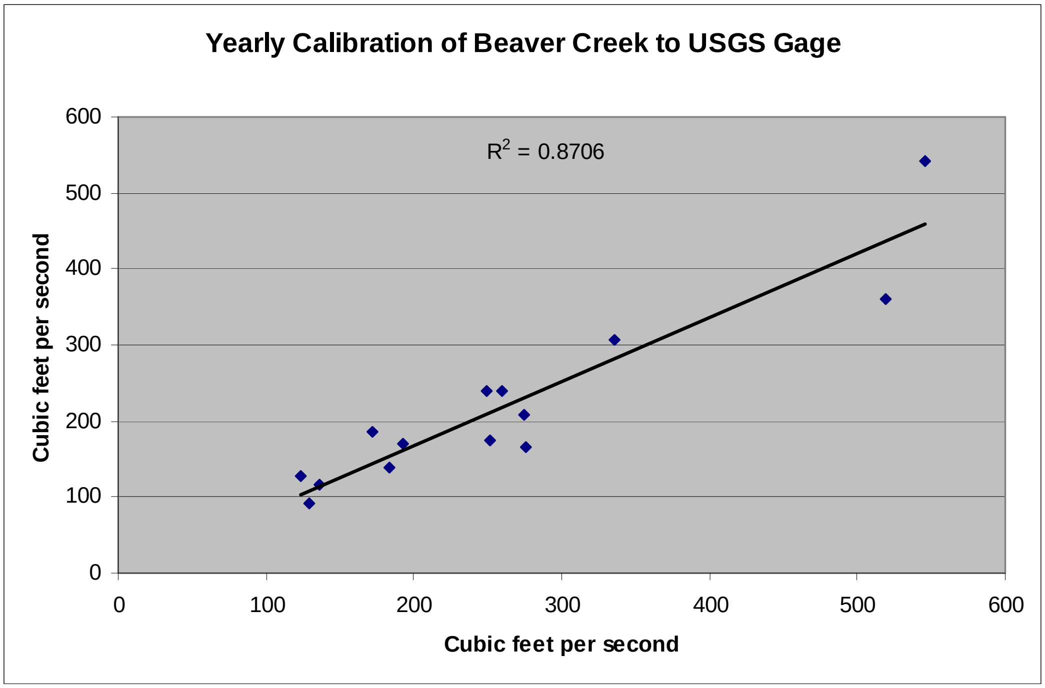

Figure C-3. Yearly flow calibration for Beaver Creek.

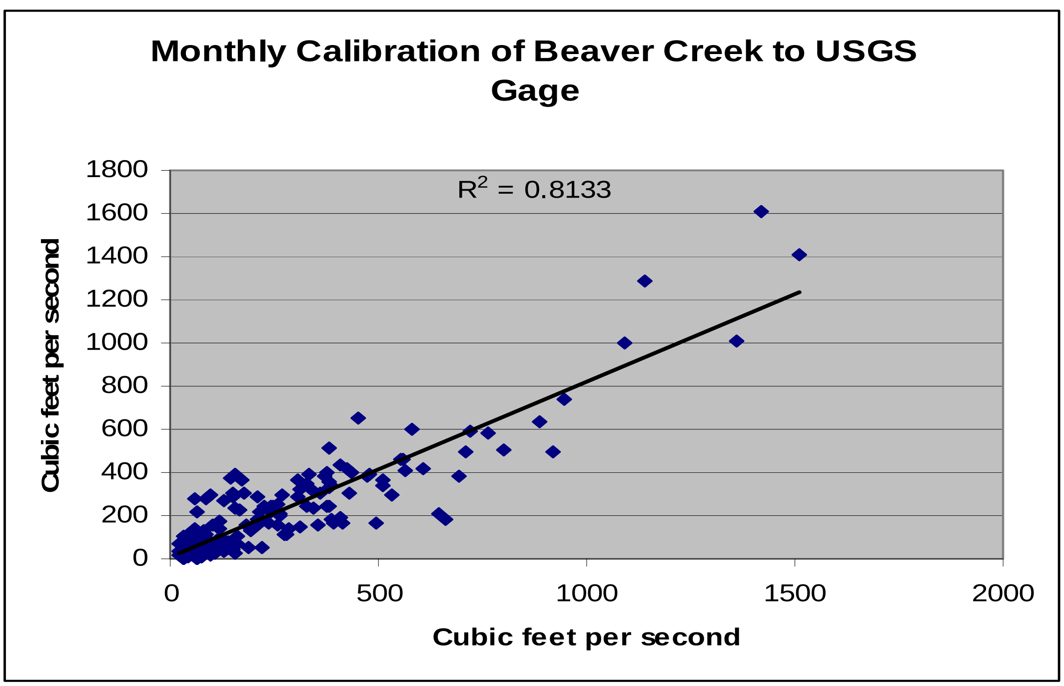

Figure C-4. Monthly flow calibration for Beaver Creek.

C.2 Validation of the Dry Run Creek Model

After the Dry Run Creek model was build using these input parameters, methods of assessing the model performance were still needed. Although there was not a properly operating gage to which to validate this and local variation in rainfall would produce high variability in daily flows between Beaver and Dry Run creeks, monthly and yearly flow patterns should be similar. Other annual basin values such as precipitation, baseflow, and evapotranspiration (ET) were compared for model agreement (Table C-2). Additionally, water yields in rural subbasins should also be comparable since these are corrected for area. In general there was good agreement between the models.

Table C-2. Key parameter comparison for the two watersheds.

Parameter	Beaver Creek	Dry Run Creek
Precipitation	884.7 mm	821.8 mm
Surface Q	116.17 mm	155.75 mm
Total GW Q*	128.81 mm	125.62 mm
Baseflow %	52.60%	44.60%
ET	622.6 mm	524.4 mm

**Total GW Q consists of groundwater Q, lateral Q, and tile drain Q.*

The differences between baseflow and ET between the two models can both be accounted for by the increase in impervious surface percentages. In the Dry Run Creek watershed the impervious surfaces reduce vegetation leading to less ET and at the same time reduce the amount of water that can infiltrate and move as a component of groundwater which decreases baseflow. Comparisons of flow between models yielded r-square values of .78 for yearly and .62 for monthly flows. Surface water yields in rural subbasins were also compared on an annual basis. There was good agreement between the models for this component. A sampling of years is shown below in figure (C-5). Of the years chosen to compare, 1994 and 1999 were considered near average precipitation years while 2003 was a below average year and 2008 was an above average year.

Validations were also performed using r-square values for the yearly and monthly flow comparisons (figures C-5 and C-6).

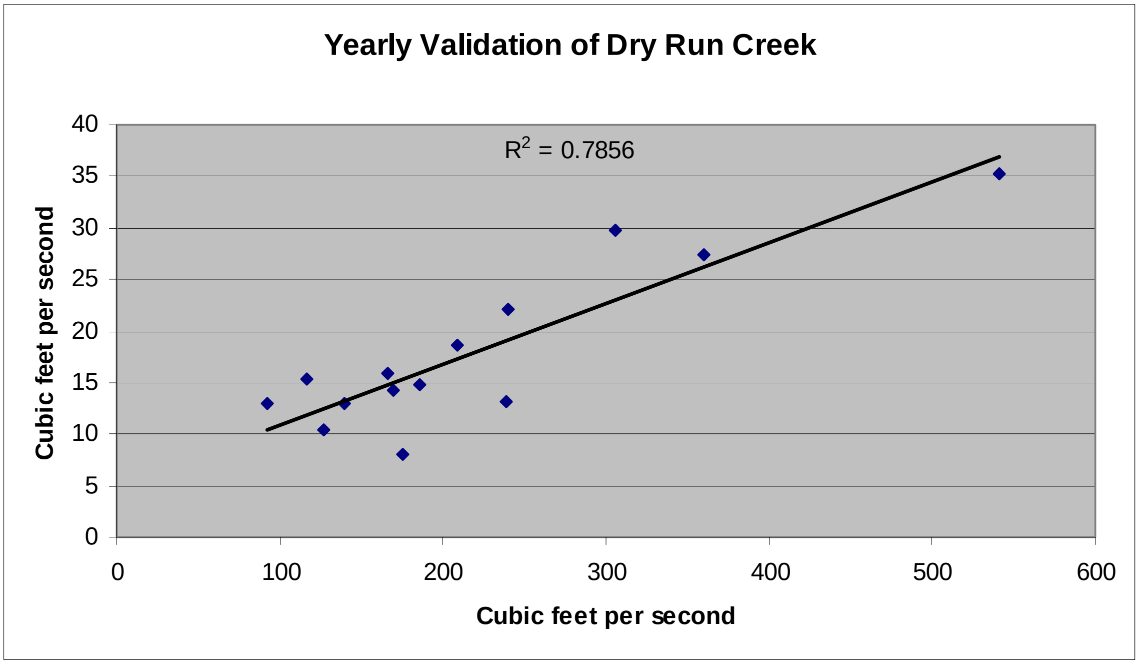

Figure C-5. Yearly flow validation for Dry Run Creek.

