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Hydraulic and pollutant conveyance assessment in highway bioinfiltration practice in Coralville, Iowa

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HYDRAULIC AND POLLUTANT CONVEYANCE ASSESSMENT IN HIGHWAY BIOINFILTRATION PRACTICE IN CORALVILLE, IOWA

by

Rai A Tokuhisa

A thesis submitted in partial fulfillment
of the requirements for the Master of Science
degree in Civil and Environmental Engineering (Water Resources) in the
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The University of Iowa

August 2016

Thesis Supervisors: Professor William Eichinger
Professor Elmer Arthur Bettis III

Graduate College
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CERTIFICATE OF APPROVAL

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MASTER'S THESIS

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This is to certify that the Master's thesis of

Rai A Tokuhisa

has been approved by the Examining Committee for the thesis requirement for the Master of Science in Civil and Environmental Engineering (Water Resources) at the August 2016 graduation.

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Gregory H. LeFevre

To my sister, Rebekah, without whom I would be very, very lost.

"Man's engineering capabilities are nearly limitless. Our economic views are too insensitive to be the only criteria for judging the health of the river organism. What is needed is a gentler basis for perceiving the effects of our engineering capabilities. This more humble view of our relation to the hydrologic system requires a modicum of reverence for rivers."

Luna B. Leopold, PhD

"A Reverence for Rivers", keynote address

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Finally, for my family in every sense of the word, those who poured ineffable gallons of love and support in my general direction—Thank you!

ABSTRACT

This thesis project monitors the quantity and quality of stormwater entering and leaving a bioretention system in Coralville, Iowa. Bioretention is among many engineered solutions designed to provide treatment for runoff that might otherwise be drained directly to a body of water. Increased quantities of stormwater can impact stream morphology, degrade aesthetics, increase flood frequency, peak flow and peak duration; as well as increased sedimentation and sediment transport. Decreases in water quality can impair fish or other aquatic populations, and increase the treatment requirements for downstream intakes. The number of communities, presently 47, affected by stormwater control ordinances increases as the Environmental Protection Agency continues to require smaller Municipal Storm Sewer Systems to adhere to National Pollutant Discharge Elimination System permits.

The City of Coralville is setting an example by using infiltration practices to treat runoff from a 4-lane divided thoroughfare. Preliminary monitoring shows that the system in Coralville provides an average reduction in effluent temperature g of 3.7°C, an average reduction in peak flow of 2 cfs, and an average peak delay of 45 minutes. The project provides infiltrative treatment for the water quality volume and the empirical curve number for the project is 77.4. The urban runoff to the project is within literature values and the pollutant concentrations in the project effluent are below legal limits.

PUBLIC ABSTRACT

This thesis project monitors the quantity and quality of stormwater entering and leaving a bioretention system in Coralville, Iowa. Bioretention is among many engineered solutions designed to provide treatment for runoff from urbanized areas. Standards for urban runoff (MS4 permits) are applicable to 47 municipalities or universities in Iowa. Urbanization impacts Iowan health and economy by increasing local flooding potential and decreasing water quality throughout the watershed. Water quality affects the recreation services the state may provide, the safety of the landscape for human contact and use, and the cost of water treatment. Understanding the ability for engineered systems to reduce flood volumes and increase water quality helps communities stay within legal standards and improve our waterways.

The system in Coralville provides an average reduction in effluent temperature of 3.7°C, an average reduction in peak flow of 2 cfs, and an average peak delay of 45 minutes. The project provides infiltrative treatment for the water quality volume and the empirical curve number for the project is 77.4. The urban runoff to the project is within literature values and the pollutant concentrations in the project effluent are below legal limits.

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CHAPTER 1: INTRODUCTION

Urban stormwater and agricultural runoff are the two major contributors to the degradation of Iowan waterways. To address the quality of urban contributions nation-wide, the Environmental Protection Agency (EPA) enacted the National Pollutant Discharge Elimination System (NPDES) Stormwater Permit Program in the 1990. The phased program regulates the effluent from many point-sources, including municipal separate storm sewer systems (MS4s). To improve water quality without employing a large-scale wastewater treatment plant, many municipalities have opted to use best management practices (BMPs) that allow urban runoff to be filtered and biologically treated at or close to the source.

Bioretention cells are one form of BMP that is common in urban settings because of the small footprint it has relative to the catchment area. Bioretention cells are landscaped depressions that typically include a rock chamber and engineered soil media to temporarily store and percolate runoff into the surrounding, *in-situ*, soil. Stormwater enters the practice through a curb cut or a pipe, is filtered by the media, and may be evaporated, taken up by vegetation, discharged by an underdrain, or exfiltrated into the *in-situ* soil below the practice (Iowa Department of Natural Resources, 2016). This technology is not new to the United States as a whole—there are many documented cases throughout New England and the Pacific Northwest—but very little has been done to characterize the performance of bioretention systems in Iowa.

CHAPTER 2: LITERATURE REVIEW

Impacts of Stormwater

The impact of urban runoff is threefold. Firstly, impervious surfaces like roads, parking lots, and roofs, do not allow precipitation to penetrate into the ground below, resulting in hydrograph peaks in nearby streams associated with urban land use (United States Department of Agriculture, 1986). Secondly, the decrease in infiltration is reflected in smaller volumes recharged into the aquifers and larger volumes of resultant surface flow. The combination of large volumes and quick conveyance then cause damage by flooding or scouring. Finally, high-intensity traffic increases the amount of pollutants that accumulate on roadways and are entrained during precipitation events (Weibel, Anderson, & Woodward, 1964). Impervious surfaces encourage the pollutants to be transported quickly downstream (Kayhanian, et al., 2012) where they degrade water quality of the receiving body (National Research Council, 2008).

Pollutants may be suspended or dissolved and degrade the water quality with physical, chemical, and biological mechanisms. For example, sediments decrease the clarity (increase turbidity) of the water and transport chemical pollutants that have sorbed onto the media. Nutrients from stormwater encourages algae growth, which increases turbidity. When the blooms perish, the decomposers that consume them exhaust the dissolved oxygen (DO) that other aquatic species need to respire. The decrease in water quality shifts the ecology of the system away from native or desirable species in favor of less desirable species (Leopold, 1968). Similar effects can be seen for changes in stream temperature, pH, and concentrations of toxins above threshold values for sensitive species and primary consumers.

Evolution of Urban Pollutant Concern

The pollutants of urban stormwater first reported were total suspended solids (TSS), nutrients such as nitrogen and phosphorus, and heavy metals (Marsalek, Guillaume, Rochfort, Grapentine, & Lafont, 2013). As of 2010, the list has grown to more than 600 chemical substances (Marsalek, Guillaume, Rochfort, Grapentine, & Lafont, 2013) to include pharmaceuticals, hydrocarbons, and other compounds with specific effects on aquatic ecosystems and human health (Zimmer, Heathcote, Whiteley, & Schroeter, 2007) . Research has also expanded to include spatial (Merchan, et al., 2014) and temporal variability, and persistence (Marsalek, Guillaume, Rochfort, Grapentine, & Lafont, 2013).

Recent progress has been made in the realm of dissolved pollutants in terms of sorption, vegetative uptake, and biodegradation of dissolved pollutants (LeFevre, et al., 2014). Dissolved pollutants may contribute a significant amount to total pollutant loading (LeFevre, et al., 2014). Pollutant removal strategies may be improved as we learn more about the synergistic/antagonistic effects and the fate and transport of dissolved pollutants. Decay is a key component for characterizing pollutants and the lengths at which they persist. Cullin (2014) found that he could model and predict the decay of sulfamethoxazole within an order of magnitude for smaller reaches, but encountered error outside of uncertainty at long reach lengths. Cullin suspects the error may have been from differing optical (measurement) properties of the model tracers compared to the actual contaminant, or path-related unknowns including lateral inflows or bank storage. This illustrates the difficulty in tracking pollutants through a system.

In addition to the complexity of pollutant movement is the intricacy of cycles and speciation, which may be dependent on a single parameter like pH or temperature, a combination of parameters, or the presence of biota. The most familiar example is the nitrogen cycle, in which nitrogen is applied to the land in fertilizer as ammonium or ammonia (NH_4^+ and NH_3, respectively), oxidized to nitrite (NO_2^-) and then nitrate (NO_3^-), and anaerobically converted to nitrogen gas (N_2). Since the anaerobic conditions to produce nitrogen gas are infrequently present in traditional stormwater conveyance, and nitrates persist in the effluent. Similarly persistent are trace metals and organics. These pollutants may be volatilized (for organics), sorbed, biodegraded, or taken up by plants and other materials (LeFevre, et al., 2014). Like the anaerobic conditions required to convert nitrite/nitrate to nitrogen gas, these conditions do not often exist in traditional stormwater infrastructure and must be deliberately introduced. In bioretention systems, an anaerobic region may be designed by using an upturned elbow in the underdrain to restrict water movement to times in which new water is added to the system. Such design considerations are not standardized, and are often site- or pollutant-specific.

The pollutants of concern for this project are *E. coli* bacteria, chloride, sulfate, nitrate/nitrite as N, ortho-phosphate as P, total phosphorus as P, total suspended solids, oil and grease (hexane extractable materials), and total extractable hydrocarbons. Table 1 summarizes literature values for the contaminants of concern or their chemical proxies, as is the case for TDS and chloride. These constituents were chosen by interested municipal parties to address emerging design goals green infrastructure.

Table 1: Literature values for relevant contaminants

	Median	Mean	Range	C.o.V.	Source
E. coli	1750			2.3	Pitt, Maestre & Morquecho (2004) (overall summary)
NO_2	572			0.48	Nationwide Urban Runoff Program (US EPA 1983)
	0.6			0.7	Pitt, Maestre & Morquecho (2004) (mixed freeway)
	0.08	0.14		1.15	Wu et al. 1998 (Site III)
O&G	4			1.6	Pitt, Maestre & Morquecho (2004) (mixed freeway)
	1.1	1.3		0.5	Wu et al. 1998 (Site III)
OP	0.16	0.17		0.52	Wu et al. 1998 (Site III)
pH	7.8			0.06	Pitt, Maestre & Morquecho (2004) (mixed freeway)
P. HC			0.7-6.6		Shepp 1996
SP	80			0.71	Nationwide Urban Runoff Program (US EPA 1983)
TDS	174			0.4	Pitt, Maestre & Morquecho (2004) (mixed freeway)
TP	0.26	0.47		0.86	Nationwide Urban Runoff Program (US EPA 1983)
	0.26			0.8	Pitt, Maestre & Morquecho (2004) (mixed freeway)
TSS		150	20-2,890		Bastian, 1997
	81			1.2	Pitt, Maestre & Morquecho (2004) (mixed freeway)
	14	30		1.07	Wu et al. 1998 (Site III)

C.oV. —coefficient of variation
EC—*Escherichia coli* , [MPN]/100 mL
TDS.—Total dissolved solids, mg/L
NO_2—Nitrate and nitrite (as N), mg/L
OP—Orthophosphate (as P, mg/L
TP—Total phosphorus, mg/L
TSS—Total suspended solids, mg/L
O&G—Oil and greaseppm
P. HC—Petroleum hydrocarbons, µg/L

Traditional Stormwater Infrastructure and Low-Impact Development

Stormwater infrastructure was originally designed to remove runoff as quickly as possible to protect urban property from flooding (Zimmer, Heathcote, Whiteley, & Schroeter, 2007). Since the 1970's, design considerations have expanded to include reduction of flooding further downstream and the pollutants transported by the system. Many of these new goals use a design strategy called low-impact development (LID).

LID designs are intended to preserve the pre-development hydrologic conditions for high-probability storm events and are often implemented by reducing impervious cover and choosing strategic geometries that promote infiltration and evapotranspiration (Zimmer, Heathcote, Whiteley, & Schroeter, 2007). LID is applicable across a range of scales, and often uses infiltration-based best management practices (BMPs) to treat stormwater close to the source by allowing soils and plants to filter and remove pollutants.

Infiltration Practices

Treating stormwater close to the source or in the headwaters may also increase the maximum benefit available. Holman-Dodds, Bradley, and Potter (2003) noted that the geomorphology of many basins provides pervious soils in the headwaters with increasingly less pervious soils approaching the river. They suggest that the most effective infiltrative BMPs will be located near the top of the watershed.

The *in-situ* soil dictates performance as the hydraulic conductivity limits the exfiltration capacity of the BMP. Davis, Traver, Hunt, Lee, Brown, and Olszewski (2012) compared bioretention cells in Maryland, North Carolina, and Pennsylvania, and found that volumetric performance correlated with the hydrologic soil group (HSG) of the site.The sandier soils for Davis et al. (2012) in North Carolina (HSG A or B) permitted only 14% of the total inflow volume to be discharged. The other sites, (HSG C) discharged 23% (Maryland) and 48%

(Pennsylvania) of the total inflow volume. The researchers compared the overall performance of the cells by comparing theoretical and empirical NRCS curve numbers—low numbers represent higher runoff retention capacity—and found empirically that the BMPs reduced the expected curve numbers for the urbanized catchments from 84-87 to 75-78. The *in-situ* soil was a large factor in the success of the system, but Davis et al. (2012) also noted that the curve number may be reduced by increasing the storage volume.

Bioretention Design

Hydrologic performance in bioretention systems is a function of engineering design. Storage volume in infiltration BMPs is limited horizontally by available plan area, and is limited in depth by the cost of excavation and elevation of the water table or other geologic concerns (Iowa Department of Natural Resources, 2016). Volumetric management in general is also limited by media and vegetative characteristics of the cell (Davis, et al., 2012). Since the engineered ecosystem should imitate a natural ecosystem (Greene, Hutchinson, Christianson, & Moore, 2009), native vegetation is recommended as it increases habitat availability for native species, often has deeper root systems than non-native species (in suitable regions), and is more likely to survive the regional climate. The roots allow deeper preferential pathways for water to infiltrate and a greater depth to which plants may use the water for growth and maintenance (Greene, Hutchinson, Christianson, & Moore, 2009). Vegetation may directly transform stormwater pollutants (LeFevre, Müller, Li, Luthy, & Sattely, 2015) in addition to improving conditions required for uptake (LeFevre, Hozalski, & Novak, 2016).

Soil structure and biota (including microorganisms) contribute to plant productivity and biogeochemical cycling, and are the foundation for healthy ecosystems (Griffiths & Philippot, 2012). A challenge in designing bioretention systems for specific pollutant removal is in regarding the engineered media as an ecological building block. Soil amendments have included compost, iron filings (Minesota Pollition Control Agency, 2014), red mud—an aluminum manufacturing by-product (Lucas & Greenway, 2011), fly-ash (Zhang, Brown, Storm, & Zhang, 2009), calcite, steel wool, blast furnace slag (Erickson, Gulliver, & Weiss, 2007), and a myriad of others to promote pollutant retention and degradation. Even exposure to contaminants themselves may increase biodegradation (LeFevre, Holzaki, & Novak, 2012). LeFevre, Novak, and Hozalski (2011) found that 5 months of exposure to naphthalene encouraged the bacteria that degrade it—based on the genetic information contained in the soil—supporting the framework of bioretention media as an ecosystem fundamental as well as an engineering material. Soil amendments may also be a potential source of nutrient export, and must be chosen with care.

Stormwater Maintenance and Education

Purposeful selection of components is not the only intellectual challenge in implementing and maintaining infiltration BMPs. Exfiltrative capacity is limited by the compaction of the underlying soil. Contractors must limit or eliminate the compression applied by excavation machinery (Virginia Department of Environmental Quality, 2011)—to do so it is vitally important that operators understand the benefits gained by following these restrictions, so that they may fully comply with the non-compaction needs. Additionally, silt and construction-fines need special attention in the form of silt fences, mulch socks, and designated concrete washout pits, so they do not clog the interface or subsequent media layers (Virginia Department of Environmental Quality, 2011). Construction is a vulnerable stage for the system because of the opportunities to foul the *in-situ* advantages.