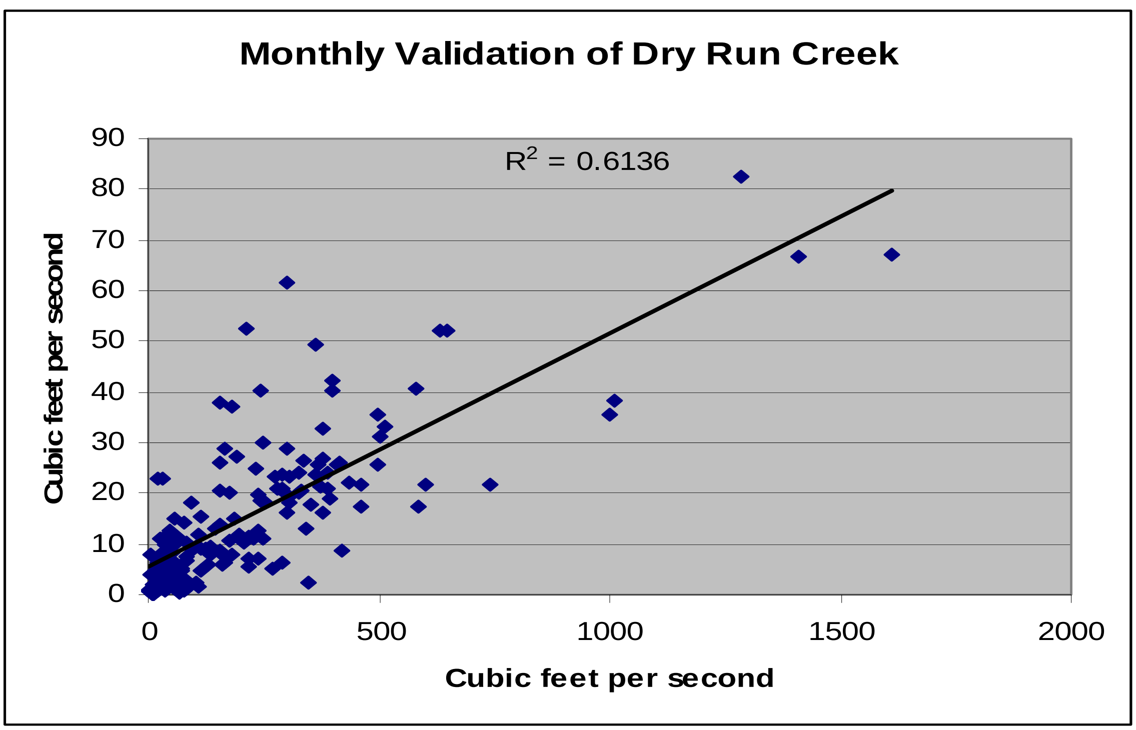

Figure C-6. Monthly flow validation for Dry Run Creek

C.3 Assessing the effects of impervious surface

After the model to model comparisons were made, the Dry Run Creek model was then analyzed for differences between urban and rural subbasins to determine the current effects of the impervious surfaces within the watershed. Differences were already noted in the decreased baseflow and ET seen within Dry Run Creek model output. However, understanding the resulting differences in flow and water yields per landuse would allow for better BMP targeting within watershed improvement plans.

Water yields were compared between rural and urban subbasins. Any subbasin with a landuse comprised of 50 percent urban landuse or more was designated as an urban subbasin while any subbasin whose landuse was 50 percent or more in corn, soybean, or pasture was designated as rural. Overall water yields were 20 to 50 percent higher in urban watersheds than in rural watersheds. A sample of these can be seen in figure C-6 using the same sample years chosen for the comparison used in figure C-5.

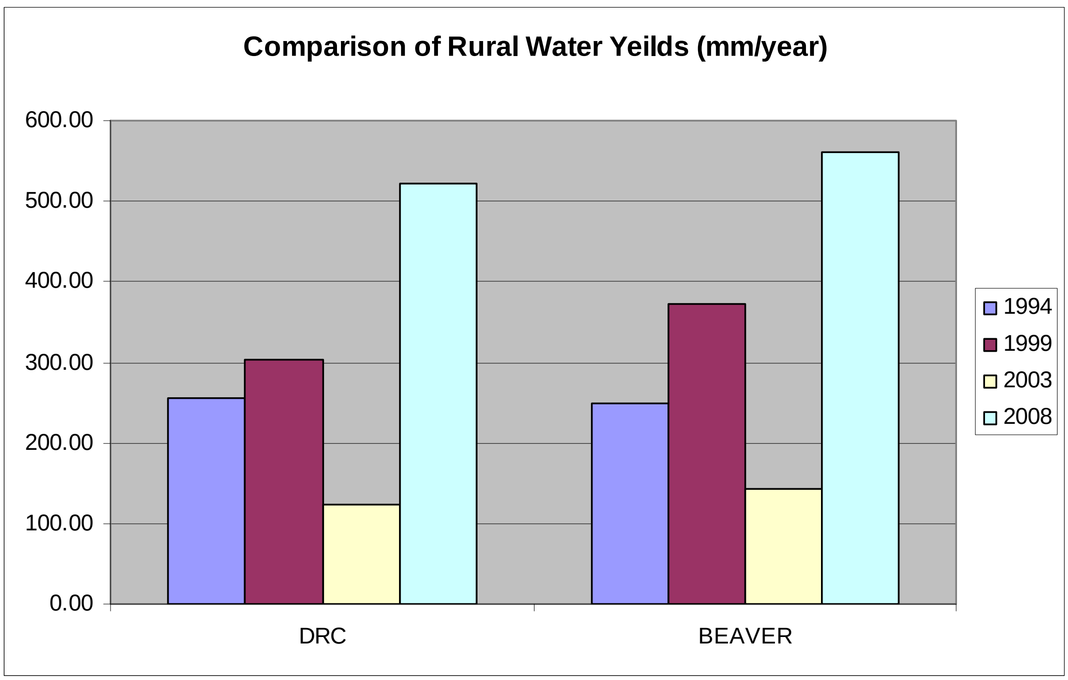

Figure C-7 Comparison of water yields from rural subbasins in Beaver and Dry Run Creek Watersheds

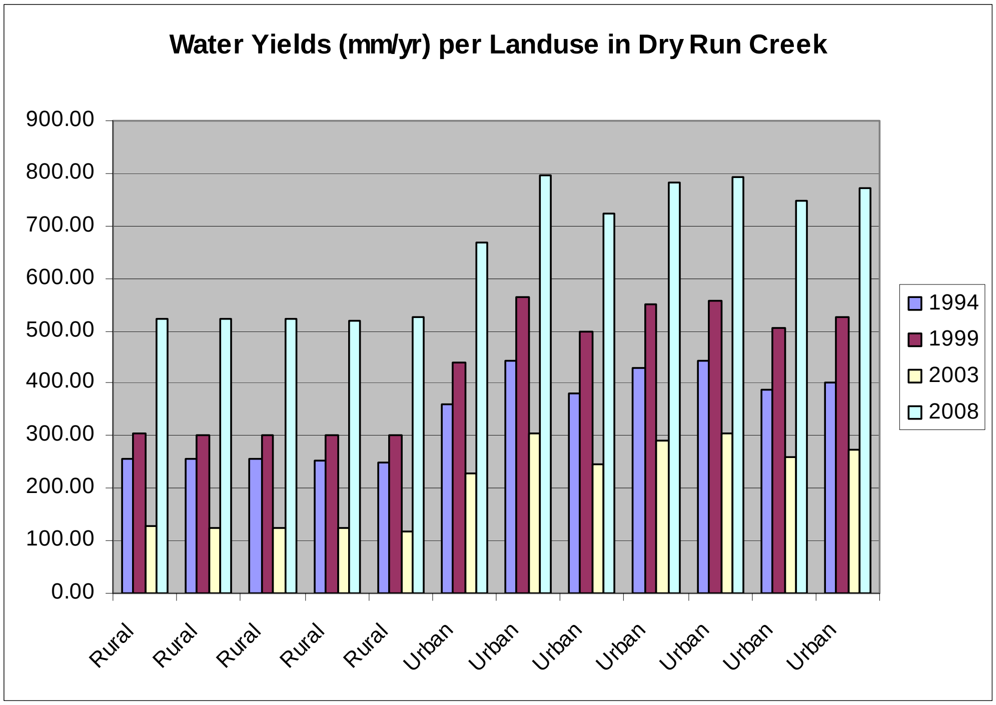

Figure C-8 Comparison of rural and urban subbasin water yields in Dry Run Creek Watershed.

Scientific literature indicates that a connected impervious surface percentage of greater than 10 percent is a threshold at which both fish and macroinvertebrate populations begin to suffer. SWAT assigns an impervious and connected impervious percentage to each urban landuse and allows the user to manipulate these within the database. To model the effects of modifying the urban landscape to achieve 10 percent connected impervious surface or less, all the urban landuses with the exception of transportation were set to a connected impervious surface percentage of 10 percent. Transportation was set at 50 percent since 10 percent was considered to be an impossible target.

Flow duration curves comparing the difference in flows between existing conditions and the decreased impervious surface scenario were built (Figure C-7). These curves show two important differences between the existing conditions and the reduced CIS scenario and the associated flows. The first and most important difference is the reduction of flow at the lower percentiles. This represents larger storm events or periods of increased flows. The reduced CIS scenario results in a significant reduction in flow which is accounted for by the reduced runoff. Additionally, the reduction in runoff results in increased baseflow which are evident at the higher percentile which represents dominant low flow conditions.

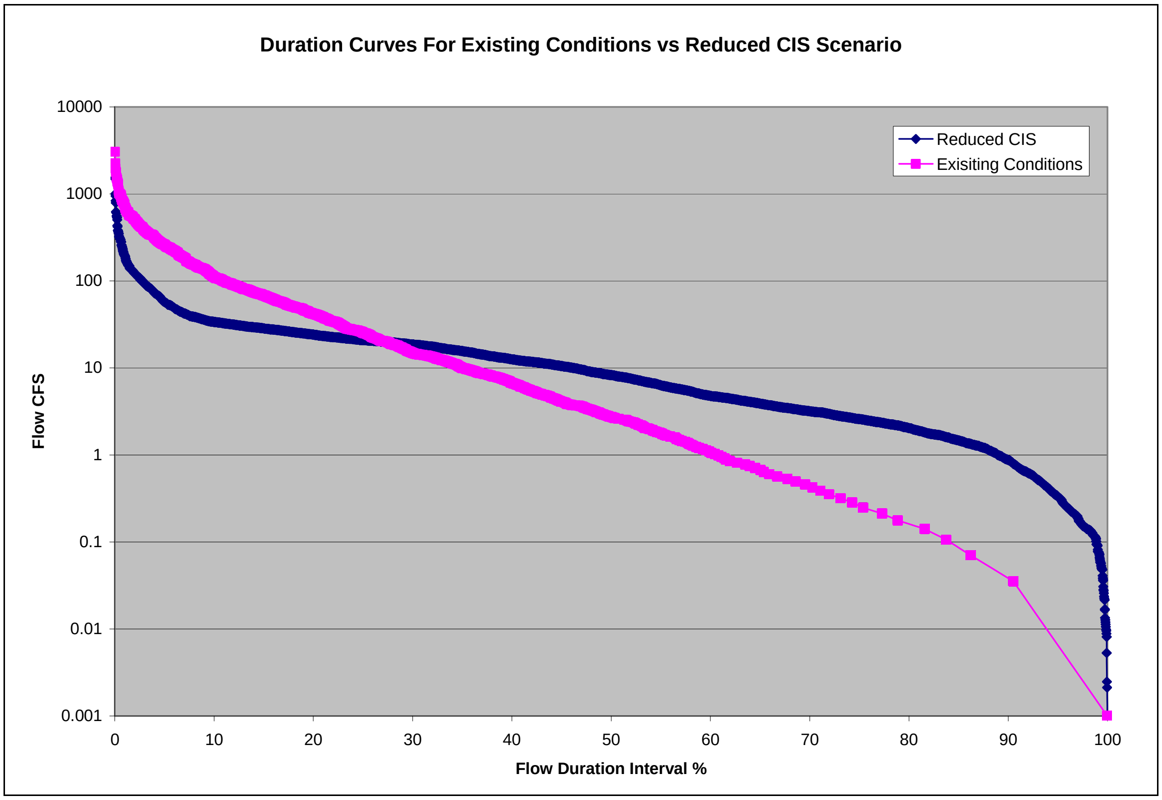

Figure C-9 Duration curve depicting differences in flow between modeled existing conditions and modeled scenario of 10 percent connected impervious surface.

Because of the nature of this impairment, assigning a maximum daily flow target would be impractical since rain events and the resulting overland flow are episodic in nature. However, a daily maximum is required by the Clean Water Act. In an attempt to provide a meaningful daily number that would both satisfy the Clean Water Act requirement and still be useful to watershed improvement groups and city managers, the target was set to the 24-hour water quality event of 1.25 in. (+/- 0.125 inches) for this region of Iowa. The criteria used can be found in the Iowa Stormwater Management Manual at the following link: http://www.intrans.iastate.edu/pubs/stormwater/documents/2C-2%20Rainfall%20and%20Runoff%20Analysis.pdf

This was chosen because many BMPs are designed to this size storm event. Also, it is unrealistic to expect any BMPs to control runoff of larger events that cause flooding. Any daily maximum assigned to large events would therefore also be impractical. A discussion of the BMPs that would be useful in the Dry Run Creek watershed for the smaller return events is found in section 4 of the TMDL. Each event was compared between the existing initial conditions and the revised CIS conditions for flow (Table C-3). Not surprisingly, the percent difference decreases with the larger events as BMPs would transition from increasing infiltrations and detaining smaller episodic flows more toward BMPs for flood control. The revised CIS flows were then used for the maximum daily load targets for this TMDL.

Table C-3 Resulting flow reductions from decreasing impervious surface to 10 percent.

Date	Recorded Rainfall (inches)	Flow Current CIS (CFS)	Flow 10% CIS (CFS)
6/12/1994	1.14	57.02	17.07
7/4/1994	1.26	71.93	32.57
7/13/1994	1.18	70.28	36.54
8/12/1994	1.14	66.36	32.64
6/28/1995	1.30	130.45	93.14
8/29/1995	1.34	84.77	37.28
10/29/1996	1.18	61.81	24.97
9/22/1997	1.18	66.92	31.49
5/23/1998	1.22	93.49	55.48
6/20/1998	1.30	254.07	249.06
6/24/1998	1.34	258.44	251.51
8/17/1998	1.22	112.28	84.91
10/4/1998	1.26	106.30	70.67
4/22/1999	1.34	144.69	114.24
5/12/1999	1.18	119.49	92.44
7/26/1999	1.14	118.06	93.66
11/23/1999	1.18	59.96	17.99
6/23/2000	1.26	140.28	119.18
7/4/2002	1.14	68.43	31.48
5/8/2003	1.18	81.41	48.62
8/3/2004	1.26	78.54	34.00
8/26/2004	1.30	70.84	26.74
4/22/2005	1.14	61.39	23.72
5/12/2005	1.18	73.01	30.75
8/11/2005	1.18	72.49	36.58
7/11/2006	1.14	63.98	27.03
6/21/2007	1.18	97.72	65.45
6/22/2007	1.26	148.16	114.10
7/18/2007	1.18	90.55	52.61
8/18/2007	1.14	76.90	47.29
8/20/2007	1.26	361.55	362.95
8/24/2007	1.18	300.72	320.46
10/2/2007	1.14	172.45	154.14
Average Flows (CFS)		**116.20**	**85.7797879**
Resulting Reduction		**26.18**	**percent**

Appendix D --- Public Comments

No public comments were received during the comment period.