After installation, regular maintenance is the next challenge in preserving the function of infiltration BMPs. Blecken, Hunt, Al-Rubaei, Viklander, and Lord (2015) reviewed common maintenance issues in several types of infiltration BMPs, and concluded that long-term maintenance of BMPs is just as important for hydrologic success as design adaptation and construction. They found that the inter-disciplinary overlap in engineering, traffic planning, ecology, horticulture, etc. created 'loopholes' by which no single entity was explicitly responsible for BMP maintenance because the different care mechanisms could fall within multiple jurisdictions.

In tandem with non-explicit responsibility may be the lack of knowledge of maintenance routines including (but not limited to): adequate grass height, detriments of fertilizer use, necessity of weeding during establishment, clearing flotsam from the cell, and the structural integrity of curbs, piping, and grates (Blecken, Hunt, Al-Rubaei, Viklander, & Lord, 2015).

In a suburban study, Dietz and Clausen (2004) found that nitrate concentrations were decreased by 75% and bacterial concentrations also decreased significantly when homeowners are responsible for lot-scale non-point BMPs such as rain barrels, gutter diversion, and informed fertilization. They also found that residents exposed to intense education programs such as workshops, BMP installations at schools, or stream clean-ups, are more likely to be capable of identifying behavior that contributes to stormwater pollutants, and more willing to assist in improvement strategies (Giacalone, Mobley, Sawyer, Witte, & Eidson, 2010). These non-structural measures are an excellent way to put the treatment goals into context. Taylor & Fletcher (2007) propose the following five categories by which stormwater issues can be universally addressed:

1. Town planning controls, or rules binding developers to implement a stormwater strategy addressing water quality;
2. Institutional controls, such as citywide management plans and available funding for BMPs;
3. Maintenance, from pollution prevention to sustaining BMP efficiency;
4. Education, participation in programs using targeted, interactive, or intensive methods to increase knowledge and promote certain behavior; and
5. Regulation, to enforce local laws to improve erosion and sediment control at construction sites.

With these five categories, the different temporal categories of the effects of urbanization are separated and addressed according to the motivators of each population. A homeowner has no control over erosion maintenance during construction, and developers similarly have no input to the water uses of residents. Separating the variables contributing to stormwater pollution helps increase efficiency of targeted strategies. Eidson (2008) eloquently stated "…each citizen plays an individual and collective role as both a consumer of natural capital and a steward of the environment" and thus, ensuring that the entire community is on the same proverbial page for watershed management is vitally important for the success of stormwater BMPs.

CHAPTER 3: PROJECT BACKGROUND AND SCOPE

Watershed History and Project Goals

The project is located in Coralville, Iowa at 41°42'29.06"N, 91°36'30.30"W (Section 25 Township 80 N Range 7 W) along Coral Ridge Avenue (Highway 965) between Oakdale Boulevard and Heartland Drive. Coral Ridge Avenue road is a major artery in the corridor between Coralville and the town of North Liberty. It is presently a combination of commercial and residential land use, with zoning for further development within the watershed. Prior to the 2000's, the surrounding land was agricultural row-crops and pasture. The 1800's historic vegetation was prairie (Iowa State University Geographic Information Systems Support & Research Facility, 2016). The soil types are Fayette silt loams and a portion of the Chelsea-Lamont-Fayette complex, both of which are hydrologic soil group (HSG) B or C. For predicting runoff volumes and sizing the bioretention system, HR Green used the SCS curve-number method. A curve number of 67 was selected for the total pervious area, corresponding to HSG B brush in poor condition. The soils alone are moderately permeable (Schermerhorn, 1983) loams (7-27% clay, 28-50% silt, <52% sand). They fall within capability subclasses II- III, and VI-e, indicating that they are prone to erosion problems. Expected soil properties are summarized in Table 1.

Table 2: In-situ *soil properties from Johnson County Soil Survey*

	Permeability (in/hr)	Available water capacity (in/in)	Shrink-swell potential	Organic Matter (%)
Chelsea	6.0-20	0.06-0.15	low	0.5-1
Fayette	0.6-2.0	0.18-0.22	low to moderate	0.5-2
Lamont	2.0-6.0	0.14-0.18	low	0.5-1

Coral Ridge Avenue is a portion of Highway 965 previously owned by the Iowa Department of Transportation. In 2005, ownership was transferred from the DOT to the City of Coralville. The City of Coralville was tasked with expanding the road to four lanes to accommodate growing traffic intensity and commercial access demands. The city implemented a design with traditional stormwater infrastructure that was completed in 2010, then retrofitted with green infrastructure beginning in 2014 to set an example of infiltration BMPs in municipal service. The green infrastructure retrofit was funded in part by the Watershed Improvement Review Board (WIRB), Rockwell Collins, and the City of Coralville.

The overall goals for the Coral Ridge Avenue Stormwater Project in a statement to the WIRB are to improve the quality of stormwater, reduce peak stormwater flows, create a cost-feasibility study to compare Low-Impact Development (LID) with traditional infrastructure, create a replicable urban design, extend the lifespan of an existing regional detention basin, and educate other municipalities and contractors. In corollary with these overarching goals, my thesis goals are to 1. Provide reproducible instrumentation setup for long-term monitoring and appropriate post-processing tools, 2. Evaluate the hydrological performance of a subset of the bioretention system, and 3. Characterize the baseline urban runoff.

Stormwater Requirements

In accordance with the NPDES permit obtained for the city's MS4, the City of Coralville has published a post-construction ordinance governing the treatment standards of stormwater for new development. The ordinance, Chapter 159 Post-Construction Stormwater Control, is applicable to all new construction impacting areas equal to or greater than one acre, and also to any development resulting in impervious exceeding 5,000 square feet. It requires stormwater management for the water quality volume (first 1.25 inches) via infiltration, and for the channel protection volume (first 2.38 inches) via infiltration or 24-hour detention, following design standard specifications laid out in the Iowa Stormwater Management Manual (ISWMM). This is not unusual—of the 47 communities with MS4 permits in Iowa, 15 of them reference ISWMM and of those, 8 require BMP performance guarantees (Iowa Storm Water Education Partnership, 2016).

No effluent pollutants in addition to those already controlled are specifically governed by Coralville NPDES permit—there are no maximum daily loads (MDLs), but extensive measureable goals include public education and outreach on storm water impacts, public involvement and participation, illicit discharge detection and elimination, construction site storm water control, and pollution prevention/good housekeeping (see Appendix A:) The Iowa Department of Natural Resources (Iowa DNR) first proposed the NPDES permit in 2014, classifying the Iowa River as class A1, B(WW-1), and HH and Clear Creek as class A3 and B(WW-2). This classification system indicates that the receiving waterbodies of Coralville MS4 have designated water quality goals based on their uses. For the Iowa River, discharge may be recreational with prolonged and direct exposure; suitable for maintaining warm water game fish populations; and supportive of human fish consumption or human drinking water supply. In Clear Creek, children commonly recreate and the stream is capable of supporting native nongame fish and invertebrate species.

Site Description

The portion of Coral Ridge Avenue that drains into the selected stormwater best management practices (BMPs) is a 4-lane divided thoroughfare ½ mile in length. The hillslopes draining into the BMPs are then 7.9 acres, of which 3.3 acres (42%) are impervious land. The road crowns along the centerline, allowing runoff to enter bioretention units along the outer edges and enter into the median. This setup up is abnormal, as traditionally-engineered highway have cross-slopes which drain all water to the outside of the highway system (away from the median) to avoid compromising aggregate stability in the subbase. The median swale is equipped with an overflow structure that prevents magnitudes of water which might destabilize the infrastructure.

Traditional storm sewer inlets collect the runoff of Coral Ridge Avenue and convey it in 12, 15, 18, and 24” standard concrete pipes into four subsections of the bioretention system: the median bioswales, a set of 2 bioswales west of the road, 1 bioswale east of the road, and 2 small bioretention cells west of the road.

I chose to investigate the two western bioswales. The first bioswale is a set of 3 bioretention cells constructed at grade and connected in series with check dams and grass-only swales delineating each cell. The final swale is a single cell with 150 feet of grass-only bioswales upstream. The cells slope mildly downstream and are vegetated with plantings other than grass. The grass-only portions between the cells also contain aggregate storage, but are vegetated with grass to provide continuous cover and help reduce movement of TSS. The naming scheme for the cells used by HR Green uses decreasing ordinals in the downstream direction, while the research station names are increasing ordinals in the downstream direction. Both nomenclatures are maintained in case of reference to the original engineering documents.

The cells are fed runoff from the five north-most inlets on Coral Ridge Avenue south of Oakdale Boulevard. Of the total project area, this encompasses 5 acres of the sub-watershed, 1 of which is impervious. The engineering design anticipates an area-weighted curve number of 77.7 for the bioswale project.

Runoff from the highway and overland flow from the pervious project area is directed into the cells. For events accumulating less than the overflow volume, all water entering the cells via the hillslope or the apron inlets passes through the engineered media. The media is 90% sand, 10% compost, and protected by a layer of chip mulch. Below the engineered media is a rock chamber—2- to 3- inch filter layer of 3/8-inch limestone chip aggregate and a 12-inch base stone layer of 1- to 2-inch limestone aggregate. A typical cross section is shown in Figure 1.

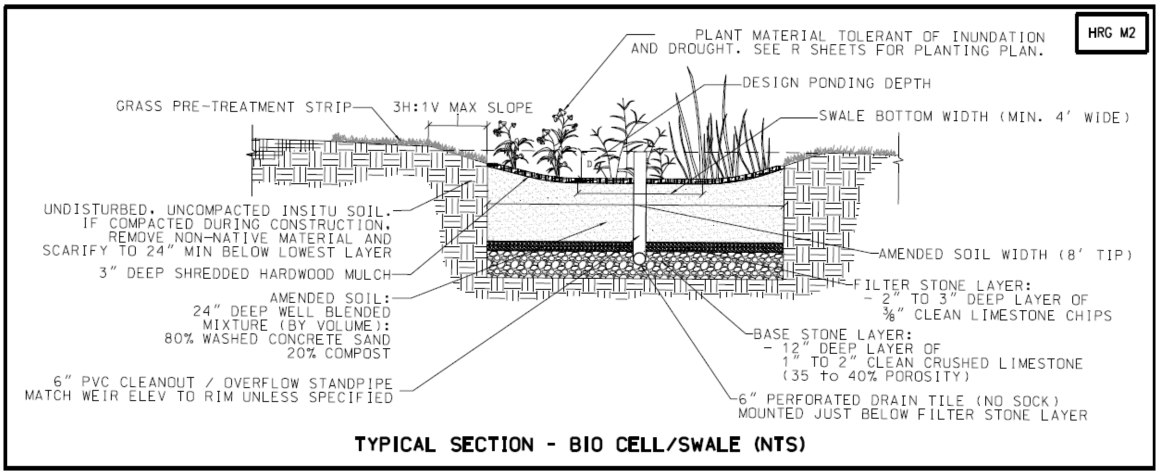

Figure 1: Typical cell cross-section, used with permission from HR Green

Within the base layer is a continuous perforated underdrain pipe to ensure adequate storage for subsequent runoff. Water entering the underdrains flows beneath the cells until it connects to the overflow structure in the downstream-most portion the cell. For cell 4, all overflow/underdrain flow daylights in cell 3. For cell 3, the overflow/underdrain flow is conveyed in an 18-inch pipe to the final outlet.

The final outlet is drop-shaft junction 100 feet away from the overflow structure of cell 4. This junction meets with a small portion of untreated stormwater. Both effluents mix in the 15 foot fall, and are discharged into the receiving ephemeral stream in a concrete trough. Figure 2 contains a sketch of the north project modified from the engineering documents provided by HR Green depicting the hydraulic connectivity of the bioretention systems. As named, CRO1, CRO2, CRO3 and CRO5 contain road-only effluent; CRO4 is a combination of overflow from cell 4 and runoff, and CRO6 is instrumented to isolate the overflow from cell 3.

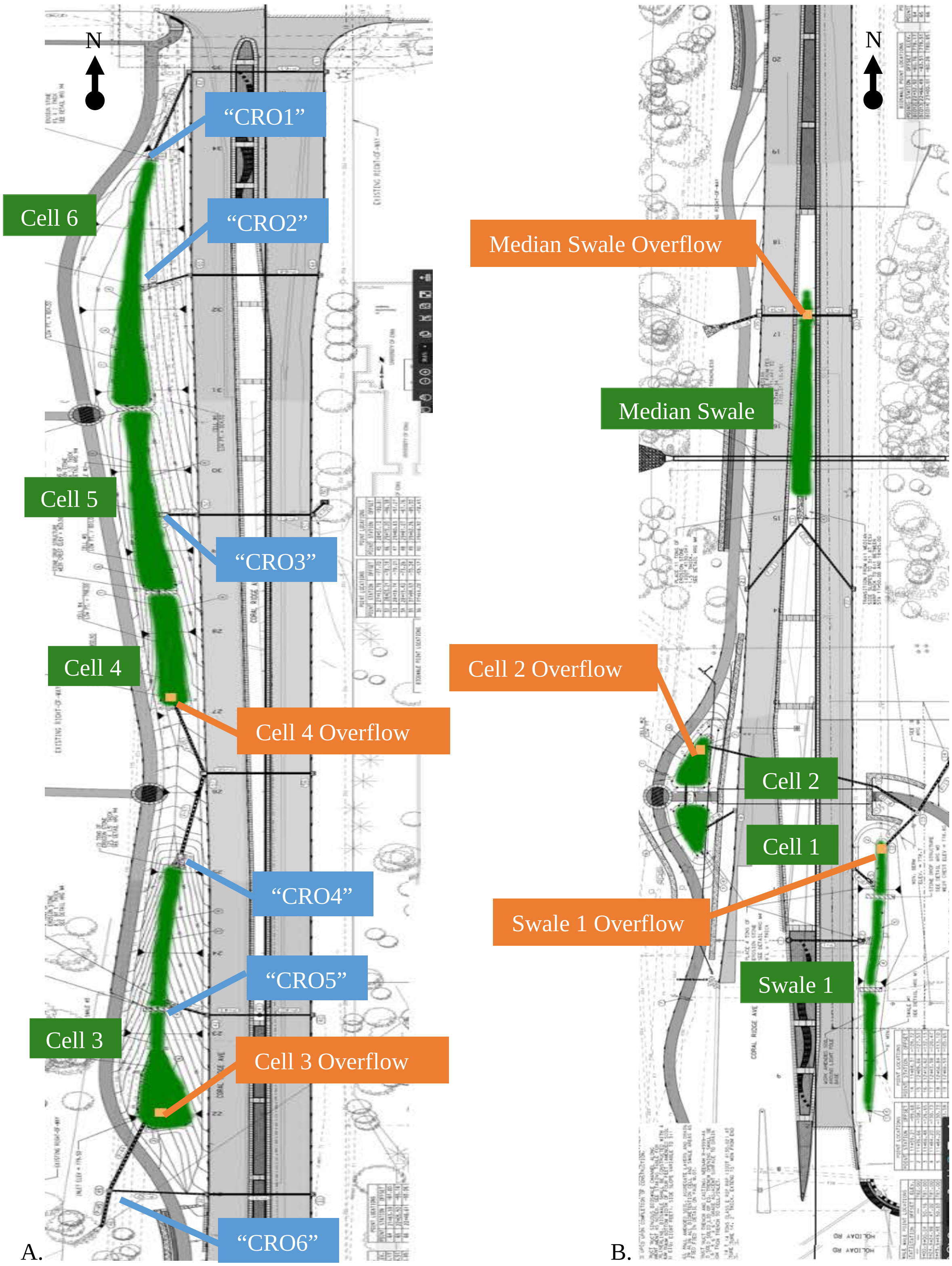

Figure 2: Schematic modified with permission from the engineering documents of HR Green, with bioretention units in green and overflow structures in orange: A. north half of watershed, b. south half of watershed. Not to scale.

CHAPTER 4: APPROACH AND METHODS

Continuous records are available for water depth, temperature, and electrical conductivity. These observations in turn provide volumes and effluent temperature entering and exiting the practice, as well as a proxy for continuous chloride estimates. Reductions in effluent temperature were estimated using the difference in maximum temperatures within a given flow event. Event-based samples are collected to characterize bacteria, chloride, sulfate, nitrate, phosphorus, total suspended solids, and oil and grease. These observations characterize the incoming and outgoing pollutant loads and the spatial variability between the inlets.

Volumetric estimates were obtained using a right-handed trapezoidal definite integration of the flow estimates. The volumes exfiltrated (infiltrated into the *in-situ* soil beneath the aggregate storage) are assumed to be the difference between inflow and outflow volumes. Transpiration is assumed negligible at this juncture as the vegetation in the system is not well-established to contribute major uptake, and the engineered media has such a high hydraulic conductivity that water is not available for evaporation for prolonged periods.

I used SCS-curve number to compare hydrologic performance based on the observed exfiltration (retention). The curve number (CN) is an empirical parameter that can be used to predict runoff (Q, in cfs) for a given rainfall (P, in inches) based on the soil type, land use, and antecedent moisture conditions:

$$Q = \frac{(P - I_a)^2}{P - I_a + S} \qquad \textit{Eq. 1}$$

for which I_a is the initial abstraction and S is the potential maximum retention of rainfall. Often, I_a is simplified as I_a=0.2S, leaving Q a function of only precipitation and retention. In predicting runoff, S is related to soil and cover conditions, which may be calculated based on tabular values for the curve number:

$$S = \frac{1000}{CN} - 10 \qquad \textit{Eq. 2}$$

For hydrologic comparison, the observed retention (in inches) can be used in rearranging the equation to solve for the curve number. The observed retention is represented by the ratio of the difference in cumulative inlet and outlet volumes to the cell area. The resultant curve number solely represents the performance of the cell, and may be used in an area-weighted average to describe the hydrologic performance of the sub-catchment.

Cell Inlet Flow Estimation, Electrical Conductivity, and Temperature Measurements

Global Water pressure transducers (models 16FLU and 16WLU) provide 20 second interval data for water depth. Four 16FLU models are installed at CRO1, CRO2, CRO3, and CRO6, while CRO4 and CRO5 are equipped with the 16WLU. The 16FLU models are equipped with a barometric pressure vent, while the 16WLUs are not. Both sensors consist of a silicone diaphragm. The sensor is calibrated to associate the recorded voltage differential in the meter with a specific diaphragm deflection, which was calibrated at 0 and 1 feet of depth using a 5-gallon bucket. The material properties of the diaphragm paired with assumptions about fluid density provide a pressure estimate with a manufacturer uncertainty of 0.1% of the measurement range. The measurement range is specified during instrument setup, and was set to 36 inches for all pipes so that any depth reading above the pipe diameter could be assumed to represent pressurized flow (and therefore invalid with the weir equation). Variables that may affect measurement uncertainty are atmospheric pressure and temperature, and fluid densities deviant from those assumed. Variations in barometric pressure are assumed negligible because the sensors are calibrated in water, which is much denser than air. The variation in temperature is also assumed negligible because the thermal range for runoff at a single sensor for a given rainfall event is expected to be less than the overall range. Finally, density fluctuations are ignored

Decagon ES-2 meters provide minute-interval electrical conductivity and temperature data. The sensors were factory-calibrated and have a reported uncertainty of 0.01 dS/cm (1000 μS/cm) or 10% (whichever is greater) for electrical conductivity and within 1°C. The ES-2s were specified to record in μS/cm and °C.

The cell inlet aprons are outfitted with a 90° sharp-crested v-notch weir constructed of marine-grade plywood. The ¾ inch thick plywood was cut with a band saw and beveled to a 45° surface within the notch using a mill and angled bit. Holes were drilled in the face of the weir for the measurement devices to have access to the flow. The U.S. Bureau of Reclamation via Chin (2013) recommends an upstream measurement distance of 4H to avoid backwater effects, where H is the head (depth) of the flow within the weir. This is physically not feasible in the pipes, and the backwater effects are ignored because of the low pipe slopes (0.3-0.5% slope).

The weirs are installed in the inlet pipe just upstream of the apron and secured using silicon. The instruments were inserted facing the flow and sealed in place using silicon. The cables were either directly adhered to the pipe, or encased in slit corrugated plastic tubing (for removal) which was adhered to the pipe using silicone. The data loggers are mounted on square traffic sign posts driven 24 into the ground by the City of Coralville. The full external setup is shown in Figure 3.

Figure 3: Internal and external setup of cell inlet apron instrumentation

Well Measurements

Observation wells were installed near the overflow structures of cells 4 and 3 (named CRW1 and CRW2, respectively). The well was constructed using 2” solid PVC pipe. The pipe is slotted at the lowest elevation to allow water to enter the well, and is capped to prevent soil and aggregate migration into the well. At the top of the aggregate layer and the engineered media layer (referred to as “biosoil” in Figure 4) is a bentonite (clay) seal intended to prevent preferential infiltration along the vertical surface of the well. Each well is equipped with a locking cap to discourage tampering.

Wells were developed before instrument installation by using a hand pump to remove water from the well and encourage water movement into the pipe. This ensures that stray soil or fine particulate matter from construction and installation is removed prior to measurement and that the contents of the measurements and samples represent water that has moved within the gravel layer during the event.

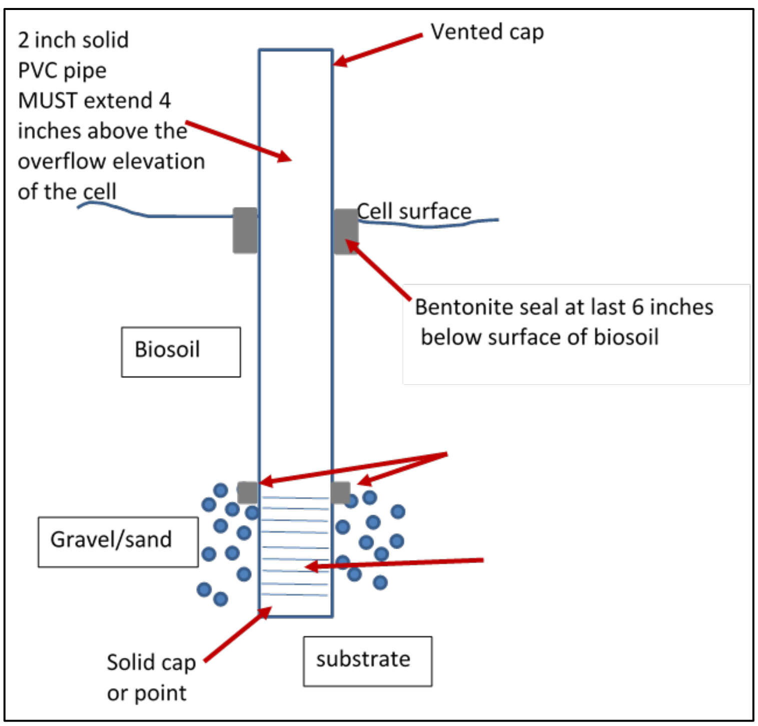

Figure 4: Obs. well schematic, used with permission from A.Bettis

A Decagon CTD-10 sensor was installed in each observation well—2 within the thesis project area near the overflow structures in cells 4 and 3. The Decagon CTD-10 records well depth, electrical conductivity, and temperature on minute-interval records. The information is stored in a Decagon Em5- data-logger mounted directly to the overflow structure, above the intake. The cable was buried beneath the mulch layer and protected above surface with ½ PVC pipe to prevent damage from landscaping machinery or animals.

First Flush Devices and Grab-Samples

The first flush devices are the Thermo Scientific Nalgene 1160-1000 Storm Water Samplers with amber glass collection jars to inhibit photolytic decay. Each 1 L amber jar is equipped with two caps; a storage cap and a collection cap. The collection cap has a bulb to encourage laminar flow into the jar, and a floater that rises to the top of the jar as it is filled. When the jar is full, the floater prevents any additional water from entering the sample jar. The jar is housed in a capped cylinder with orifices in the top and sides of the unit. The housing was permanently installed within the apron riprap of each cell inlet. Since the aprons are not perfectly level, the housing was placed as near to the lowest invert as feasible. The amber jar device and housing installation for the first flushes are shown in Figure 5.

Figure 5: left—first flush jar; right—housing in rock apron

First flush devices were deployed if the precipitation forecast indicated an appreciable amount of rain. The jars were collected within 12 hours of the end of the storm event and stored in a refrigerated facility until they could be analyzed. First flush devices were used to characterize electrical conductivity and pH, and estimate total dissolved solids (TDS) and sodium chloride. A Nitratax *plus* sc was used to measure the above properties. The manufacturer specifies uncertainty at 3%.

The first flush devices only capture 1 liter of sample, which is not enough to process for the constituents of concern at the State Hygienic Laboratory (SHL) at the University of Iowa. To increase the sample volumes at each site, grab samples were collected at appropriately large events. Events for which there was enough runoff at each inlet for collection usually corresponded in time and intensity to the 3-month 30-minute return interval storm outlined in the ISWMM (0.57 inches cumulative precipitation). Smaller events did not produce flow at the outfall sufficient for collecting.

The grab samples were collected by using a hand pump to extract water from behind the weir. If the flow in the apron was deep enough to submerge the pump collection tube, the water was collected downstream of the weir in an attempt to preserve the integrity of the depth measurements upstream of the weir. The water was pumped into a pre-labelled plastic 1-gallon jug. When sufficient water was present in the observation wells (when the bowl of the cell experienced ponding greater than 8 inches in depth), water was also pumped from the wells for sampling. Once all samples had been collected for the system, they were transported to the University of Iowa Hydraulic Annex 1, where each sample was subdivided into vessels provided by SHL containing appropriate preservatives for the constituent of interest. Vessels were labelled and kept cool in a refrigerator or in coolers with icepacks until they were delivered to SHL. Many of the storms occurred at night, such that the samples could not be delivered until the next business day. The grab samples were tested for *E. coli* bacteria, chloride, sulfate, Nitrite/nitrate as N, ortho-phosphate as P, total phosphorus as P, total suspended solids, oil and grease (hexane extractable materials), and total extractable hydrocarbons.

Outlet Instrumentation

Since the project outlet pipes enter a dropshaft before daylighting, the instrumentation in the outlet pipe was uniquely outfitted to accommodate the space and access restrictions. The 18-inch inner-diameter pipe for CRO6 was fitted with an 18-inch outer diameter plastic collar 10 inches long. Six inches remained in the collar, providing surface area for adhesive contact, and 4 inches protruded from the end of the pipe.

Figure 6: Outfall instrumentation

A sharp-crested compound weir (compound rectangular and v-notch) was constructed in the same manner as the other weirs and adhered to the inside of the collar with silicone. Holes were drilled in the collar to serve as access ports such that the sensors could be mounted from beneath to collar. One access port per sensor upstream of the weir, in addition to a third port downstream of the weir from which flexible vinyl tubing provide a feed for the first flush device. The sensors and feed were secured with zipties and silicone, and the instrumented collar was fastened with Liquid Nails heavy-duty construction adhesive to the outfall pipe.

The first-flush device was suspended via cable and anchored above the outfall pipe using a Tapcon concrete screw. The feed from the collar was secured above the first flush device housing with duct-tape. A splash skirt was constructed from plastic sheeting to shield the orifices of the first-flush device from water outside the feed.

The CRO6 data-loggers were mounted in the same fashion as the inlet data-loggers. The sensor cables are placed in the notch of the manhole cover to prevent damage and crimping of the barometric pressure vent. The pipe collar, splash skirt, and cabling are show in Figure 6.

Data Download

The measurement frequency and allotted memory space constrain the length of the data record to ~9 days. The data is downloaded once a week using a Panasonic Toughbook with the proprietary software Global Flow Monitor and ECH20. The Decagon data-logger AA batteries have lasted through the wet season, but the Global Water 9V batteries must be replaced on a weekly basis after downloading. While the Global Water software will not give a % remaining to indicate battery life, one 9V batter is replaced if the voltage differential is less than 14V, and both are replaced at less than 10V. The loggers are re-synched to the Toughbook after disconnection from power. The ECH20 software automatically gives each file download a unique file name based on the logger name and date of download. The Global Flow Monitor software does not automatically give unique file names, so they must be assigned at download to be compatible with the processing scripts.

Data Processing

The records were concatenated by station to create one complete archive for each logger (see Appendix C). The Global Water records were aggregated by minute so that each timestamp is an average of three measurements within the minute. The depths recorded for all inlets were manipulated as-is, while the outlet was decreased by 2 inches to reflect the offset from the v-notch to the collar. The equation for estimating flow within a V-notch are dependent on *H*, the depth of the water within the weir; the angle of the notch, θ (=90°); the acceleration of gravity, g (=9.8066 m/s^2), and a discharge coefficient C_{d1} assumed equal to 0.581 (Chin, 2013). The flow within a V-notch weir, *Q*, is then estimated to be:

$$Q = \frac{8}{15} C_{d1} \sqrt{2g} * tan\left(\frac{\theta}{2}\right) H^{\frac{5}{2}} \qquad \textit{Eq. 3}$$

The equation for estimating flow in a compound weir is a combination of the above v-notch equation and that of a rectangular weir. The discharge coefficient, C_{vd}, is assumed to be 0.6 (McCuen, 1998) and the discharge coefficient C_{d2} varies linearly with the ratio of the head within the weir, *H*, to the crest height, H_w (Rouse, 1946) so that

$$C_{d2} = 0.611 + 0.075 \frac{H}{H_w} \qquad \textit{Eq. 4}$$

The compound equation to estimate flow is then

$$Q = \frac{2}{3} C_{d2} \sqrt{2g} * bH_1^{\frac{3}{2}} + C_{vd} A \sqrt{2g(H_1 + \frac{H_2}{3}} \qquad \textit{Eq. 5}$$

where *b* is the width of the rectangle, $H_1$is the water above the bleeder (v-notch) and H_2 is the height of the bleeder. These equations are only valid for depths within the weir.

CHAPTER 5: RESULTS AND DISCUSSION

Flow Estimates

The temperature at the cell inlets, observation wells, and outlet characterizes the movement of water and changes in effluent temperature. The highest peak is the first flush of water that has absorbed much of the heat that is stored in the pavement prior to the storm. The temperature in the wells responds as the warm water infiltrates, and finally the outlet temperature rises and falls with the passing of the peak of flow, shown in Figure 7.