Appendix E --- Water Quality Data

	2005												
Site DRC 1	06/09/05	06/16/05	06/23/05	06/30/05	07/07/05	07/14/05	07/21/05	07/28/05	08/04/05	08/11/05	08/18/05	08/25/05	09/01/05
Ammonia N as N (mg/L)	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
E.coli (colonies/100mL)	960	530	5200	590	500	550	6300	140	380	34000	6600	340	130
Nitrate + Nitrite N (mg/L)	3.8	2.9	2.2	9.7	4.9	2.7	1.8	2.3	1.9	1.2	1	1.8	1.8
Total Kjeldahl N (mg/L)	0.3	0.15	0.16	0.49	0.16	0.05	0.54	0.21	0.1	0.62	0.9	0.1	0.2
Total Phosphate (mg/L)	0.03	<0.02	0.03	0.11	0.04	0.07	0.09	0.04	0.03	0.13	0.28	0.05	0.03
Temp ^{o}C		17.2	20.4	19.5	18.6	20.6	22.1	19.6	19.5			19.3	17
DO (mg/L)		5.45	6.6	5.6	6.5	7.8	4.8	7	9.2			6.6	7.8
pH					8	8							
Chloride (ppm) (test strips)													
Site DRC 2	06/09/05	06/16/05	06/23/05	06/30/05	07/07/05	07/14/05	07/21/05	07/28/05	08/04/05	08/11/05	08/18/05	08/25/05	09/01/05
Ammonia N as N (mg/L)	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	
E.coli (colonies/100mL)	210	210	210	160	150	370	580	140	82	3000	1400	200	
Nitrate + Nitrite N (mg/L)	1.3	0.9	0.95	2.3	1.3	1	1.2	1	1.1	0.087	0.8	0.92	
Total Kjeldahl N (mg/L)	0.05	0.14	0.18	0.3	0.1	0.1	0.19	0.22	0.1	0.34	0.32	0.1	
Total Phosphate (mg/L)	0.03	<0.02	0.03	0.06	0.03	0.06	0.05	0.03	0.03	0.09	0.12	0.04	
Temp ^{o}C		16.6	20.7	17.8	18.1	19.2	20	17.6	18.3			19.5	
DO (mg/L)		5.6	5	5.8	6.9	7.1	6.5	7.3	7.2			7.1	
pH					7.8	7.8							
Site DRC 3	06/09/05	06/16/05	06/23/05	06/30/05	07/07/05	07/14/05	07/21/05	07/28/05	08/04/05	08/11/05	08/18/05	08/25/05	09/01/05
Ammonia N as N (mg/L)	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
E.coli (colonies/100mL)	1100	200	500	520	540	730	10000	240	120	42000	11000	160	100
Nitrate + Nitrite N (mg/L)	4.8	4.1	3	11	6.5	3.8	2.1	3.2	2.5	1.3	1.2	2.5	2.6
Total Kjeldahl N (mg/L)	0.22	0.24	0.05	0.56	0.38	0.13	0.55	0.24	0.1	0.62	0.98	0.2	0.2
Total Phosphate (mg/L)	0.05	0.02	0.06	0.11	0.04	0.04	0.12	0.04	0.04	0.12	0.32	0.05	0.04
Temp ^{o}C		17.4	22.1	19.5	19.5	21.4	23.2	20	21			19.8	17.9
DO (mg/L)		5.55	5.5	6.5	6.5	7.3	5.6	7.5	9.3			7.8	7.9
pH					7.7	7.8							
Chloride (ppm)													
Site DRC 4	06/09/05	06/16/05	06/23/05	06/30/05	07/07/05	07/14/05	07/21/05	07/28/05	08/04/05	08/11/05	08/18/05	08/25/05	09/01/05
Ammonia N as N (mg/L)	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
E.coli (colonies/100mL)	370	160	240	300	350	410	910	200	110	3400	3100	240	100
Nitrate + Nitrite N (mg/L)	4.3	3.6	2.8	10	5.5	3.5	2.5	3.1	2.6	2.1	2.2	2.5	2.6
Total Kjeldahl N (mg/L)	0.12	0.34	0.05	0.24	0.1	0.1	0.25	0.12	0.1	0.33	0.1	0.1	0.2
Total Phosphate (mg/L)	0.02	0.01	0.04	0.12	0.05	0.06	0.06	0.05	0.03	0.07	0.08	0.06	0.03
Temp ^{o}C		16.8	20.5	18.4	18.1	20	20.4	20.2	23			20.6	16.3
DO (mg/L)		5.3	4.9	6.3	6	6.5	6	6.6	8.8			5.9	7.5
pH					8.1	7.3							

Chloride (ppm)

2005													
Site DRC 5	06/09/05	06/16/05	06/23/05	06/30/05	07/07/05	07/14/05	07/21/05	07/28/05	08/04/05	08/11/05	08/18/05	08/25/05	09/01/05
Ammonia N as N (mg/L)	0.025	0.12	0.025	0.025	0.025	0.025	0.11	0.025	0.025	0.07	0.08	0.025	0.025
E.coli (colonies/100mL)	1400	570	4200	630	900	1200	13000	710	1900	21000	21000	110000	6900
Nitrate + Nitrite N (mg/L)	7.4	8.8	7.1	13	11	6.5	2	3.3	2	0.8	0.57	0.92	0.71
Total Kjeldahl N (mg/L)	0.45	0.61	0.9	0.74	0.4	0.22	0.89	0.48	0.34	0.75	1.3	0.4	0.5
Total Phosphate (mg/L)	0.02	0.03	0.05	0.17	0.05	0.09	0.22	0.07	0.03	0.13	0.44	0.1	0.06
Temp ^{o}C		17.4	23.3	20.7	19.4	23.1	24.3	18	19.1			22.2	19.4
DO (mg/L)		5.4	5.2	6.6	5.7	6.7	4.7	6.8	8.3			8.1	8.5
pH					8.1	7.5							
Chloride (ppm)													
Site DRC 6	06/09/05	06/16/05	06/23/05	06/30/05	07/07/05	07/14/05	07/21/05	07/28/05	08/04/05	08/11/05	08/18/05	08/25/05	09/01/05
Ammonia N as N (mg/L)	0.05	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
E.coli (colonies/100mL)	420	330	550	350	510	340	1100	570	210	5100	2600	660	1400
Nitrate + Nitrite N (mg/L)	9.4	8.5	4.9	16	14	10	4	6.5	3.6	0.84	0.96	0.25	0.15
Total Kjeldahl N (mg/L)	0.52	0.62	1	0.38	0.46	0.3	0.59	0.74	1.9	0.71	0.7	1.1	2.2
Total Phosphate (mg/L)	0.07	0.06	0.08	0.13	0.08	0.12	0.08	0.09	0.21	0.1	0.17	0.26	0.46
Temp ^{o}C		17.3	22.2	19.5	18.8	21.7	23.4	19.4	22.5	21.6		21.6	18.6
DO (mg/L)		5	4.3	6	5.7	5.6	3.5	6	6	3.4		6.6	5.5
pH					7.9	7.5							
Chloride (ppm)													
Site DRC 7	06/09/05	06/16/05	06/23/05	06/30/05	07/07/05	07/14/05	07/21/05	07/28/05	08/04/05	08/11/05	08/18/05	08/25/05	09/01/05
Ammonia N as N (mg/L)	0.025	0.08	0.025	0.025	0.025	0.025	0.025	0.025			0.025		
E.coli (colonies/100mL)	130	160	310	130	60	30	400	210			2200		
Nitrate + Nitrite N (mg/L)	13	13	13	14	14	14	11	11			5.2		
Total Kjeldahl N (mg/L)	0.38	0.52	0.46	0.23	0.55	0.42	0.39	1.1			0.77		
Total Phosphate (mg/L)	0.01	0.02	0.04	0.11	0.07	0.13	0.05	0.2			0.1		
Temp ^{o}C		13.9	17.4	18.1	17.6	17.4	19.4	18.8					
DO (mg/L)		6.23	5.5	5.6	6.4	5.8	4.9	6.9					
pH					8.1	7.3							
Chloride (ppm)													
Site DRC 8	06/09/05	06/16/05	06/23/05	06/30/05	07/07/05	07/14/05	07/21/05	07/28/05	08/04/05	08/11/05	08/18/05	08/25/05	09/01/05
Ammonia N as N (mg/L)	0.025	0.025	0.025	0.025	0.025	0.025	0.05	0.025	0.025	0.025	0.025	0.025	0.025
E.coli (colonies/100mL)	970	440	8300	450	410	570	3900	2900	560	12000	8100	160	280
Nitrate + Nitrite N (mg/L)	9.6	10	8	14	13	7.3	1.9	3.4	2.2	0.65	0.47	1.2	1.1
Total Kjeldahl N (mg/L)	0.56	0.42	0.48	0.46	0.45	0.35	0.56	0.55	0.42	0.8	0.9	0.4	0.5
Total Phosphate (mg/L)	0.03	0.07	0.06	0.17	0.05	0.06	0.09	0.08	0.04	0.14	0.26	0.06	0.06
Temp ^{o}C		17	22.4	19.5	18.7	21.4	24.6	19.8	21.8	19.8		21.1	18.2
DO (mg/L)		5.2	5	6.4	6.7	6	5.1	5.7	6.7	4.5		6.4	6.7
pH					7.5	7.7							
Chloride (ppm)													

						2005							
Site DRC 9	06/09/05	06/16/05	06/23/05	06/30/05	07/07/05	07/14/05	07/21/05	07/28/05	08/04/05	08/11/05	08/18/05	08/25/05	09/01/05
Ammonia N as N (mg/L)	0.025	0.025	0.025	0.025	0.025	0.025	0.05	0.025	0.025	0.025	0.05	0.09	0.025
E.coli (colonies/100mL)	340	450	2100	240	250	780	2500	230	600	2200	2700	260	730
Nitrate + Nitrite N (mg/L)	13	12	11	15	14	11	7.7	7.1	5.3	3.5	1.5	2.7	2.6
Total Kjeldahl N (mg/L)	0.25	0.19	0.09	0.32	0.1	0.24	0.43	0.35	0.42	0.4	1.2	0.4	0.2
Total Phosphate (mg/L)	0.01	0.07	0.09	0.1	0.04	0.07	0.07	0.05	0.07	0.12	0.5	0.07	0.08
Temp ^{o}C		14.7	18.6	17.8	16.5	18.6	20	18	20.8	21.1		19.2	15.8
DO (mg/L)		6.6	4.8	5.6	5.5	5.5	5.2	6.8	6.8	5.8		5.7	6.2
pH					7.7	7.1							
Chloride (ppm)													
Site DRC 10	06/09/05	06/16/05	06/23/05	06/30/05	07/07/05	07/14/05	07/21/05	07/28/05	08/04/05	08/11/05	08/18/05	08/25/05	09/01/05
Ammonia N as N (mg/L)	0.05	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
E.coli (colonies/100mL)	950	530	1200	490	580	520	3600	230	270	29000	6800	110	270
Nitrate + Nitrite N (mg/L)	13	13	11	16	16	11	1.5	5.6	2.2	0.59	0.51	0.63	0.16
Total Kjeldahl N (mg/L)	0.37	0.29	0.31	0.7	0.1	0.17	0.66	0.61	0.34	0.53	0.79	0.2	0.4
Total Phosphate (mg/L)	0.04	0.06	0.07	0.15	0.05	0.08	0.09	0.08	0.04	0.07	0.16	0.07	0.06
Temp ^{o}C		16.4	20.8	19.8	17.4	20.4	23.5	18.2	21.3			20.5	17
DO (mg/L)		6	5.2	6.7	6.5	5.6	4.2	6.2	5			7	5.5
pH					8	7.7							
Chloride (ppm)													