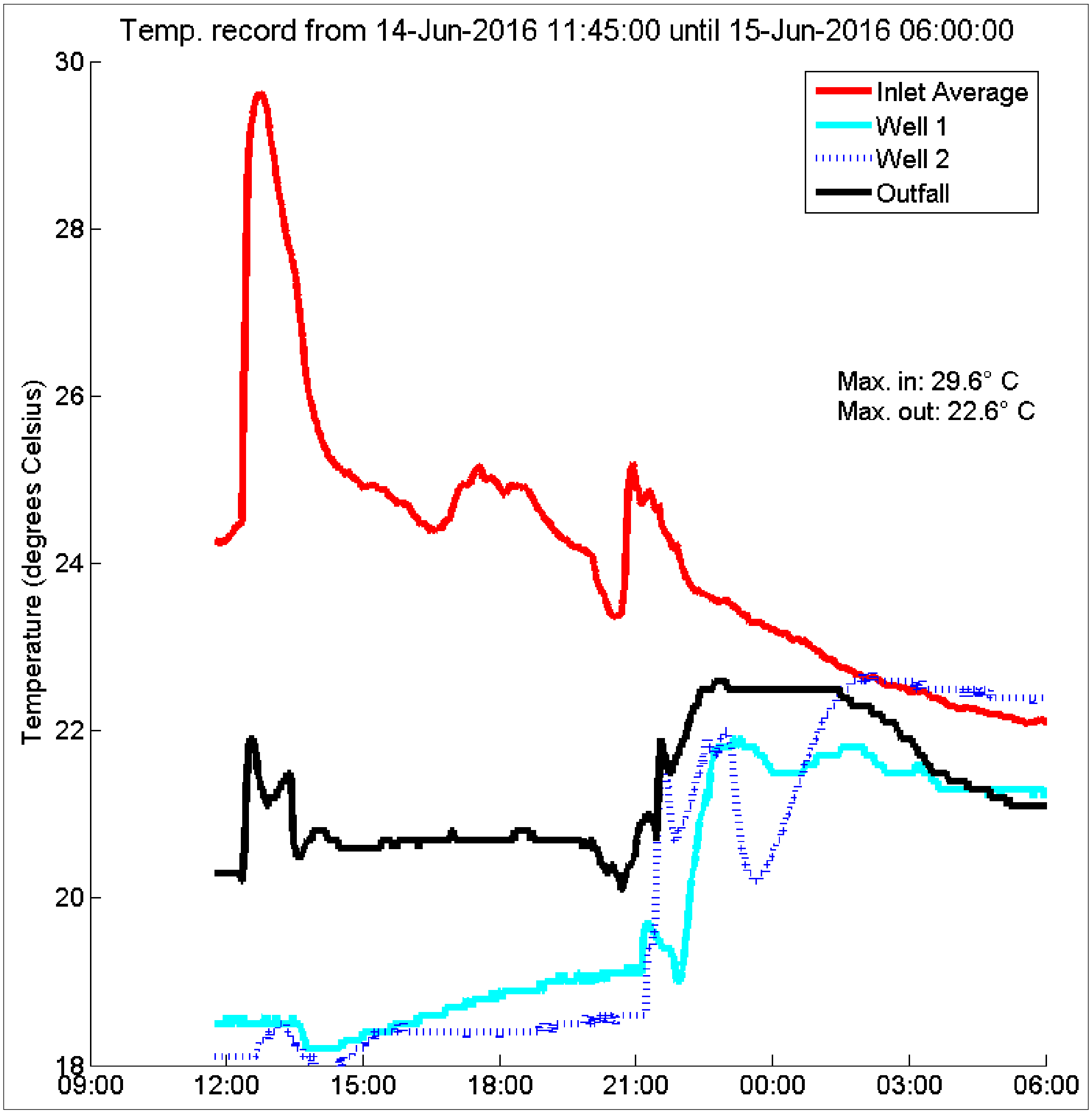

Figure 7: changes in effluent temperature from June 14, 2016

The same set of events in terms of flow is shown in Figure 8. Regrettably, the northmost inlet of cell 6 was non-operational for this event. The listed values for total inflow volume and assumed exfiltration are both underestimates. Visible are two distinct events, the first flow peak (Figure 8) at 12:15 pm is also visible in the effluent temperature (Figure 7) at 29.6°C. The lag between the first inlet and outlet flows is approximately 45 minutes.

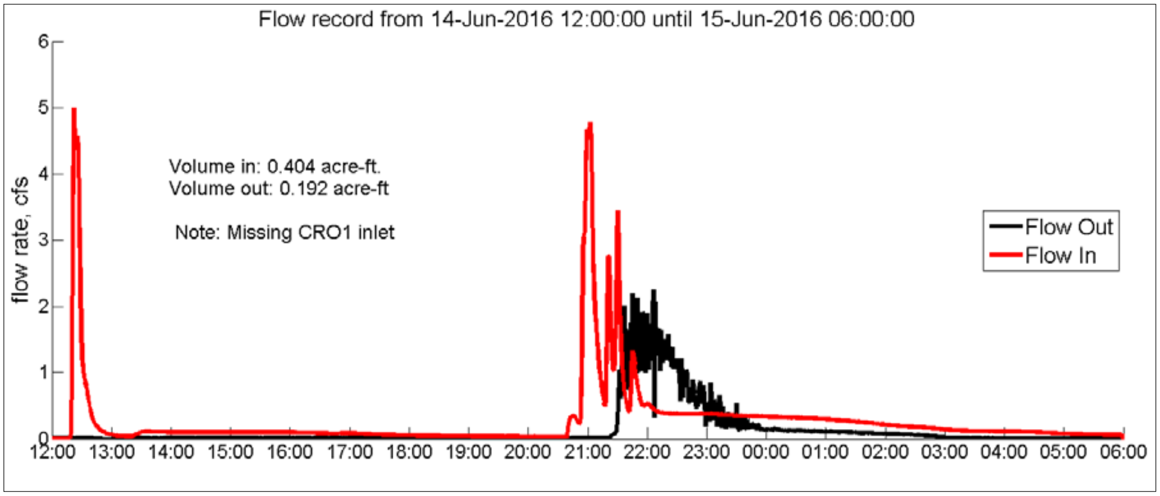

Figure 8: Inlet and outlet hydrographs from June 14, 2016

Ten events (summarized in Table 2) produced sufficient data to evaluate the performance of the cells in a manner similar to the June 14, 2016 events. Three events could not be fully analyzed for volumetric performance because a sensor (either CRO1 or CRO3) was non-operational. The assumed exfiltration, denoted by an *, is then an underestimate for events 9 and 10 for which CRO1 (the upstream-most sensor) was nonoperational. This also results in an overestimated curve-number. In event 10, the outlet flowrate exceeded depths for which the compound weir equation was still valid. It is likely that the flow was pressurized and more water exited than is reflected in the calculation, in which case the exfiltration may be overestimated. There is no correction for this error, because the flow rates are outside the instrumental range.

For event 4, CRO3 was non-operational, resulting in negative exfiltration estimates. Since the curb inlet for CRO3 is nearly halfway down the slope, it intercepts more water than CRO1 so that volumetric estimates are unreasonable and no curve number was calculated. The event remains in the dataset because the outflow estimates from CRO6 provide thermal and exeunt volume information. The thermal reduction for all events, including 4, 9 and 10, remains representative as the values are calculated based on maximum average values.

The curve numbers for the cells are listed in Table 3, and the median of these was used in final area-weighted curve number for the sub-watershed. The design area-weighted curve number was calculated as 77.7, and the empirical CN is 77.4. For reference, within HSG B, the CN for ¼-acre residential lots is 75 and close-seeded straight-row crops is 77. The close proximity indicates that the hydrologic performance of this system was accurately predicted and that the sub-watershed behaves more similarly to residential lots or farmland than highway. The lowered curve number indicates that the increased storage allows the catchment to behave according to pre-200's condition, but does not restore it completely to historic 1800's prairie behavior.

On several occasions, flow was observed in the dropshaft seeping from the vertical and junction joints, indicating shallow groundwater flow was heavily influenced by the exfiltration from the cells. The time and duration of the shallow groundwater response cannot be characterized, but the response in and of itself indicates that the surface and groundwater remain coupled in a physically sound manner.

Table 3: Ten 2016 summer events for effluent temperature and flow estimates

	From	**To**	**% Exfiltrated**	**Thermal reduction, °C**	**CN**
1	4/28/2016 8:00	4/29/2016 00:000	95	1.1	73.3
2	4/30/2016 7:00	4/30/2016 21:00	61	0.2	23.2
3	5/1/2016 15:00	5/1/2016 22:00	97	0.7	60.3
4	5/27/2016 15:00	5/28/2016 6:00	NA	4.5	
5	5/31/2016 15:00	6/1/2016 1:00	97	4.7	41.0
6	6/4/2016 1:00	6/4/2016 4:00	98	3.8	55.1
7	6/4/2016 18:00	6/4/2016 23:00	89	5.2	84.9
8	6/11/2016 1:30	6/11/2016 4:30	97	4.9	60.8
9	6/14/2016 11:00	6/15/2016 6:00	52*	7	27.5
10	6/21/2016 22:00	6/22/2016 12:00	71*	4.5	6.9
	AVERAGE		66.5	3.7	55.1(med)

First Flush Devices and Grab-Samples

As of July, 3 suites of grab samples have been processed. None of the outlet concentrations are above the maxima listed in the Iowa Surface Water Quality Standards, ISWQS.Only the 5/28/2016 event is a full suite containing all inlets, outlet, wells, and analysis for all pollutant constituents. The 5/13/2016 event has all analyses, but no values for CRO1, CRO6 or wells. The 5/2/2016 event has all inlets and outlet, but does not have samples from the wells or analysis for TSS, hexane extractable materials or total hydrocarbons. The values listed in Table 5 represent population ranges *n*=1-3 for inlets, *n*=1 for wells, and *n*=1-2 for the outlet.

The concentrations of *E. coli*, chloride, total phosphorus, sulfate, TSS, hexane extractable materials and total hydrocarbons decrease from the average inlet value to the outlet (downslope), but have not been statistically evaluated for significance because of the small populations. There is some inconsistency in the downslope trend for these pollutants within the observation wells. *E. coli* and chloride decrease downslope as expected, suggesting that these constituents are either sorbed onto the media, deactivated (in the case of *E. coli*), or potentially exfiltrated into the surrounding soil. Total phosphorus, TSS, and total hydrocarbons (specifically motor oil) increase from CRW1 to CRW2, but the CRO6 (exit) values are lower than CRW2. This downslope-increasing pattern is consistent for the isolated 5/28/2016 event as well.

The difference in collection times (about 15 minutes from CRO6 to CRW1, and 15 minutes again from CRW1 to CRW2) does not indicate a source of error, as the timing between all station collection was approximately 15 minutes. The inconsistency in concentrations could be indicative of some pollutant accumulation in the downstream-most portion of the cells. The downstream-most concentrations would be reflected by the observation well values, but not in the outlet values because the underdrain runs the entire length of the cell. Finally, the inconsistency may be an artifact of well installation—either that the observation wells are not flushed between events, or that the bentonite seal is encouraging accumulation.

Table 4: Summary of pollutant loading characteristics

Station ID	*E. coli*	Chl.	Sulf.	NO_x	OP	TP	TSS	HEM	Gas	MS	Ker.	Dies.	M. oil	T. HC
AVERAGE in	609.54	62.00	20.96	0.53	0.26	0.53	208.80	7.50	<100	<100	<100	<100	2436.67	2463.00
CRW1	200	18	27	0.47	0.34	0.83	52	<5.0	<100	<100	<100	<100	300	300
CRW2	<100	8.1	13	0.29	0.79	1.5	110	<5.0	<100	<100	<100	<100	370	370
AVERAGE out	60.00	16.00	25.50	0.59	0.29	0.51	28.00	<5.0	<100	<100	<100	<100	300.00	300.00

E. coli - *Escherichia coli* , [MPN]/100 mL

Chl. - Chloride, mg/L

Sulf. – Sulfate, mg/L

NO_2 – Nitrate and nitrite (as nitrogen), mg/L

OP – Orthophosphate (as phosphorus, mg/L

TP – Total phosphorus, mg/L

TSS – Total suspended solids, mg/L

HEM – Hexane extractable materials, ppm

Gas – Gasoline, µg/L

MS – Mineral spirits, µg/L

Ker – Kerosene, µg/L

Dies – Diesel Fuel, µg/L

M. oil – Motor oil, µg/L

T. HC – Total hydrocarbons, µg/L

The concentration of sulfate, nitrite/nitrate, and orthophosphates increases from average inlet to average outlet values. This is a common phenomenon in systems that have been fertilized. Against recommendations for establishing native vegetation, the cells were hydro-mulched during the month of May, which is a likely source of the nutrients. As the vegetative system grows, the nutrient export should decrease if no additional fertilizer is added to the system. Similar inconsistencies between the wells and the outlet exist: the sulfate and nitrite/nitrate concentrations decrease downslope between the wells while the inlet and outlet values increase downslope. The concentration of orthophosphate increases both between wells and from inlet to outlet. None of these constituents are governed by the ISWQS, but they are of interest in light of the overall nutrient export from the state of Iowa.

The lower detection bounds for the hexane extractable materials and total hydrocarbons limit the conclusions regarding these constituents. Concentrations in the total hydrocarbon category as well as the hexane extractable materials were at or below detection limit such that the only identified constituent within the group was motor oil. The values are low for a high traffic-intensity area. Notably, none of the businesses with direct access to Coral Ridge Avenue are large distributors or warehouses, so it is possible that the number of diesel-using engines is lower than expected. As the native vegetation begins to develop, it is expected that more microorganisms within the soil will develop and thrive, increasing hydrocarbon degradation capacity and decreasing still the concentrations in the final outfall.

The inlet concentrations of *E. coli* (Figure 9) are generally less than half the literature value of 1750 [MPN]/100mL (most probable number per 100 mL) from Pitt, Maestre and Morquecho (2014) and the outlet is below the Iowa Surface Water Quality Standard of geometric mean below 126 organisms/100 mL. The outlier at CRO3 for the 5/28/2016 event and at CRO2 for the 5/13/2016 event are likely from roadkill observed within cell 5 during the month of May.

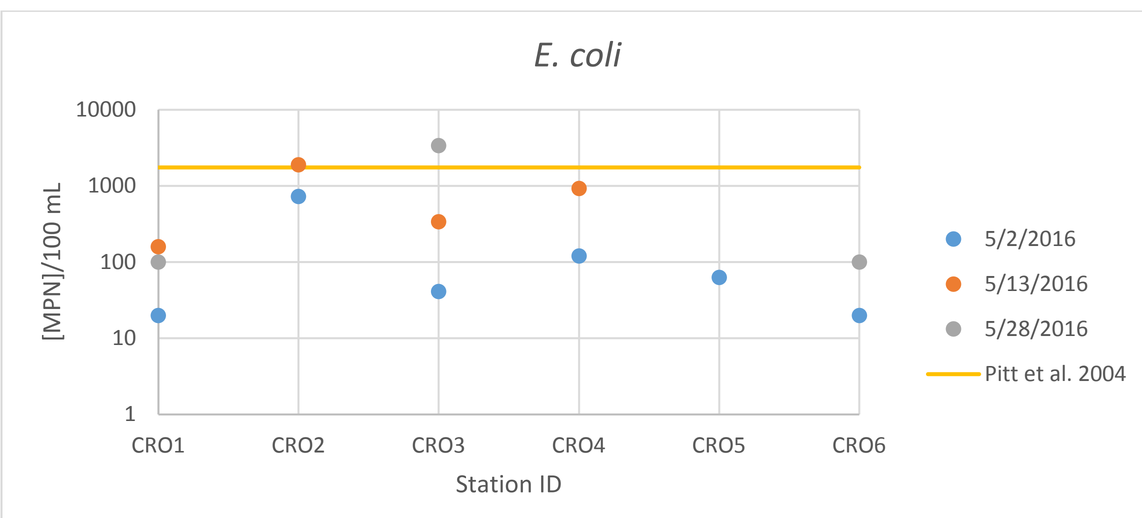

Figure 9: E.Coli values from grab samples

The concentrations of chloride (Figure 10) range from a tenth to three times the literature value from Pitt et al. of 81 mg/L. The ISWQS for chloride is .389 mg/L for chronic levels and 629 mg/L for acute violations.