2006

Site DRC 1	03/09/06	04/12/06	04/26/06	05/02/06	05/24/06	06/08/06	06/15/06	06/20/06	07/05/06	07/18/06	08/01/06
Ammonia N as N (mg/L)	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.050	0.025	0.025	0.025
E.coli (colonies/100mL)	220	73	82	270	220	360	880	6900	630	1400	710
Nitrate + Nitrite N (mg/L)	3.4	4.2	5.5	13.0	4.9	4.1	4.8	3.6	2.8	2.3	2.2
Total Kjeldahl N (mg/L)	0.8	0.4	0.2	0.6	0.1	0.1	0.3	0.6	0.1	0.1	0.2
Total Phosphate (mg/L)	0.10	0.03	0.02	0.10	0.03	0.03	0.04	0.10	0.04	0.06	0.03
Ortho-phosphate (mg/L)		0.01	0.01	0.06	0.01	0.02	0.02	0.03	0.03	0.02	0.01
TSS (mg/L)		5	5	17	5	6	6	58	6	5	4
TDS (mg/L)									330	310	340
Temp ^{o}C	6	15.7	13	12.3	21.9	20.1	18.2	18.5	16	17.8	19.8
DO (mg/L)	11.6	9.5	9.6	9.2	6.8	6.7	6.8	6.4	10.1	9.3	9.1
pH	7.9	8.2	8.4	8.4	8.2	8.3	8.2	8.2	8.3	8.3	8.4
Turbidity (NTU)	40	4.7	2.3	8.4	3.2	3	3.8	34.7	4	1.4	2
Transp. (mm)	190	>600	>600		>600	>600	>600		>600	>600	
Chloride (ppm)	208	34		46	33	33	33		24	23	24
flow rate (CFS)									28		26

Site DRC 2	03/09/06	04/12/06	04/26/06	05/02/06	05/24/06	06/08/06	06/15/06	06/20/06	07/05/06	07/18/06	08/01/06
Ammonia N as N (mg/L)	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.120	0.025	0.025	0.025
E.coli (colonies/100mL)	280	40	240	60	300	480	260	4000	370	380	160
Nitrate + Nitrite N (mg/L)	3.0	1.0	1.3	3.4	1.4	1.5	1.3	1.1	1.3	1.4	1.4
Total Kjeldahl N (mg/L)	1.0	0.2	0.2	0.3	0.1	0.1	0.1	0.6	0.1	0.1	0.1
Total Phosphate (mg/L)	0.14	0.02	0.01	0.05	0.03	0.03	0.02	0.10	0.02	0.02	0.02
Ortho-phosphate (mg/L)		0.01	0.01	0.02	0.01	0.01	0.07	0.02	0.01	0.01	0.01
TSS (mg/L)		1	2	6	6	3	3	39	2	3	3
Temp ^{o}C	5	16.2	14.8	14.9	21.1	20.1	18.6	17.6	19.4	19.5	21.2
DO (mg/L)	10.9	8.8	7.9	8.1	6.1	6.3	6.1	5.8	6.6	6	6.1
pH	7.8	8.3	8.3	8.4	8.3	8.3	8.4	8.3	8.3	8.4	8.3
Turbidity (NTU)	35.8	1.3	0.8	5.8	3.5	1.9	1.4	19.3	2.4	2.5	3
Transp. (mm)	240	>600			>600	>600	>600	350	>600	>600	>600
Chloride (ppm)	135	27		33	33	33	33		27	29	27

Site DRC 3	03/09/06	04/12/06	04/26/06	05/02/06	05/24/06	06/08/06	06/15/06	06/20/06	07/05/06	07/18/06	08/01/06
Ammonia N as N (mg/L)	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.250	0.025	0.025	0.025
E.coli (colonies/100mL)	380	150	50	290	170	450	1200	25000	450	820	1500
Nitrate + Nitrite N (mg/L)	3.6	5.1	6.8	14.0	6.0	5.2	5.9	3.0	3.6	2.9	2.8
Total Kjeldahl N (mg/L)	0.9	0.5	0.2	0.6	0.2	0.1	0.4	1.0	0.2	0.1	0.1
Total Phosphate (mg/L)	0.12	0.04	0.03	0.11	0.04	0.05	0.04	0.15	0.04	0.03	0.04
Ortho-phosphate (mg/L)		0.01	0.01	0.06	0.01	0.02	0.02	0.03	0.02	0.02	0.02
TSS (mg/L)		5	2	23	9	5	7	63	9	5	4
Temp ^{o}C	5.2	16.9	12.5	12.4	21.8	18.8	18.2	17.7	20	22.3	21.1
DO (mg/L)	11.4	8.4	9.6	7.5	6.5	6.8	6.8	5.7	7.3	6.3	6.5
pH	8	8.3	8.3	8.1	8.2	8.4	8.2	8.2	8.2	8.3	8.1
Turbidity (NTU)	55.2	4.3	1.7	21.9	5.4	3.3	7.7	55.7	5.2	5.5	3
Transp. (mm)	140	>600	>600		>600	>600	>600	120	>600	>600	>600
Chloride (ppm)	225	48		46	33	33	33		34	27	27

Site DRC 4	03/09/06	04/12/06	04/26/06	05/02/06	05/24/06	06/08/06	06/15/06	06/20/06	07/05/06	07/18/06	08/01/06
Ammonia N as N (mg/L)	0.060	0.100	0.025	0.025	0.025	0.025	0.025	0.120	0.025	0.025	0.025
E.coli (colonies/100mL)	460	290	20	210	220	50	490	4200	150	310	190
Nitrate + Nitrite N (mg/L)	4.8	4.6	5.4	12.0	4.4	4.0	3.9	2.6	3.0	2.7	2.5
Total Kjeldahl N (mg/L)	0.7	0.6	0.1	0.5	0.3	0.1	0.2	0.6	0.1	0.05	0.2
Total Phosphate (mg/L)	0.10	0.05	0.03	0.08	0.03	0.04	0.04	0.13	0.03	0.06	0.03
Ortho-phosphate (mg/L)		0.01	0.01	0.04	0.01	0.02	0.01	0.03	0.03	0.02	0.02
TSS (mg/L)		6	1	12	4	9	6	76	4	2	3
TDS (mg/L)									350	350	360
Temp ^{o}C	5.3	15.1	11.5	13.3	19.8	17.6	17.6	17.3	16	17.8	19.2
DO (mg/L)	10.6	8.5	8.9	8	5.7	6.7	6.1	6.6	9.2	8.5	7.9
pH	7.7	8.1	8.4	8.1	8	8.1	8.1	8.2	8.2	8	8
Turbidity (NTU)	28	2.8	1.2	11.9	2.7	4.5	3.3	118	3.8	3.8	2*
Transp. (mm)	200	>600	>600		>600	>600	>600	88		>600	
Chloride (ppm)	112	27		39	39	33	33	<33	29*	33	30*
flow rate (CFS)									20		17

Site DRC 5	03/09/06	04/12/06	04/26/06	05/02/06	05/24/06	06/08/06	06/15/06	06/20/06	07/05/06	07/18/06	08/01/06
Ammonia N as N (mg/L)	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.240	0.025	0.025	0.025
E.coli (colonies/100mL)	200	270	100	140	560	2200	2500	25000	3200	10000	7400
Nitrate + Nitrite N (mg/L)	3.2	7.2	14.0	18.0	14.0	14.0	15.0	4.8	9.2	5.4	5.6
Total Kjeldahl N (mg/L)	0.8	0.6	0.3	0.7	0.6	0.4	0.4	1.5	0.3	0.5	0.4
Total Phosphate (mg/L)	0.09	0.03	0.03	0.14	0.03	0.05	0.07	0.27	0.07	0.06	0.05
Ortho-phosphate (mg/L)		0.01	0.01	0.07	0.01	0.02	0.04	0.03	0.03	0.03	0.03
TSS (mg/L)		4	3	28	3	2	9	110	3	7	2
Temp ^{o}C	4.6	15.9	10	11.7	21.8	20.3	18.1	18.1	21.1	22.1	24.4
DO (mg/L)	11.8	10.3	10.5	6.7	5.9	6.2	6.1	6.3	6.5	5.4	5.1
pH	7.9	8.4	8.6	8.2	8.3	8.3	8.3	8.4	8.3	8.6	8.2
Turbidity (NTU)	24.3	5	3.6	22.1	3.4	2.3	6.5	66.1	4.9	9.2	3
Transp. (mm)	250	>600	>600		>600	>600	>600	140	>600	>600	>600
Chloride (ppm)	303	82		53	61	53	46		48	48	56