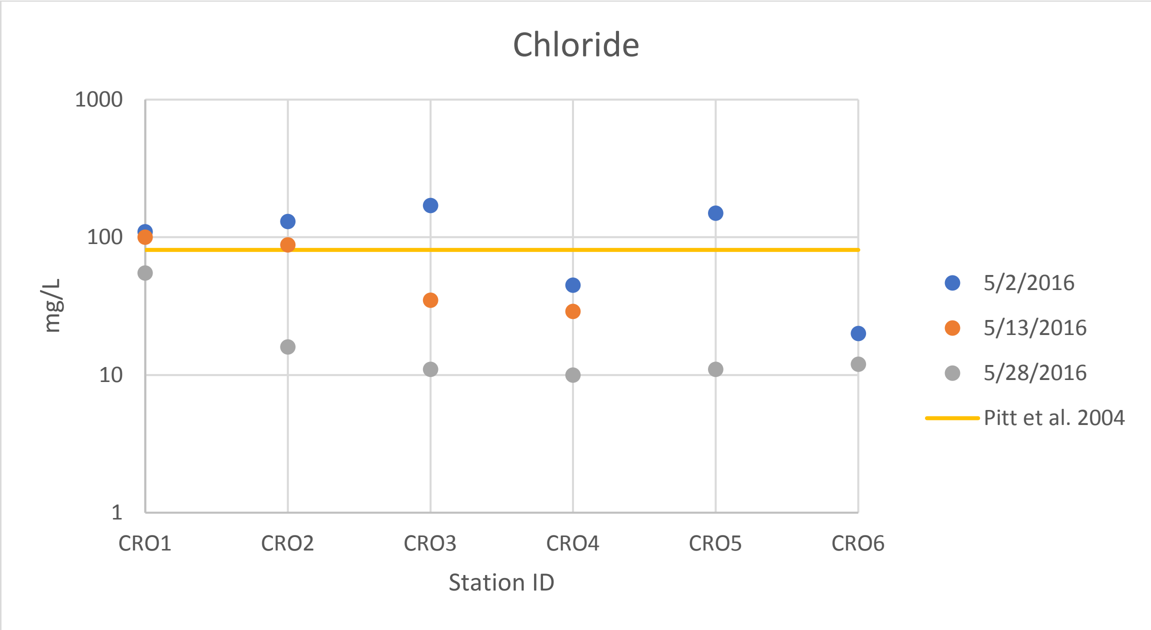

Figure 10: Chloride values from grab samples

The CRO1 chloride concentration values are suspected to be more consistent than the others because of the amount of sedimentation behind the weir at CRO1. During installation, the rock aprons designed to dissipate energy from the flow and prevent scouring in the cell were piled higher than the concrete apron invert. There was excessive ponding within the apron back into the pipe. The remaining silt has remained in place behind the weir, ranging from 1-5 cm deep. A depression just upstream of the weir has formed in the silt where the fines have scoured out, leaving the instrumentation access to the flow. Pores in the rock apron have been filling in with fines since installation and may be a source of chloride. The overall decrease may be a result of longer periods since deposition (chloride application for de-icing in the wintertime).

The concentration of sulfate (Figure 11) ranges 1.5-41 mg/L. No benchmark literature values for sulfate in stormwater are available for comparison. Within the given range, the event outlet concentrations of 24 and 27 mg/L are near the median value of 23 mg/L.

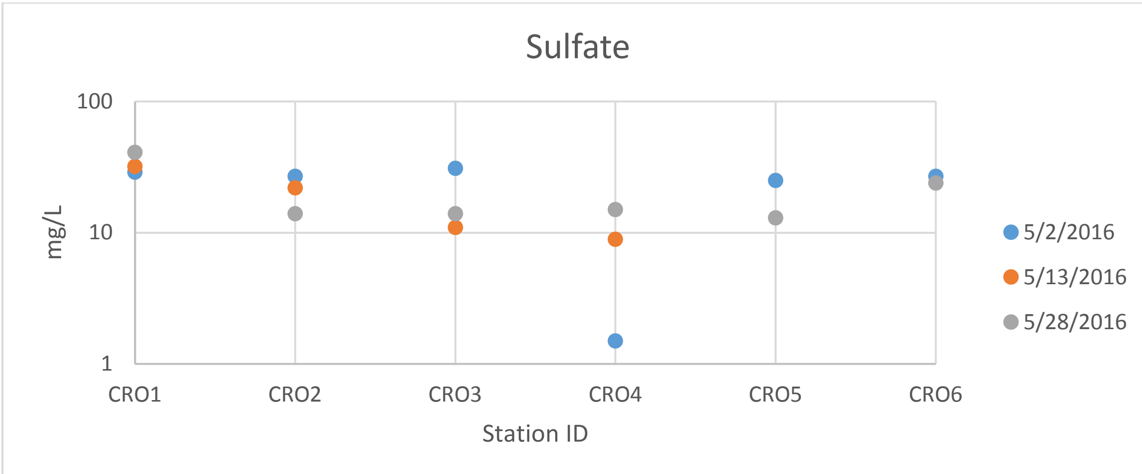

Figure 11: Sulfate values from grab samples

The concentrations of nitrite/nitrate (Figure 12) for the 5/13/2016 and 5/28/2016 events have a range of 0.4 mg/L. The similar inlet values, are all below the literature value of 0.6 given by Pitt et al. (2004) which makes sense given the % impervious area draining into each pipe—no nutrients are intentionally applied to impervious surfaces, so the nitrogen levels should be consistently low. The 5/2/2016 event was more variable, and the mean value was 0.83 mg/L.

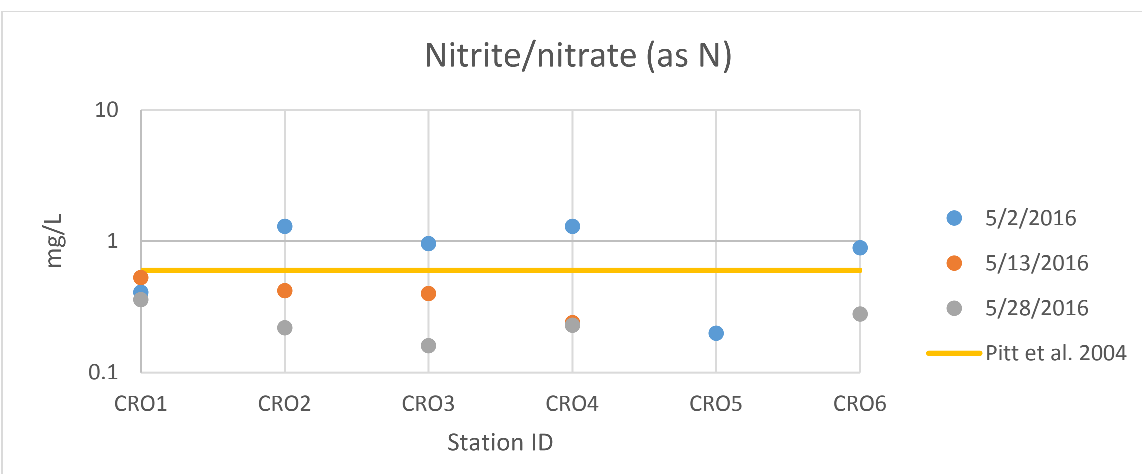

Figure 12: nitrite/nitrate (as N) values from grab samples

The orthopohospate levels and total phosphorus levels, (Figure 13 and Figure 14, respectively) are the same order of magnitude as the literature values (OP=0.16, (Wu, Allan, Saunders, & Evett, 1998)), (TP=0.26, (Pitt, Maestre, & Morquecho, 2004)), but do not display any physical trends worth noting

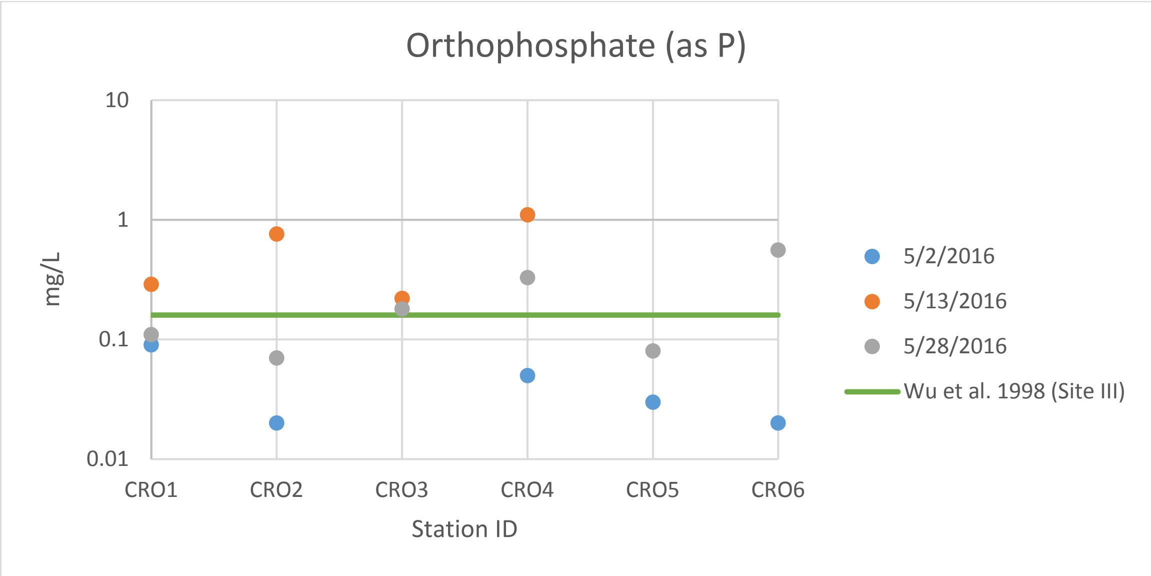

Figure 13: Orthophosphate (as P) values from grab samples

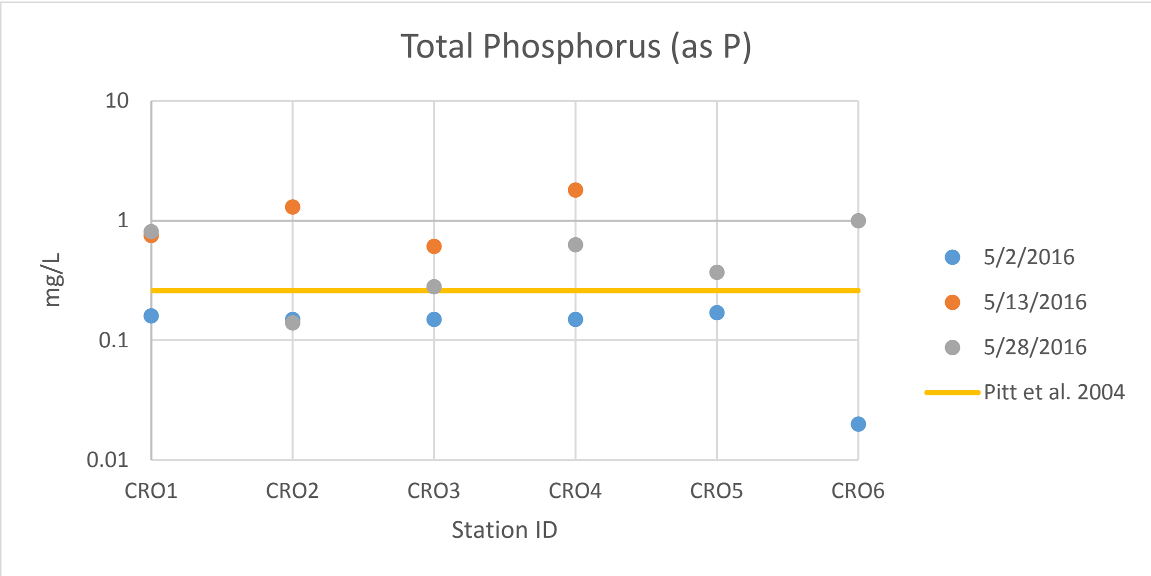

Figure 14: Total Phosphorus (as P) values from grab samples

The concentrations of total suspended solids (Figure 15) generally decreased from above the literature value of 81 mg/L (Pitt, Maestre, & Morquecho, 2004) in the 5/2/2016 event to consistently below during the 5/28/2016 event. The general decrease could be that the sediments applied throughout the winter have finally flushed through the system by the end of May. The high concentrations at CRO1 have already been explained in the context of chloride—there is a nontrivial quantity of sediment trapped behind the weir. Since the pipe slope is 0.4% and the inlet is at the top of the watershed, the flow velocity required to entrain and clear all the sediment at CRO1 may never occur.

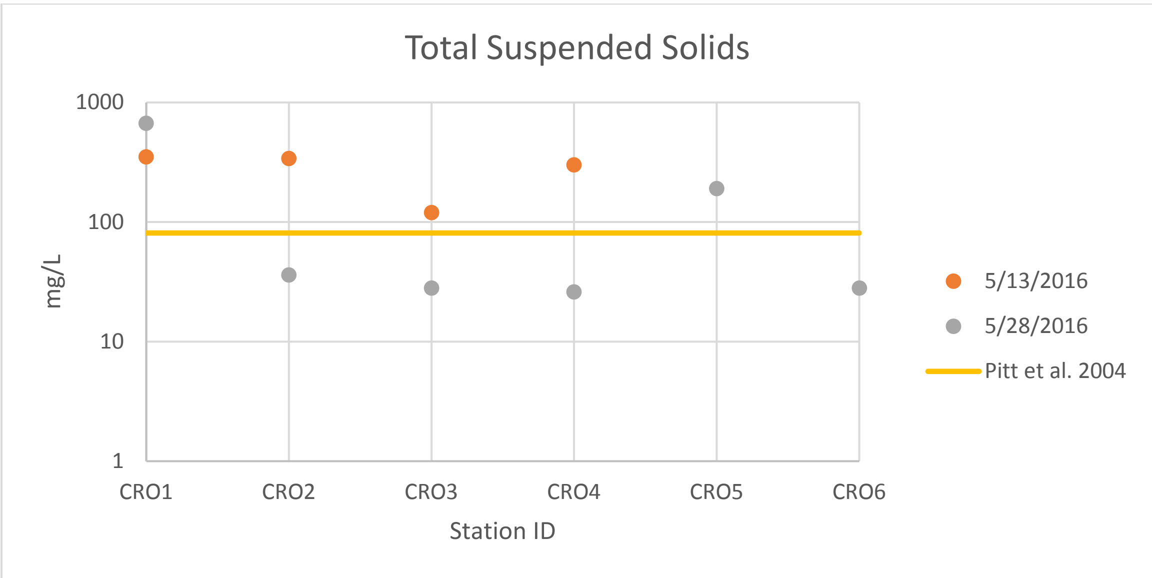

Figure 15: Total Suspended Solids values from grab samples

The constituents examined are typical for highway runoff, with some outliers due to sedimentation and application of fertilizer. Considering all analytics, CRO3 was nearest the mean values for two of the three events event and is arguably the most representative. However, in terms of representative cells, cell 3, containing CRO4 and CRO5, most often has inflow pollutant concentrations closest to the mean.

CHAPTER 6: CONCLUSIONS AND RECOMMENDATIONS

The bioswales on the west side of Coral Ridge Avenue generally reduce the effluent temperature of an event by 3.7°C, with greater thermal reductions observed in higher ambient air temperature. Performance, as indicated by curve number (77.4) is close the predicted value of 77.7, but the bioretention system does not return the project area to pre-development conditions.

The pollutant concentrations from 3 sampled events through the month of May indicate that the stormwater runoff from the roadway is typical for a high-intensity thoroughfare. There is removal of *E. coli,* chloride, sulfate, TSS, and total hydrocarbons while nutrient loading from nitrite/nitrate, orthophosphates, and phosphorus exports are higher than inlet loading. This nutrient export may decrease as the vegetation develops deeper roots and can take in more nutrients. The export of nutrients is attributed to fertilizer added during the month of May to help establish vegetation.

Of the cell inlets, CRO3 is the most representative station as it most often contains pollutant concentrations nearest the mean inlet pollutant concentrations. Cell 3, containing CRO4 and CRO5 is the most representative cell. To examine the first-flush dynamics in detail, and ISCO sampler may be used in cell to capture continuous concentrations of pollutants and therefore total pollutant mass-loading. Total mass loading, especially for chloride, may be especially important in preserving the biota and flora of the system vegetation.

The given instrumentation is not a year-round setup because of the temperature limitations of the sensors. The sensors should be removed at the end of the hydrologic year (October) and re-installed after the threat of freezing nighttime temperatures has passed in the spring.

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APPENDIX A: CITY OF CORALVILLE NPDES PERMIT (EXP. 2019)

IOWA DEPARTMENT OF NATURAL RESOURCES

NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM (NPDES) PERMIT

PERMITTEE

City of Coralville
1512 7th St.
Coralville, IA 52241

IDENTITY AND LOCATION OF FACILITY

City of Coralville

IOWA NPDES PERMIT NUMBER: 52-08-0-02

RECEIVING WATERCOURSES
Clear Creek and Iowa River

DATE OF ISSUANCE: September 1, 2014

DATE OF EXPIRATION: August 31, 2019

YOU ARE REQUIRED TO FILE FOR RENEWAL OF THIS PERMIT BY: March 4, 2019

EPA NUMBER – IA0078646

This permit is issued pursuant to the authority of section 402(b) of the Clean Water Act (33 U.S.C. 1342(b)), Iowa Code section 455B.174, and rule 567--64.13, Iowa Administrative Code. You are authorized to operate the disposal system and to discharge the pollutants specified in this permit in accordance with the monitoring requirements and other terms set forth in this permit.

You may appeal any conditions of this permit by filing written notice of appeal and request for administrative hearing with the director of this department within 30 days of receipt of this permit.

Any existing, unexpired Iowa operation permit or Iowa NPDES permit previously issued by the department for the facility identified above is revoked by the issuance of this Iowa NPDES operation permit.

FOR THE DEPARTMENT OF NATURAL RESOURCES

By ______________________
Joe Griffin
NPDES Section
Environmental Protection Division

1/12

PART I. DISCHARGES AUTHORIZED UNDER THIS PERMIT

A. Permit Area

This permit covers all areas within the boundaries of the City of Coralville totaling approximately 12 square miles which is drained by the city's Municipal Separate Storm Sewer System (MS4) and any other areas added while this permit is in effect.

B. Authorized Discharges

This permit authorizes all existing or new storm water point source discharges to waters of the State from the MS4. This permit also authorizes the discharge of storm water commingled with flows contributed by process wastewater, non-process wastewater, or storm water associated with industrial activity provided such discharges are authorized under separate NPDES permits, as required by law. This permit does not authorize discharges to the MS4.

C. Limitations on Coverage

The following discharges are not authorized or regulated by this permit:

Storm water discharges that are mixed with non-storm water and storm water associated with industrial activity except where such discharges are:

1. in compliance with a separate NPDES permit; or
2. identified by and in compliance with Part IV. of this permit.

PART II. STORM WATER POLLUTION PREVENTION & MANAGEMENT

The permittee shall continue implementing the Best Management Practices (BMPs), measurable goals and frequencies described in the following sections.

A. Public Education and Outreach on Storm Water Impacts

The permittee shall continue implementing a public education and outreach program about the impacts of storm water discharges and measures which the residents of the permittee can implement to reduce pollutants in storm water runoff that includes the following:

1. General Storm Water Education Brochure – An informational brochure shall continue to be distributed to all new businesses served by the MS4. The brochure shall present information regarding storm water impacts on water quality and measures that can be implemented to reduce water quality degradation from storm water.

   The brochure shall be distributed by the permittee to all new businesses for the duration of the permit. The brochures shall also be made available on the permittee's website, at all city offices and as an attachment to building permits issued by the permittee for the duration of the permit.

2. Telephone Hotline Number – The permittee shall provide a telephone number for the reporting of storm water related problems. The telephone number shall be made available on the website and included in other storm water educational materials.

   The telephone number shall remain in effect for the duration of the permit.

3. Storm Water Web Page – The permittee's website shall contain information regarding storm water impacts on water quality, measures residents can implement to reduce pollutants in storm water, regulations, current local topics, information in the brochures and links to other relevant websites. A form for reporting storm water complaints shall be provided on the website. The website shall be updated as needed.

   The storm water web page shall be maintained by the permittee for the duration of the permit.

4. Educational Articles – The permittee shall continue to publish articles in the city newsletter which present information regarding storm water impacts on water quality and measures residents can implement to reduce water quality degradation from storm water. At least two different articles shall be published each year of the permit.

   The two articles shall be published by the permittee each year for the duration of the permit.

5. Educational Television Program – The permittee shall continue televising a television program which presents information regarding storm water impacts on water quality and measures residents can implement to reduce water quality degradation from storm water.

   The program shall be televised by the permittee at least once each calendar year for the duration of the permit.

B. Public Involvement and Participation

The permittee shall continue implementing a public involvement and participation program that includes the following:

1. Storm Water Advisory Committee – The permittee shall continue to meet with the storm water advisory committee to participate in decision making, holding public hearings and working with volunteer groups. Businessmen, developers, homeowners, members of environmental groups and members of the public at large shall be allowed to participate, if interested. However, the permittee may place reasonable limits on the total number of individuals participating in the group.

   The meetings shall be held at least once each calendar year for the duration of the permit.

2. Public Notice Requirements - When implementing a public involvement and participation program, the permittee must comply with all state and local public notice requirements

C. Illicit Discharge Detection and Elimination

The permittee shall continue implementing and enforcing a discharge detection and elimination program that includes the following:

1. Illicit Discharge Prohibition Ordinance – An ordinance shall continue to be enforced and amended as necessary by the permittee that prohibits anything other than storm water, allowable non-storm water and pollutants for which an NPDES permit has been issued and when the discharge is in compliance with the permit from entering the MS4. The ordinance shall include language that enables the permittee to inspect private property if an illicit discharge is suspected and penalties for non-compliance.

   The ordinance shall continue to be enforced and amended as necessary by the permittee for the duration of the permit.

2. Illicit Discharge Detection and Elimination Program – A program shall continue to be implemented to identify and eliminate illicit discharge to the MS4. The program shall include annual dry weather flow inspections of all outfalls not already inspected since flows from newly developed or re-developed areas have been discharged from the outfalls, sampling and analyses of these dry weather flows, procedures to identify the sources of the dry weather flows and procedures for disconnecting illicit connections. Dry weather flow inspections may be made at manholes and other points prior to the flows joining larger portions of the MS4 to facilitate detection of illicit discharges. Records shall be kept of when inspections are performed, the results of the inspections and measures taken to identify and, when appropriate, eliminate the sources of any dry weather flows. The plan shall be evaluated annually to assess the effectiveness of the program and any necessary changes made. All illicit discharges found must be eliminated no more than 21 days after discovery. If it is not possible to eliminate an illicit discharge within 21 days of discovery, the permittee shall submit to the Department the reasons why the discharge cannot be eliminated within 21 days of discovery and a plan which contains a timeline of activities which will result in the elimination of the discharge. This statement and plan shall be submitted within 21 days of discovery of the illicit discharge. If the Department does not approve the plan, the permittee will then be required to eliminate the discharge no later than a date specified by the Department. All illicit discharges shall be reported to the Department no later than the end of the first business day after the day of the discovery.

   The plan shall continue to be implemented by the permittee for the duration of the permit.

D. <u>Construction Site Storm Water Runoff Control</u>

The permittee shall continue implementing and enforcing a construction site storm water runoff control program to reduce pollutants in any storm water runoff from construction activities for which storm water permit coverage is required and that includes the following:

1. Construction Site Runoff Control Ordinance – An ordinance shall continue to be enforced and amended as needed and enforced on all sites for which NPDES permits are required that requires proper soil erosion and sediment control. This ordinance shall also address waste at construction sites that may cause adverse impacts to water quality such as building materials, concrete truck washout, chemicals, solid waste and sanitary waste. Authority to issue an order to terminate activities due to failure to implement or maintain pollution control BMPs, authority for the permittee to enter private property for the purposes of compliance inspections and penalties for non-compliance shall be included. The ordinance shall require site plan and pollution prevention plan review and approval by the permittee prior to issuance of any permits for the site by the permittee. The ordinance shall require compliance with the Department's Storm Water General Permit no. 2.

The ordinance shall continue to be enforced and amended as necessary by the permittee for the duration of the permit.

2. Construction Site Review and Inspection Program - The permittee shall require site plan and pollution prevention plan review and approval by the permittee prior to issuance of any permits for the site by the permittee for construction activities for which an NPDES permit is required. The program shall require compliance with the Department's Storm Water General Permit no. 2 and inspections by the permittee of all sites for which coverage under General Permit no. 2 is required. The program shall require each of these sites be inspected by the permittee at least once each calendar quarter and as complaints are received. City personnel shall ensure that all topsoil preservation requirements stipulated by General Permit no. 2 are implemented on those sites for which they are required.

   The program shall continue to be implemented by the permittee for the duration of the permit.

3. BMP Manual – The permittee shall continue to make available a Best Management Practices design manual which shall include design criteria for structural controls to be implemented at construction sites. The manual shall also be included on the website and amended as necessary.

   The manual shall be made available by the permittee for the duration of the permit.

E. <u>Post-construction Storm Water Management</u>

The permittee shall continue implementing and enforcing a program to address storm water runoff from new construction and re-construction projects for which storm water coverage is required. The program must ensure that controls are in place that will prevent or minimize water quality impacts and shall include the following:

1. Post-construction Site Runoff Control Policy Ordinance – An ordinance shall continue to be enforced and amended as necessary which will address the control of runoff from building activities after construction has been completed. The ordinance shall require water quality and quantity components be considered in the design of new construction and implemented when practical. The ordinance shall promote the use of storm water detention, retention, infiltration, other Best Management Practices specific to each site which address water quality and quantity issues and proper operation and maintenance of these facilities. The permittee shall require storm water concept plan review and approval by the permittee prior to issuance of any permits, including occupancy permits, for the site by the permittee for post-construction runoff controls for sites for which an NPDES or City of Coralville Construction Site Runoff (CSR) permit is required.

   The ordinance shall continue to be enforced by the permittee and amended as necessary for the duration of the permit.

2. Site Plan Review of Post-construction Runoff Controls – The permittee shall establish procedures and acceptance criteria for review of post-construction runoff controls for all construction sites for which coverage under NPDES storm water permits are required. The permittee shall not allow construction activities to commence until the plans for post-construction runoff controls have been reviewed and approved.

   The program shall continue to be implemented for the duration of the permit.

3. Inspection of Runoff Control Devices – Storm water control devices and structures shall be inspected and reviewed for proper maintenance. Educational materials shall continue to be made available to landowners which outline proper maintenance procedures. The permittee shall properly maintain its own control devices and structures.

   Inspections shall be conducted by the permittee for the duration of the permit. The educational materials shall continue to be available by the permittee for the duration of the permit.

4. Watershed Assessment Program – A watershed assessment program and comprehensive land use plan shall continue to be implemented which outlines measures to be implemented which reduce flooding, reduce erosion in ditches and streams, improve water quality and reduce degradation of habitat for fish and wildlife. The permittee shall then implement the program whenever possible to meet these goals.

   The program shall be implemented by the permittee for the duration of the permit.

F. Pollution Prevention/Good Housekeeping

The permittee shall continue implementing an operation and maintenance program, including a training component, that shall prevent or reduce pollutant runoff from municipal operations and that shall include the following:

1. Operation and Maintenance of MS4 - A program for inspecting, maintaining and cleaning all components of the MS4 including street sweeping shall continue to be implemented. All above-ground components of the MS4 shall be inspected at least once each year and maintenance performed as appropriate.

   The program shall be implemented by the permittee for the duration of the permit.

2. Pesticide and Fertilizer Management Program – A pesticide and fertilizer management program shall continue to be implemented and enforced which shall reduce pollutant discharge associated with storage, application and disposal of pesticides and fertilizers for municipal operations. The program shall identify all entities that apply pesticides and fertilizers, require that application of these chemicals be applied by properly trained individuals, require training on management techniques addressing storage, application and disposal. Data regarding the application rates of pesticides and fertilizers shall be gathered and evaluated to determine if lower rates would be equally effective. Should it be determined that lower application rates would be equally or nearly as effective it shall be required that the lower rates be applied.

   The program shall continue to be implemented by the permittee for the duration of the permit.

3. Training Program for Municipal Employees – The permittee shall continue to implement a program for training municipal employees regarding practices to be implemented in city operations to reduce pollutants in storm water.

   The program shall continue to be implemented by the permittee for the duration of the permit.

4. City Facilities BMPs – A program shall continue to be implemented to assess BMPs at city facilities to be implemented that reduce pollutants in storm water from these facilities. These measures shall then be implemented whenever practical.

inspections by the permittee at least every 7 days and include any other provisions necessary to ensure compliance by contractors with the storm water General Permit no. 2. Inspections made by the permittee that satisfy the requirements of General Permit no. 2 may be used to satisfy the requirements of this permit.
A map of the MS4, including all outfalls, shall be maintained for the duration of this permit.

All salt storage shall be in a structure impervious to precipitation and any spillage due to handling activities in an area subject to runoff shall be immediately removed.

The permittee may directly place snow, free of trash, into or onto a Water of the State.

The manner in which actions required by this permit are accomplished by the permittee is subject to review and approval by the Department. Should the Department give notice to the permittee that the approach used by the permittee to comply with any permit provision is unacceptable, the permittee must modify its approach as required in order to be considered in compliance with the permit.

PART V. STANDARD CONDITIONS

A. Pemittee's Duty to Comply

The permittee must comply with all conditions of this permit. Any permit noncompliance constitutes a violation of the Clean Water Act (CWA) and is grounds for enforcement action; for permit termination, revocation and reissuance, or modification; or for denial of a permit renewal application. Issuance of this permit does not relieve the permittee of the responsibility to comply with all local, state and federal laws, ordinances, regulations or other legal requirements applying to the operation of this facility (see 40 CFR 122.41(a) and 567-64.3(11) IAC).

B. Duty to Provide Information

The permittee shall furnish to the Department, within a time specified by the Department, any information that the Department may request to determine whether cause exists for modifying, revoking and reissuing, or terminating this permit or to determine compliance with this permit. The permittee must also furnish to the Department, upon request, copies of any records required to be kept by this permit.

C. Need to Halt or Reduce Activity Not a Defense

It shall not be a defense for a permittee in an enforcement action that it would have been necessary to halt or reduce the permitted activity in order to maintain compliance with the conditions of this permit.

D. Signatory Requirements

Storm Water Pollution Prevention Plans, reports, certifications or information either submitted to the Department or that this permit requires be maintained by the permittee, shall be signed as follows:

For a municipality, State, Federal, or other public facility: by either a principal executive officer or ranking elected official. For purposes of this section, a principal executive officer of a Federal agency includes 1) the chief executive officer of the agency, or 2) a senior executive officer having responsibility for the overall operations of a principal geographic unit of the agency.