Site DRC 6	03/09/06	04/12/06	04/26/06	05/02/06	05/24/06	06/08/06	06/15/06	06/20/06	07/05/06	07/18/06	08/01/06
Ammonia N as N (mg/L)	0.080	0.840	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
E.coli (colonies/100mL)	1000	910	30	82	40	520	830	2800	180	82	150
Nitrate + Nitrite N (mg/L)	5.5	9.2	14.0	18.0	14.0	13.0	11.0	7.6	8.2	5.4	6.3
Total Kjeldahl N (mg/L)	1.2	1.9	0.6	0.9	0.4	0.6	0.5	0.9	0.4	0.5	0.5
Total Phosphate (mg/L)	0.15	0.16	0.04	0.08	0.05	0.10	0.08	0.12	0.06	0.06	0.07
Ortho-phosphate (mg/L)		0.07	0.01	0.05	0.01	0.03	0.03	0.02	0.04	0.04	0.04
TSS (mg/L)		13	11	10	12	36	19	44	7	6	6
TDS (mg/L)									410	390	400
Temp ^{o}C	5	13.8	10	12.3	20	20.6	18.2	18.9	19.5	23.3	24.2
DO (mg/L)	9.8	9.1	9	7.9	5.6	5.5	5.8	6.1	7.4	6.3	6.5
pH	7.7	8.1	8.4	8	8	8.1	8.2	8.1	8	8	7.7
Turbidity (NTU)	51.6	9.3	2.2	5.89	6.2	20.3	12.3	37.4	5.5	5.5	5*
Transp. (mm)	140	350	>600		>600	380	425		>600	>600	
Chloride (ppm) (test strips)	81	41		39	46	39	39		35	35	31

Site DRC 7	03/09/06	04/12/06	04/26/06	05/02/06	05/24/06	06/08/06	06/15/06	06/20/06	07/05/06	07/18/06	08/01/06
Ammonia N as N (mg/L)	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
E.coli (colonies/100mL)	10	5	5	50	10	10	5	270	280	45	120
Nitrate + Nitrite N (mg/L)	13.0	17.0	18.0	23.0	20.0	22.0	19.0	19.0	19.0	18	17
Total Kjeldahl N (mg/L)	0.2	0.2	0.2	0.6	0.2	0.1	0.2	0.2	0.1	0.1	0.2
Total Phosphate (mg/L)	0.04	0.01	0.02	0.11	0.02	0.03	0.02	0.02	0.04	0.03	0.04
Ortho-phosphate (mg/L)		0.01	0.01	0.09	0.01	0.01	0.01	0.02	0.01	0.01	0.01
TSS (mg/L)		3	2	1	1	14	1	5	1	1	10
Temp ^{o}C	4.5	9	9.1	13.4	14.8	15.5	15.3	15.4	16.6	18.4	18.5
DO (mg/L)	10.2	10.2	8.6	7.3	7.2	6.8	6.5	6.4	6.1	6.2	4.9
pH	7.5	8.1	8.2	7.6	7.9	7.5	7.9	7.7	7.7	7.1	7.5
Turbidity (NTU)	1.6	1.1	0.8	1.96	0.7	2.7	0.7	9.7	2	3.2	7
Transp. (mm)	600	600	600		600	600	600	600		600	600
Chloride (ppm)	<31	27		33	33	33	33	33	27	27	<27

Site DRC 8	03/09/06	04/12/06	04/26/06	05/02/06	05/24/06	06/08/06	06/15/06	06/20/06	07/05/06	07/18/06	08/01/06
Ammonia N as N (mg/L)	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
E.coli (colonies/100mL)	40	5	55	55	100	520	780	11000	830	720	390
Nitrate + Nitrite N (mg/L)	3.4	9.4	15.0	19.0	16.0	16.0	17.0	5.4	9.8	7.6	5
Total Kjeldahl N (mg/L)	0.8	0.6	0.4	0.7	0.4	0.3	0.3	0.8	0.4	0.4	0.4
Total Phosphate (mg/L)	0.07	0.04	0.03	0.12	0.04	0.04	0.06	0.10	0.06	0.04	0.05
Ortho-phosphate (mg/L)		0.01	0.01	0.06	0.01	0.01	0.07	0.01	0.03	0.03	0.03
TSS (mg/L)		5	2	19	3	4	2	36	3	2	4
Temp ^{o}C	6.1	16.4	11.9	14	21.4	21.2	18	18.9	22.4	23.5	23.7
DO (mg/L)	11.1	9.2	10.5	7.8	6.8	6.7	6.8	5.8	7	6	5.4
pH	7.9	8.3	8.4	8	8.1	8.2	8.2	8.2	8.2	8.2	8.2
Turbidity (NTU)	11.2	5.8	2.1	18.2	2.6	2.2	2.7	39.1	3.3	4	3
Transp. (mm)	>600	>600	>600		>600	>600	>600		>600	>600	>600
Chloride (ppm)	303	73		53	53	46	46		48	48	56

Site DRC 9	03/09/06	04/12/06	04/26/06	05/02/06	05/24/06	06/08/06	06/15/06	06/20/06	07/05/06	07/18/06	08/01/06
Ammonia N as N (mg/L)	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
E.coli (colonies/100mL)	20	50	30	370	60	540	940	2900	480	900	1600
Nitrate + Nitrite N (mg/L)	6.3	9.9	13.0	18.0	14.0	15.0	15.0	33.0	13.0	9.9	8.2
Total Kjeldahl N (mg/L)	0.6	0.4	0.4	0.4	0.3	0.7	0.3	0.5	0.3	0.3	0.2
Total Phosphate (mg/L)	0.09	0.03	0.02	0.07	0.03	0.13	0.06	0.07	0.05	0.06	0.06
Ortho-phosphate (mg/L)		0.01	0.01	0.04	0.01	0.02	0.09	0.01	0.03	0.04	0.04
TSS (mg/L)		5	13	20	13	10	14	33	11	16	12
Temp ^{o}C	4.7	11.7	8.2	13.6	17.8	15.4	15.7	14.5	15.4	20.7	19.9
DO (mg/L)	10.6	11	10	7.4	7.3	7	6.7	6.2	6.4	6.3	5.6
pH	7.9	8.2	8.4	7.7	8.1	8.1	8.2	8.2	8.4	7.9	8.1
Turbidity (NTU)	7.2	6.1	1.9	10.7	5.5	4.9	7.6	16.2	5.4	7.1	6
Transp. (mm)	>600	>600	>600		>600	>600	>600	395		>600	>600
Chloride (ppm)	81	48		39	39	33	39	33	34	34	27

Site DRC 10	03/09/06	04/12/06	04/26/06	05/02/06	05/24/06	06/08/06	06/15/06	06/20/06	07/05/06	07/18/06	08/01/06
Ammonia N as N (mg/L)	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
E.coli (colonies/100mL)	27	30	130	91	140	550	780	3000	530	440	500
Nitrate + Nitrite N (mg/L)	4.6	15.0	19	22.0	18.0	18.0	19.0	18.0	15.0	11	7.8
Total Kjeldahl N (mg/L)	0.8	0.4	0.4	0.6	0.4	0.5	0.3	0.3	0.4	0.3	0.3
Total Phosphate (mg/L)	0.09	0.03	0.03	0.11	0.02	0.05	0.07	0.05	0.05	0.1	0.06
Ortho-phosphate (mg/L)		0.01	0.01	0.07	0.01	0.02	0.02	0.01	0.03	0.03	0.03
TSS (mg/L)		2	2	13	2	6	5	9	4	4	10
Temp ^{o}C	4.4	12.3	8	13.5	16.5	16.7	16.4	15.6	16.7	23.4	22.5
DO (mg/L)	11.3	12.1	10.4	7.6	6.3	6.2	6.1	6.5	6.5	6.6	5.2
pH	8.6	8.2	8.4	7.7	8.4	8.5	8.4	8.6	8.5	8.2	8.2
Turbidity (NTU)	10.1	3.1	2	8.84	2.7	3.2	4.1	4.8	4.1	10.5	4
Transp. (mm)	>600	>600	>600		>600	>600	>600	>600		>600	>600
Chloride (ppm)	375	73		46	46	46	39	39	48	48	48

2007

Site DRC 1	1/11/2007	2/15/2007	3/6/2007	3/20/2007	4/3/2007	4/17/2007	5/1/2007	5/15/2007	5/30/2007	6/13/2007	6/27/2007
Ammonia N as N (mg/L)	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025		0.025	0.025
E.coli (colonies/100mL)	130	50	5	310	2800	20	73	210		490	710
Nitrate + Nitrite N (mg/L)	12	8.8	7.5	8.9	6	7.3	7.9	5.5		5.6	5.1
Total Kjeldahl N (mg/L)	0.2	0.3	0.3	0.4	2.2	0.4	0.1	0.05		0.2	0.2
Total Phosphate (mg/L)	0.02	0.01	0.07	0.04	0.65	0.04	0.06	0.04		0.04	0.05
Ortho-phosphate (mg/L)	0.01	0.01	0.03	0.03	0.2	0.02	0.02	0.01		0.01	0.02
TSS (mg/L)	2	0.5	5	5	270	3	7	4		6	15
TDS (mg/L)		400	430	390	290	330	340	330		340	340
Temp ^{o}C	1.8	0.3	0.0	3.9	11.2	10.7	14.7	14.8		18.1	19.6
DO (mg/L)	16.3	14.3	15.7	12.0	11.2	12.8	10.5	9.7		9.3	9.4
pH	8.4	8.2	8.2	8.3	7.8	8	7.7	8		8	8
Turbidity (NTU)	2.4				230	1.7	2.9	1.1		2.1	5.8
Transp. (mm)	300		300	300							
Chloride (ppm)	44	64	98	55	40	39	37	32		28	28
Chlorophyll A (µg/L)		0.5	3.4	3.1	10	10	3	3		0.5	0.5
Dissolved Inorganic Carbon (mg/L)		2	4		1.4	31	48	47		48	46
Dissolved Organic Carbon (mg/L)		52	47	44	5.6	1.7	1.1	0.8		0.9	0.7
flow rate (CFS)		1.1	2	1.5		36	14	11		40	39
Total Biochemical Oxygen Demand (5 day)		1	1	1	3	1	1	1		1	1
Total Organic Carbon (mg/L)		1.6	3	2.2	24	1.7	1.5	1.5		1.3	1.7
Total Volatile Suspended Solids (mg/L)		0.5	2	1	44	1	1	1		2	3

Site DRC 2	1/11/07	2/15/07	3/6/07	3/20/07	4/17/2007	4/3/2007	5/1/2007	5/15/2007	5/30/2007	6/13/2007	6/27/2007
Ammonia N as N (mg/L)	0.025		0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
E.coli (colonies/100mL)	190		5	30	5	550	50	80	360	390	230
Nitrate + Nitrite N (mg/L)	5.2		3.7	4.5	1.1	2.2	1.5	1.2	1.4	1.4	1.5
Total Kjeldahl N (mg/L)	0.4		0.7	0.4	0.2	1.1					
Total Phosphate (mg/L)	0.03		0.08	0.05	0.03	0.26	0.04		0.03	0.05	0.04
Ortho-phosphate (mg/L)	0.01		0.04	0.04	0.01	0.08	0.01	0.02	0.01	0.01	0.01
TSS (mg/L)	0.05		8	2	5	130	3	3	5	4	10
Temp ^{o}C	0.3		0.0	4.1	14.9	10.5	17.6	14.8	18.1	18.7	19.3
DO (mg/L)	17.5		14.8	12.8	13.7	11.6	10.1	9.9	7	8.8	9
pH	8.4		8.3	8.3	8.2	7.8	7.8	7.8	7.8	8	8
Turbidity (NTU)	1.9		7	4.6	3.2	138	2.6	2.1	3	3.4	5.7
Transp. (mm)	300		300	300	600	80	600	600	600	600	600
Chloride (ppm)	50		238	90							

Site DRC 3	1/11/2007	2/15/2007	3/6/2007	3/20/2007	4/17/2007	4/3/2007	5/1/2007	5/15/2007	5/30/2007	6/13/2007	6/27/2007
Ammonia N as N (mg/L)	0.025		0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
E.coli (colonies/100mL)	73		20	10	10	3200	110	270	500	290	600
Nitrate + Nitrite N (mg/L)	12		7.8	9.2	9	6.5	9	7.2	7.8	7.4	6.7
Total Kjeldahl N (mg/L)	0.1		0.4	0.3	0.4	2.1	0.2	0.2	0.1	0.2	0.3
Total Phosphate (mg/L)	0.04		0.05	0.05	0.05	0.65	0.04	0.02	0.04	0.04	0.04
Ortho-phosphate (mg/L)	0.01		0.02	0.03	0.03	0.22	0.02	0.01	0.01	0.01	0.02
TSS (mg/L)	2		5	6	4	280	5	4	7	6	10
Temp °C	1.9		0.4	4.2	11.4	9.2	14.9	14.9	18	19.4	20.3
DO (mg/L)	16.3		15.6	12.4	13.1	11	10.4	10.2	9	7.3	9.5
pH	8.4		8.2	8.2	8	7.7	7.8	7.9	7.8	8	8
Turbidity (NTU)	2.4		4.8	5.5	5	291	4.9	4.1	4.9	5.3	9.9
Transp. (mm)	600		600	600	600	40	600	600	600	600	558
Chloride (ppm)	43		90	57							

Site DRC 4	1/11/2007	2/15/2007	3/6/2007	3/20/2007	4/3/2007	4/17/2007	5/1/2007	5/15/2007	5/30/2007	6/13/2007	6/27/2007
Ammonia N as N (mg/L)	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
E.coli (colonies/100mL)	110	20	30	30	5800	30	27	73	210	430	630
Nitrate + Nitrite N (mg/L)	11	8.5	8	9.2	6.6	8.2	8.4	5.6	6.1	5.7	5.6
Total Kjeldahl N (mg/L)	0.2	0.2	0.3	0.3	2	0.4	0.2	0.05	0.1	0.1	0.3
Total Phosphate (mg/L)	0.03	0.02	0.05	0.04	0.56	0.06	0.04	0.04	0.04	0.05	0.05
Ortho-phosphate (mg/L)	0.01	0.01	0.03	0.03	0.13	0.04	0.03	0.04	0.01	0.01	0.03
TSS (mg/L)	4	0.5	5	9	320	5	6	5	7	7	11
TDS (mg/L)		360	400	370	250	340	340	340	340	350	350
Temp °C	2.3	0.2	0.8	3.4	9.1	10.5	13.4	14.9	17.1	17.4	18.6
DO (mg/L)	15.7	15.2	16.2	12.5	11.1	12.6	10.8	9.2	8	8.4	8.9
pH	8.2	8.4	8.0	8.2	7.6	7.9	7.6	7.6	7.8	7.6	7.8
Turbidity (NTU)	2.8				240	2.1	2.3	1.8	2.9	3.8	4.1
Transp. (mm)	>600		>600	>600							
Chloride (ppm)	37	47	71	38	24	36	36	33	32	32	32
Chlorophyll A (µg/L)		0.5	2.7	5	14	12	2	2	1	0.5	0.5
Dissolved Inorganic Carbon (mg/L)		2	4		12	39	45	47	47	48	47
Dissolved Organic Carbon (mg/L)		50	48	43	5.4	1.1	0.9	0.9	0.7	0.7	0.9
flow rate (CFS)		1	1.3	1.4	87	22	8	11	21	22	22
Total Biochemical Oxygen Demand (5 day)		1	1	1	2	1	1	1	1	1	1
Total Organic Carbon (mg/L)		1.5	2.2	1.9	19	2.1	1.4	1.4	1.6	1.3	1.4
Total Volatile Suspended Solids (mg/L)		0.5	1	2	44	2	0.5	1	1	2	2

Site DRC 5	1/11/2007	2/15/2007	3/6/2007	3/20/2007	4/17/2007	4/3/2007	5/1/2007	5/15/2007	5/30/2007	6/13/2007	6/27/2007
Ammonia N as N (mg/L)	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
E.coli (colonies/100mL)	110	45	10	100	20	1400	55	360	260	530	870
Nitrate + Nitrite N (mg/L)	12	9.3	8	9.3	12	7.1	12	12	14	14	12
Total Kjeldahl N (mg/L)	0.2	0.2	0.4	0.4	0.4	2.2	0.3	0.3	0.2	0.4	0.4
Total Phosphate (mg/L)	0.04	0.02	0.06	0.08	0.03	0.72	0.04	0.02	0.03	0.07	0.05
Ortho-phosphate (mg/L)	0.01	0.01	0.03	0.03	0.01	0.26	0.02	0.01	0.02	0.01	0.02
TSS (mg/L)	3	0.5	5	7	2	400	4	3	3	3	11
Temp ^{o}C	1.8	0.6	0.2	4.3	10.4	9.3	14.7	14.7	17.2	18.6	20.3
DO (mg/L)	16.2	14.5	14.7	13.0	12.4	10.8	11.4	9.3	9	8.9	9
pH	8.2	8.4	8.0	8.0	8	7.7	7.8	8.1	7.9	8	8
Turbidity (NTU)	3.1		4	6.5	3.5	273	3.6	2.4	3	3.5	8.6
Transp. (mm)	>600		>600	>600	600	50	600	600	600	600	508
Chloride (ppm)	43			65							