Certification Any person signing documents shall make the following certification:

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gathered and evaluated the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

E. Duty to Mitigate

The permittee shall take all reasonable steps to minimize or prevent any discharge in violation of this permit that has a reasonable likelihood of adversely affecting human health or the environment.

F. Property Rights

The issuance of this permit does not convey any property rights of any sort, nor any exclusive privileges, nor does it authorize any injury to private property nor any invasion of personal rights, nor any infringement of Federal, State, or local laws or regulations.

G. Severability

The provisions of this permit are severable, and if any provision of this permit, or the application of any provision of this permit to any circumstance, is held invalid, the application of such provision to other circumstances, and the remainder of this permit shall not be affected thereby.

H. State/Environmental Laws

Nothing in this permit shall be construed to preclude the institution of any legal action or relieve the permittee from any responsibilities, liabilities, or penalties established pursuant to any applicable State law or regulation under authority preserved by Section 510 of the Act. No condition of this permit shall release the permittee from any responsibility or requirements under other environmental statutes, regulations or permits.

I. Proper Operation and Maintenance

The permittee shall at all times properly operate and maintain all facilities and systems of treatment and control (and related appurtenances) that are installed or used by the permittee to achieve compliance with the conditions of this permit and with the requirements of storm water pollution prevention plans. Proper operation and maintenance also includes adequate laboratory controls and appropriate quality assurance procedures. Proper operation and maintenance requires the operation of backup or auxiliary facilities or similar systems, installed by the permittee only when necessary to achieve compliance with the conditions of the permit.

J. Inspection and Entry

The permittee shall allow the Department, an authorized representative or an authorized representative of the municipal operator of the separate storm sewer receiving the discharge, upon the presentation of credentials and other documents as may be required by law, to: enter upon the permittee's premises where a regulated facility or activity is located or conducted or where records must be kept under the conditions of this permit; have access to and copy at reasonable times, any records that must be kept under the conditions of this permit; inspect at reasonable times any facilities or equipment (including monitoring and control equipment); and to sample any discharge of pollutants.

K. Permit Actions

This permit may be modified, revoked and reissued, or terminated for cause. The filing of a request by the permittee for a permit modification, revocation and reissuance, or discontinuance, or a notification of planned changes or anticipated noncompliance does not stay any permit condition. This permit may be modified due to conditions or information on which this permit is based, including any new standard the Department may adopt that would change the required effluent limits.

L. Potential or Realized Impacts on Water Quality

If there is evidence indicating potential or realized impacts on water quality or on a listed endangered species due to any storm water discharge associated with industrial activity covered by this permit, the permit shall be modified to include different limitations and/or requirements of the Pollution Prevention Plan and its implementation.

M. Failure to submit fees

This permit may be revoked, in whole or in part, if the appropriate permit fees are not submitted within sixty (60) days of the date of notification that such fees are due.

N. Penalties For Violations of Permit Conditions

Section 309 of the CWA provides significant penalties for a person(s) who violates a permit condition implementing Section 301, 302, 306, 307, 318, or 405 of the CWA, or any permit condition or limitation implementing any such sections in a permit issued under Section 402. Any person(s) who violates any condition of this permit is subject to a civil penalty not to exceed $25,000 per day of such violation, as well as any other appropriate sanction provided by Section 309 of the CWA.

PART VI. DEFINITIONS

1. Allowable Non-Storm Water means: discharges from fire fighting activities, fire hydrant flushings, potable water sources, waterline flushings, uncontaminated groundwater, foundation or footing drains where flows are not contaminated with process materials such as solvents, springs, riparian habitats, wetlands, irrigation water, air conditioning condensate, exterior building washwater when no detergents or other surfactants are used and pavement washwaters where spills or leaks of toxic or hazardous materials have not occurred and when no detergents or other surfactants are used.

2. Best Management Practices ("BMPs") means schedules of activities, prohibitions of practices, maintenance procedures, and other management practices to prevent or reduce the pollution of waters of the State. BMPs also include treatment requirements, operating procedures, and practices to control facility site runoff, spillage or leaks, sludge or waste disposal, or drainage from raw material storage.

3. Calendar Quarter means each of the following periods: December thru February, March thru May, June thru August and September thru November.

4. CWA means Clean Water Act (formerly referred to as the Federal Water Pollution Control Act or Federal Water Pollution Control Act Amendments of 1972).

5. Department means the Iowa Department of Natural Resources (IDNR) or an authorized representative.

6. Discharge means the release of water and any elements, compounds and particles contained within or upon, from property owned or controlled by an individual, individuals, or entity.

7. Facility means any entity which discharges storm water.

8. Municipal separate storm sewer system means the conveyance or system of conveyances including storm sewers, roadways, roads with drainage systems, catch basins, curbs, gutters, ditches, constructed channels and storm drains owned or operated by the permittee.

9. Permittee means the City of Coralville.

10. Point source means any discernible, confined, and discrete conveyance, including but not limited to, any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, landfill leachate collection system, vessel or other floating craft from which pollutants are or may be discharged. This term does not include return flows from irrigated agriculture or agricultural storm water runoff.

11. Significant materials includes, but is not limited to: raw materials; fuels; materials such as solvents, detergents, and plastic pellets; finished materials such as metallic products; raw materials used in food processing or production; hazardous substances designated under Section 101(14) of Comprehensive Environmental Response, Compensation and Liability Act (CERCLA); any chemical the facility is required to report pursuant to Emergency Planning and Community Right-to-Know Act (EPCRA) Section 313; fertilizers; pesticides; and waste products such as ashes, slag and sludge that have the potential to be released with storm water discharges.

12. Storm water means storm water runoff, snow melt runoff, snow and surface runoff and drainage.

13. Storm water discharge associated with industrial activity means the discharge from any conveyance that is used for collecting and conveying storm water and that is directly related to manufacturing, processing or raw materials storage areas at an industrial plant. The term does not include discharges from facilities or activities excluded from the NPDES program. For the categories of industries identified in paragraphs (i) through (x) of this definition, the term includes, but is not limited to, storm water discharges from industrial plant yards; immediate access roads and rail lines used or traveled by carriers of raw materials, manufactured products, waste material, or by-products used or created by the facility; material handling sites; refuse sites; sites used for the application or disposal of process waste waters (as defined at 40 CFR Part 401); sites used for the storage and maintenance of material handling equipment; sites used for residual treatment, storage, or disposal; shipping and receiving areas; manufacturing buildings; storage areas (including tank farms) for raw materials, and intermediate and finished products; and areas where industrial activity has taken place in the past and significant materials remain and are exposed to storm water. For the categories of industries identified in paragraph (xi) of this definition, the term includes only storm water discharges from all areas (except access roads and rail lines) listed in the previous sentence where material handling equipment or activities, raw materials, intermediate products, final products, waste materials, by-products, or industrial machinery are exposed to storm water. For the purposes of this paragraph, material handling activities include the storage, loading and unloading, transportation, or conveyance of any raw material, intermediate product, finished product, by-product or waste product. The term excludes areas located on plant lands separate from the plant's industrial activities, such as office buildings and accompanying parking lots as long as the drainage from the excluded areas is not mixed with storm water drained from the above described areas. Industrial facilities (including industrial facilities that are Federally, State, or municipally owned or operated that meet the description of the facilities listed in paragraphs (i) to (xi) of this definition) include those facilities designated under 122.26(a)(1)(v). The following categories of facilities are considered to be engaging in "industrial activity" for purposes of this subsection.

(i) Facilities subject to storm water effluent limitations guidelines, new source performance standards, or toxic pollutant effluent standards under 40 CFR Subchapter N (except facilities with toxic pollutant effluent standards that are exempted under category (xi) of this definition);

(ii) Facilities classified as Standard Industrial Classifications 24 (except 2434), 26 (except 265 and 267), 28 (except 283 and 285), 29, 311, 32 (except 323), 33, 3441, 373;

(iii) Facilities classified as Standard Industrial Classifications 10 through 14 (mineral industry) including active or inactive mining operations (except for areas of coal mining operations no longer meeting the definition of a reclamation area under 40 CFR 434.11(l) because the performance bond issued to the facility by the appropriate SMCRA authority has been released, or except for areas of non-coal mining operations that have been released from applicable State or Federal reclamation requirements after December 17, 1990) and oil and gas exploration, production, processing, or treatment operations, or transmission facilities that discharge storm water contaminated by contact with or that has come into contact with, any overburden, raw material, intermediate products, finished products, byproducts or waste products located on the site of such operations; inactive mining operations are mining sites that are not being actively mined, but that have an identifiable owner/operator;

(iv) Hazardous waste treatment, storage, or disposal facilities, including those that are operating under interim status or a permit under Subtitle C of RCRA;

(v) Landfills, land application sites, and open dumps that have received any industrial wastes (waste that is received from any of the facilities described under this subsection) including those that are subject to regulation under Subtitle D of RCRA;

(vi) Facilities involved in the recycling of materials, including metal scrap yards, battery reclaimers, salvage yards, and automobile junkyards, including but limited to those classified as Standard Industrial Classification 5015 and 5093;

(vii) Steam electric power generating facilities, including coal handling sites;

(viii)Transportation facilities classified as Standard Industrial Classifications 40, 41, 42 (except 4221-25), 43, 44, 45 and 5171 that have vehicle maintenance shops, equipment cleaning operations, or airport deicing operations. Only those portions of the facility that are either involved in vehicle maintenance (including vehicle rehabilitation, mechanical repairs, painting, fueling, and lubrication), equipment cleaning operations, airport deicing operations, or that are otherwise identified under paragraphs (i) to (vii) or (ix) to (xi) of this subsection are associated with industrial activity;

(ix) Treatment works treating domestic sewage or any other sewage sludge or wastewater treatment device or system, used in the storage treatment, recycling, and reclamation of municipal or domestic sewage, including land dedicated to the disposal of sewage sludge that are located within the confines of the facility, with a design flow of 1.0 mgd or more, or required to have an approved pretreatment program under 40 CFR Part 403. Not included are farm lands, domestic gardens or lands used for sludge management where sludge is beneficially reused and that are not physically located in the confines of the facility, or areas that are in compliance with 40 CFR Part 503;

(x) Construction activity including clearing, grading and excavation activities that result in the disturbance of 1 acre or more of total land area or which result in the disturbance of less than 1 acre but are part of a larger common plan of development or sale of 1 acre or more;

(xi) Facilities under Standard Industrial Classifications 20, 21, 22, 23, 2434, 25, 265, 267, 27, 283, 285, 30, 31 (except 311), 323, 34 (except 3441), 35, 36, 37 (except 373), 38, 39, 4221-25, (and that are not otherwise included within categories (i) to (x)).

(xii) Waters of the State means any river, stream, lake, pond, marsh, watercourse, waterway, well, spring, reservoir, aquifer, irrigation system, drainage system and any other body or accumulation of water, surface or underground, natural or artificial, public or private, which are contained within, flow through or border upon the state or any portion thereof.

The program shall continue to be implemented by the permittee for the duration of the permit.

PART III. REPORTING REQUIREMENTS

Annual Report

The permittee shall prepare an annual report to be submitted to the Department no later than August 31 of each calendar year. The report shall be submitted to the appropriate Department field office and shall include the following:

1. The status of implementing the components of this permit. Any modifications developed by the permittee and approved by the Department or required by the Department shall also be addressed.

2. A summary of the data, including monitoring data if it exists, that is generated within the reporting period including a narrative description of storm water quality improvements or degradation. This is not to be construed as a requirement to conduct monitoring except in cases where an illicit discharge is suspected.

3. An estimate of the previous fiscal year's expenditures for implementation of the requirements of this permit and the budget for the current fiscal year.

4. A summary describing the number and nature of inspections, enforcement actions, illicit discharges discovered, ordinances adopted, public education programs conducted, components of the MS4 cleaned, stream restoration activities, meetings held and any other actions taken by the permittee required by this permit during the reporting period.

PART IV. SPECIAL CONDITIONS

Only storm water, allowable non-storm water, and pollutants for which an NPDES permit has been issued and when the discharge is in compliance with the permit, are allowed to be discharged to the MS4. The permittee shall not have nor allow any discharge of pollutants from a site, facility or source for which an NPDES permit is required unless an NPDES permit has been issued for the discharge. Upon discovery of any unpermitted discharge for which a permit is required or, if an NPDES permit has been issued for the discharge, a discharge not in compliance with the permit, the permittee shall report the discharge to the Department no later than the end of the next business day after the discharge is discovered. Floor drains and other potential sources of pollutants shall be considered discharges even if no actual pollutants have been observed entering the MS4 from such a source.

The permittee is prohibited from issuing any permit, authorization or license allowing any construction, excavating, clearing, grubbing, or any other soil disturbing activity and is prohibited from allowing a person, persons, company, political unit or other entity, public or private, from doing same for which, in whole or as part of another project, coverage under an NPDES permit is required without first ensuring that a storm water authorization from the Department has been issued for the activity.

A construction site inspection program shall continue to be implemented for construction projects owned or operated by the permittee that include areas of soil disturbance for which NPDES permits are required. The inspection program shall be used to ensure that contractors are correctly implementing BMPs which have been approved in the pollution prevention plan and any additional necessary measures. The program shall require

APPENDIX B: IOWA DEPARTMENT OF NATURAL RESOURCES NPDES NOTICE

IOWA DEPARTMENT OF NATURAL RESOURCES
National Pollutant Discharge Elimination System
Notice Date: 7/3/2014

The Iowa Department of Natural Resources is proposing to issue a NPDES (National Pollutant Discharge Elimination System) permit for the discharge described below:

DISCHARGER NAME AND ADDRESS

City of Coralville
1512 7th St.
Coralville, IA 52241

LOCATION: Johnson County

RECEIVING WATERBODIES: Iowa River, Clear Creek and other, undesignated waterways

The Iowa River at the point of discharge is a class A1, B(WW-1) and HH stream. Class A1 streams are waters in which recreational or other uses result in prolonged and direct contact with the water. Class B(WW-1) streams are waters in which temperature, flow and other habitat characteristics are suitable to maintain warm water game fish populations, native nongame fish and invertebrate species. Class HH streams are waters in which fish are routinely harvested for human consumption and which may be used as a drinking water supply.

Clear Creek at the point of discharge is a class A3 and B(WW-2) stream. Class A3 streams are waters in which recreational use by children is common. Class B(WW-2) streams are waters which are capable of supporting native nongame fish and invertebrate species.

DESCRIPTION OF PROPOSED DISCHARGES:

The permit will authorize the discharge of storm water from the municipal separate storm sewer system. Run-off water will normally be collected and discharged to the Iowa River, Clear Creek and other, undesignated waterways.

Anyone wishing to comment on or object to the proposed permit must do so in writing within 45 days of the date shown at the top of this notice. All comments received will be considered in the final decision to issue or deny the permit. If no objections are received within 45 days, the Department will issue a final permit. You may request that the Department hold a public hearing by submitting a written request citing specific reasons and a proposed list of topics to cover.

Comments, objections, and requests for hearings must be addressed to: **Department of Natural Resources, Storm Water Coordinator, 502 East 9th Street, Des Moines, IA 50319.**

Copies of this notice, the proposed permit and other information are on file and available for public inspection from 8:00 AM to 4:30 PM Monday through Friday at the above address.

APPENDIX C: STATE HYGIENIC LABORATORY WATER QUALITY RESULTS

State Hygienic Laboratory

The University of Iowa

Accession Number	377957
Date Sample Finalized	2016-06-03 15:04
Date Received	2016-05-16 09:40
Sample Source	Non-Drinking Water
Project	
Date Collected	2016-05-13 15:00
Collection Site	cr05 outfall
Collection Address	
Sample Description	non drinking water
Client Reference	bioretention researc
Collector	
Phone	

AMY BOUSKA
JOHNSON COUNTY SWCD
51 ESCORT LN
IOWA CITY, IA 52240

Note: The sample was received after established holding time but analyzed at the client's request.