Site DRC 6	1/11/2007	2/15/2007	3/6/2007	3/20/2007	4/3/2007	4/17/2007	5/1/2007	5/15/2007	5/30/2007	6/13/2007	6/27/2007
Ammonia N as N (mg/L)	0.025	0.025	0.025	0.08	0.025	0.4	0.025	0.025	0.025	0.025	0.025
E.coli (colonies/100mL)	110	5	10	10	11000	150	60	180	4100	870	950
Nitrate + Nitrite N (mg/L)	13	9.4	9	9.6	7.2	12	14	12	14	13	12
Total Kjeldahl N (mg/L)	0.3	0.2	0.3	0.4	1.7	1.2	0.2	0.3	0.3	0.3	0.5
Total Phosphate (mg/L)	0.04	0.04	0.07	0.05	0.61	0.18	0.09	0.06	0.07	0.11	0.08
Ortho-phosphate (mg/L)	0.02	0.02	0.04	0.03	0.17	0.11	0.04	0.03	0.02	0.02	0.03
TSS (mg/L)	14	1	4	8	300	12	9	9	19	28	35
TDS (mg/L)		360	410	360	280	350	350	360	360	380	380
Temp ^{o}C	2.9	0.9	0.9	3.3	8.8	8.7	12.2	13.8	16.2	16.4	18.8
DO (mg/L)	14.2	13.8	14.6	12.7	10.6	12.9	11	9.1	8.9	8.1	8.3
pH	8.2	8.4	7.8	8.0	7.6	7.7	7.6	7.8	7.6	7.5	7.8
Turbidity (NTU)	7.2				280	4.9	5.2	5.9	12	20	21
Transp. (mm)	540		>600	>600							
Chloride (ppm) (test strips)	36	39	62	34	22	33	32	32	32	31	31
Chlorophyll A (µg/L)		1.1	2.8	3.9	6	39	3	2	3	2	2
Dissolved Inorganic Carbon (mg/L)		0.5	0.5		12	35	41	40	42	43	43
Dissolved Organic Carbon (mg/L)		50	48	43	4.7	2	1.6	1.5	1.7	1	1.6
flow rate (CFS)		1.1	1.6	1.1	31	6	2	1	3	3	3
Total Biochemical Oxygen Demand (5 day)		1	1	1	2	1	1	1	1	1	1
Total Organic Carbon (mg/L)		1.6	2	2	18	2.8	2.1	1.9	2.4	2.6	2.6
Total Volatile Suspended Solids (mg/L)		0.5	2	2	44	4	2	2	3	5	6

Site DRC 7	1/11/2007	2/15/2007	3/6/2007	3/20/2007	4/17/2007	4/3/2007	5/1/2007	5/15/2007	5/30/2007	6/13/2007	6/27/2007
Ammonia N as N (mg/L)	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
E.coli (colonies/100mL)	<10	<10	<10	5	5	540	30	5	5	10	91
Nitrate + Nitrite N (mg/L)	17	14	12	14	15	9.6	18	16	19	18	16
Total Kjeldahl N (mg/L)	0.2	0.1	0.1	0.1	0.2	1		0.1		0.1	
Total Phosphate (mg/L)	0.01	0.01	0.04	0.02	0.02	0.35	0.04	0.01	0.02	0.03	0.04
Ortho-phosphate (mg/L)	0.01	0.01	0.02	0.01	0.01	0.16	0.01	0.01	0.01	0.01	0.01
TSS (mg/L)	0.5	0.5	0.5	0.5	0.5	13	0.5	0.5	0.5	3	2
Temp ^{o}C	5.6	3.1	3.2	3.3	5.5	8.7	7.8	10.2	12.4	14	15.6
DO (mg/L)	12.2	13.0	11.9	11.8	11.2	9.8	10.5	9.9	9	8	8.1
pH	7.6	8.3	7.6	8.0	7.5	8	7.5	7.6	7.2	7	7.7
Turbidity (NTU)	0.9		0.9	0.7	1	52.9	1.1	0.6	1.5	1.9	1.1
Transp. (mm)	600		600	600	600	110	600	600	600	600	600
Chloride (ppm)	30		15	15							

Site DRC 8	1/11/2007	2/15/2007	3/6/2007	3/20/2007	4/17/2007	4/3/2007	5/1/2007	5/15/2007	5/30/2007	6/13/2007	6/27/2007
Ammonia N as N (mg/L)	0.025		0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
E.coli (colonies/100mL)	91		5	82	5	680	50	160	140	330	610
Nitrate + Nitrite N (mg/L)	13		8.5	11	13	8.9	14	13	16	15	12
Total Kjeldahl N (mg/L)	0.4		0.4	0.4	0.3	1.8	0.2	0.3	0.4	0.2	0.4
Total Phosphate (mg/L)	0.05		0.05	0.05	0.03	0.54	0.05	0.03	0.03	0.05	0.05
Ortho-phosphate (mg/L)	0.01		0.02	0.04	0.01	0.25	0.02	0.01	0.01	0.01	0.01
TSS (mg/L)	14		5	7	3	200	6	2	3	4	22
Temp ^{o}C	2.3		2.1	4.9	10.9	9.3	15	13.5	16.9	18.9	19.6
DO (mg/L)	14.5		13.0	11.6	11.5	10.5	10.5	7.1	9.1	8.1	8.3
pH	8.3		7.8	8.0	8	7.7	7.8	7.8	8	8	7.9
Turbidity (NTU)	13.1		3.9	6.8	3.3	178	4.2	2.7	2.7	3.7	14.3
Transp. (mm)	450		>600	>600	600	55	600	600	600	600	441
Chloride (ppm)	50		81	65							

Site DRC 9	1/11/2007	2/15/2007	3/6/2007	3/20/2007	4/17/2007	4/3/2007	5/1/2007	5/15/2007	5/30/2007	6/13/2007	6/27/2007
Ammonia N as N (mg/L)	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
E.coli (colonies/100mL)	55	5	40	55	5	1400	20	90	210	270	530
Nitrate + Nitrite N (mg/L)	12	9.4	8.6	11	12	9	14	13	15	15	15
Total Kjeldahl N (mg/L)	0.2	0.2	0.2	0.2	0.4	1.6	0.1	0.2	0.2	0.2	0.4
Total Phosphate (mg/L)	0.04	0.01	0.05	0.04	0.03	0.53	0.04	0.03	0.02	0.05	0.04
Ortho-phosphate (mg/L)	0.02	0.02	0.03	0.03		0.25	0.02				0.02
TSS (mg/L)	8	1	4	8	7	150	14	5	5	7	14
Temp °C	2.9	0.1	1.4	2.5	6.9	8.3	10.3	11.7	14.6	15	16.8
DO (mg/L)	13.7	15.1	13.8	12.5	12.8	10.6	11.3	10.5	10.3	9.1	8.5
pH	7.8	8.0	7.6	8.1	7.6	8	7.8	7.6	7.6	7.7	7.7
Turbidity (NTU)	3		2.8	5.2	3.5	163	5.8	3.1	3.2	3.4	5.9
Transp. (mm)	>600		>600	>600	600	60	600	600	600	600	600
Chloride (ppm)	43		43	36							

Site DRC 10	1/11/2007	2/15/2007	3/6/2007	3/20/2007	4/3/2007	4/17/2007	5/1/2007	5/15/2007	5/30/2007	6/13/2007	6/27/2007
Ammonia N as N (mg/L)	0.08		0.025	0.06	0.025		0.025	0.025	0.025	0.025	0.025
E.coli (colonies/100mL)	250		45	370	3100		10	100	250	780	950
Nitrate + Nitrite N (mg/L)	15		11	14	7.2		17	15	17	17	17
Total Kjeldahl N (mg/L)	0.8		0.6	0.4	2.7		0.3	0.3	0.2	0.4	0.3
Total Phosphate (mg/L)	0.16		0.09	0.06	0.92		0.04		0.04	0.04	0.04
Ortho-phosphate (mg/L)	0.02		0.03	0.03	0.38		0.02	0.02	0.02		0.02
TSS (mg/L)	110		29	11	270		5	2	3	8	4
Temp °C	2.1		0.4	2.0	9		11.4	13	14.6	14.9	17.1
DO (mg/L)	13.9		14.5	13.3	10.6		11.4	10.1	10.3	9.5	10
pH	7.6		7.5	8.2	8		7.9	7.6	7.6	7.6	7.5
Turbidity (NTU)	79.2		10.3	7.4	402		5.3	1.9	2.7	4.9	3.5
Transp. (mm)	160		>600	>600	30		600	600	600	600	600
Chloride (ppm)	43		65	57							