Results of Analyses

E.coli Bacteria, SM 9223 B

Units	[MPN]/100mL	Analyzed In	Coralville
Date Analyzed	2016-05-16 10:36	Date Verified	2016-05-17 12:05
Analyst	JAO, CCC	Verifier	JAO

Analyte	Result	Quant Limit
E.coli	930	10

Chloride, EPA 300.0

Units	mg/L	Analyzed In	Ankeny
Date Analyzed	2016-06-03 05:43	Date Verified	2016-06-03 15:04
Analyst	BER	Verifier	DLS

Analyte	Result	Quant Limit
Chloride	29	1

Sulfate, EPA 300.0

Units	mg/L	Analyzed In	Ankeny
Date Analyzed	2016-06-03 05:43	Date Verified	2016-06-03 15:04
Analyst	BER	Verifier	DLS

Analyte	Result	Quant Limit
Sulfate	8.9	1

Nitrate + Nitrite as N, LAC 10-107-04-1J

Units	mg/L	Analyzed In	Ankeny
Date Analyzed	2016-05-24 12:10	Date Verified	2016-05-25 13:31
Analyst	RWR	Verifier	JAE

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State Hygienic Laboratory

The University of Iowa

Accession Number | 387173

Analyte	Result	Quant Limit
Mineral spirits	<100	100
Kerosene	<100	100
Diesel fuel	<100	100
Motor oil	770	100
Total Extractable Hydrocarbons	770	100

Note: The chromatographic profile of the sample extract did not match this laboratory's fuel or oil standards. Quantitation is based on this laboratory's motor oil standard.

Prep by Separatory Funnel, Iowa OA-2

Units	ug/L	Analyzed In	Coralville
Date Analyzed	2016-06-10 06:30	Date Verified	2016-06-10 11:12
Analyst	PM	Verifier	KB

Description of Units used within this report

[MPN]/100mL = Most Probable Number per 100 Milliliters
mg/L = Milligrams per Liter
ppm = Parts per Million
ug/L = Micrograms per Liter

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If you have any questions, please call Client Services at 800/421-IOWA (4692) or 319/335-4500. Thank you.

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State Hygienic Laboratory

The University of Iowa

Accession Number	395462
Date Sample Finalized	2016-07-15 13:56
Date Received	2016-06-30 10:15
Sample Source	
Project	
Date Collected	2016-06-30 09:30
Collection Site	crw2
Collection Address	CORALVILLE,
Sample Description	non drinking water
Client Reference	biorention research
Collector	beebe charles
Phone	319/899-3232

AMY BOUSKA
JOHNSON COUNTY SWCD
51 ESCORT LN
IOWA CITY, IA 52240

Note: Upon arrival, sample met container and preservation requirements for the analysis requested. Please review carefully your sample results for additional analyte comments or method exceptions.

Results of Analyses

E.coli Bacteria, SM 9223 B

Units	[MPN]/100mL	Analyzed In	Coralville
Date Analyzed	2016-06-30 14:09	Date Verified	2016-07-01 08:56
Analyst	CCC, JAO	Verifier	CCC

Analyte	Result	Quant Limit
E.coli	20.	10

Nitrate + Nitrite as N, LAC 10-107-04-1J

Units	mg/L	Analyzed In	Ankeny
Date Analyzed	2016-07-14 08:44	Date Verified	2016-07-15 13:56
Analyst	RWR	Verifier	JAE

Analyte	Result	Quant Limit
Nitrate + Nitrite nitrogen as N	0.43	0.1

Total Phosphorus as P, LAC 10-115-01-1C

Units	mg/L	Analyzed In	Ankeny
Date Analyzed	2016-07-07 14:08	Date Verified	2016-07-11 08:44
Analyst	MGB	Verifier	JAE

Analyte	Result	Quant Limit
Total Phosphorus as P	0.90	0.1

Description of Units used within this report

[MPN]/100mL = Most Probable Number per 100 Milliliters
mg/L = Milligrams per Liter

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State Hygienic Laboratory

The University of Iowa

Accession Number | 377957

Analyte	Result	Quant Limit
Nitrate + Nitrite nitrogen as N	0.24	0.1

ortho-Phosphate as P, LAC 10-115-01-1A

Units	mg/L	Analyzed In	Ankeny
Date Analyzed	2016-05-17 14:38	Date Verified	2016-05-17 15:57
Analyst	RWR	Verifier	JAE

Analyte	Result	Quant Limit
ortho-Phosphate as P	1.1	0.02

Total Phosphorus as P, LAC 10-115-01-1C

Units	mg/L	Analyzed In	Ankeny
Date Analyzed	2016-05-24 12:56	Date Verified	2016-05-25 13:16
Analyst	MGB	Verifier	JAE

Analyte	Result	Quant Limit
Total Phosphorus as P	1.8	0.1

Total Suspended Solids, USGS I-3765-85

Units	mg/L	Analyzed In	Ankeny
Date Analyzed	2016-05-18 09:01	Date Verified	2016-05-25 12:38
Analyst	AMJ	Verifier	JAE

Analyte	Result	Quant Limit
Total Suspended Solids	300	1

Oil and Grease (Hexane Extractable Material), EPA 1664

Units	ppm	Analyzed In	Coralville
Date Analyzed	2016-05-19 07:45	Date Verified	2016-05-20 13:54
Analyst	KB	Verifier	GHJ

Analyte	Result	Quant Limit
Hexane Extractable Material (HEM)	7.4	5.0

Total Extractable Hydrocarbons, Iowa OA-2

Units	ug/L	Analyzed In	Coralville
Date Analyzed	2016-05-17 16:26	Date Verified	2016-05-24 12:12
Analyst	PM	Verifier	SJM
Analysis Prep	Prep by Separatory Funnel, Iowa OA-2		

Analyte	Result	Quant Limit
Gasoline	<1000	1000

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The University of Iowa

Accession Number | 377957

Analyte	Result	Quant Limit
Mineral spirits	<1000	1000
Kerosene	<1000	1000
Diesel fuel	<1000	1000
Motor oil	2700	1000
Total Extractable Hydrocarbons	2700	1000

Note: The chromatographic profile of the sample extract did not match this laboratory's fuel or oil standards. Quantitation is based on this laboratory's motor oil standard.

Prep by Separatory Funnel, Iowa OA-2

Units	ug/L	Analyzed In	Coralville
Date Analyzed	2016-05-17 07:40	Date Verified	2016-05-18 07:45
Analyst	KB	Verifier	GHJ

Description of Units used within this report

[MPN]/100mL = Most Probable Number per 100 Milliliters
mg/L = Milligrams per Liter
ppm = Parts per Million
ug/L = Micrograms per Liter

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State Hygienic Laboratory

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Accession Number	377958
Date Sample Finalized	2016-06-03 15:04
Date Received	2016-05-16 09:40
Sample Source	Non-Drinking Water
Project	
Date Collected	2016-05-13 15:00
Collection Site	cr04 outfall
Collection Address	
Sample Description	non drinking water
Client Reference	bioretention researc
Collector	
Phone	

AMY BOUSKA
JOHNSON COUNTY SWCD
51 ESCORT LN
IOWA CITY, IA 52240

Note: The sample was received after established holding time but analyzed at the client's request.

Results of Analyses

E.coli Bacteria, SM 9223 B

Units	[MPN]/100mL	Analyzed In	Coralville
Date Analyzed	2016-05-16 10:36	Date Verified	2016-05-17 12:05
Analyst	JAO, CCC	Verifier	JAO

Analyte	Result	Quant Limit
E.coli	340	10

Chloride, EPA 300.0

Units	mg/L	Analyzed In	Ankeny
Date Analyzed	2016-06-03 06:15	Date Verified	2016-06-03 15:04
Analyst	BER	Verifier	DLS

Analyte	Result	Quant Limit
Chloride	35	1

Sulfate, EPA 300.0

Units	mg/L	Analyzed In	Ankeny
Date Analyzed	2016-06-03 06:15	Date Verified	2016-06-03 15:04
Analyst	BER	Verifier	DLS

Analyte	Result	Quant Limit
Sulfate	11	1

Nitrate + Nitrite as N, LAC 10-107-04-1J

Units	mg/L	Analyzed In	Ankeny
Date Analyzed	2016-05-24 12:10	Date Verified	2016-05-25 13:31
Analyst	RWR	Verifier	JAE

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Analyte	Result	Quant Limit
Nitrate + Nitrite nitrogen as N	0.40	0.1

ortho-Phosphate as P, LAC 10-115-01-1A

Units	mg/L	Analyzed In	Ankeny
Date Analyzed	2016-05-17 14:40	Date Verified	2016-05-17 15:57
Analyst	RWR	Verifier	JAE

Analyte	Result	Quant Limit
ortho-Phosphate as P	0.22	0.02

Total Phosphorus as P, LAC 10-115-01-1C

Units	mg/L	Analyzed In	Ankeny
Date Analyzed	2016-05-24 12:56	Date Verified	2016-05-25 13:16
Analyst	MGB	Verifier	JAE

Analyte	Result	Quant Limit
Total Phosphorus as P	0.61	0.1

Total Suspended Solids, USGS I-3765-85

Units	mg/L	Analyzed In	Ankeny
Date Analyzed	2016-05-18 09:01	Date Verified	2016-05-25 12:38
Analyst	AMJ	Verifier	JAE

Analyte	Result	Quant Limit
Total Suspended Solids	120	1

Oil and Grease (Hexane Extractable Material), EPA 1664

Units	ppm	Analyzed In	Coralville
Date Analyzed	2016-05-19 07:45	Date Verified	2016-05-20 13:54
Analyst	KB	Verifier	GHJ

Analyte	Result	Quant Limit
Hexane Extractable Material (HEM)	<5.0	5.0

Total Extractable Hydrocarbons, Iowa OA-2

Units	ug/L	Analyzed In	Coralville
Date Analyzed	2016-05-17 20:21	Date Verified	2016-05-24 12:15
Analyst	PM	Verifier	SJM
Analysis Prep	Prep by Separatory Funnel, Iowa OA-2		

Analyte	Result	Quant Limit
Gasoline	<1000	1000

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The University of Iowa

Accession Number | 377958

Analyte	Result	Quant Limit
Mineral spirits	<1000	1000
Kerosene	<1000	1000
Diesel fuel	<1000	1000
Motor oil	4500	1000
Total Extractable Hydrocarbons	4500	1000

Note: The chromatographic profile of the sample extract did not match this laboratory's fuel or oil standards. Quantitation is based on this laboratory's motor oil standard.

Prep by Separatory Funnel, Iowa OA-2

Units	ug/L	Analyzed In	Coralville
Date Analyzed	2016-05-17 07:40	Date Verified	2016-05-18 07:45
Analyst	KB	Verifier	GHJ

Description of Units used within this report

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mg/L = Milligrams per Liter
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State Hygienic Laboratory

The University of Iowa

Accession Number	377960
Date Sample Finalized	2016-06-14 13:32
Date Received	2016-05-16 09:40
Sample Source	Non-Drinking Water
Project	
Date Collected	2016-05-13 14:40
Collection Site	cr02 outfall
Collection Address	
Sample Description	non drinking water
Client Reference	bioretention researc
Collector	
Phone	

AMY BOUSKA
JOHNSON COUNTY SWCD
51 ESCORT LN
IOWA CITY, IA 52240

Note: The sample was received after established holding time but analyzed at the client's request.

Results of Analyses

E.coli Bacteria, SM 9223 B

Units	[MPN]/100mL	Analyzed In	Coralville
Date Analyzed	2016-05-16 10:36	Date Verified	2016-05-17 12:05
Analyst	JAO, CCC	Verifier	JAO

Analyte	Result	Quant Limit
E.coli	160	10

Chloride, EPA 300.0

Units	mg/L	Analyzed In	Ankeny
Date Analyzed	2016-06-08 06:11	Date Verified	2016-06-14 13:32
Analyst	PMR	Verifier	BRW

Analyte	Result	Quant Limit
Chloride	100	1

Sulfate, EPA 300.0

Units	mg/L	Analyzed In	Ankeny
Date Analyzed	2016-06-04 00:04	Date Verified	2016-06-10 22:28
Analyst	BER, PMR	Verifier	BRW

Analyte	Result	Quant Limit
Sulfate	32	1

Nitrate + Nitrite as N, LAC 10-107-04-1J

Units	mg/L	Analyzed In	Ankeny
Date Analyzed	2016-05-24 12:10	Date Verified	2016-05-25 13:31
Analyst	RWR	Verifier	JAE

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State Hygienic Laboratory

The University of Iowa

Accession Number | 377960

Analyte	Result	Quant Limit
Nitrate + Nitrite nitrogen as N	0.53	0.1

ortho-Phosphate as P, LAC 10-115-01-1A

Units	mg/L	Analyzed In	Ankeny
Date Analyzed	2016-05-17 14:42	Date Verified	2016-05-17 15:57
Analyst	RWR	Verifier	JAE

Analyte	Result	Quant Limit
ortho-Phosphate as P	0.29	0.02

Total Phosphorus as P, LAC 10-115-01-1C

Units	mg/L	Analyzed In	Ankeny
Date Analyzed	2016-05-24 12:56	Date Verified	2016-05-25 13:16
Analyst	MGB	Verifier	JAE

Analyte	Result	Quant Limit
Total Phosphorus as P	0.75	0.1

Total Suspended Solids, USGS I-3765-85

Units	mg/L	Analyzed In	Ankeny
Date Analyzed	2016-05-18 09:01	Date Verified	2016-05-25 12:38
Analyst	AMJ	Verifier	JAE

Analyte	Result	Quant Limit
Total Suspended Solids	350	1

Oil and Grease (Hexane Extractable Material), EPA 1664

Units	ppm	Analyzed In	Coralville
Date Analyzed	2016-05-19 07:45	Date Verified	2016-05-20 13:54
Analyst	KB	Verifier	GHJ

Analyte	Result	Quant Limit
Hexane Extractable Material (HEM)	7.6	5.0

Total Extractable Hydrocarbons, Iowa OA-2

Units	ug/L	Analyzed In	Coralville
Date Analyzed	2016-05-18 04:11	Date Verified	2016-05-24 12:26
Analyst	PM	Verifier	SJM
Analysis Prep	Prep by Separatory Funnel, Iowa OA-2		

Analyte	Result	Quant Limit
Gasoline	<1000	1000

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Analyte	Result	Quant Limit
Mineral spirits	<1000	1000
Kerosene	<1000	1000
Diesel fuel	<1000	1000
Motor oil	5700	1000
Total Extractable Hydrocarbons	5700	1000

Note: The chromatographic profile of the sample extract did not match this laboratory's fuel or oil standards. Quantitation is based on this laboratory's motor oil standard.

Prep by Separatory Funnel, Iowa OA-2

Units	ug/L	Analyzed In	Coralville
Date Analyzed	2016-05-17 07:40	Date Verified	2016-05-18 07:45
Analyst	KB	Verifier	GHJ

Description of Units used within this report

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mg/L = Milligrams per Liter
ppm = Parts per Million
ug/L = Micrograms per Liter

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Accession Number	377959
Date Sample Finalized	2016-06-14 13:32
Date Received	2016-05-16 09:40
Sample Source	Non-Drinking Water
Project	
Date Collected	2016-05-13 15:00
Collection Site	cr03 outfall
Collection Address	
Sample Description	non drinking water
Client Reference	bioretention researc
Collector	
Phone	

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JOHNSON COUNTY SWCD
51 ESCORT LN
IOWA CITY, IA 52240

Note: The sample was received after established holding time but analyzed at the client's request.

Results of Analyses

E.coli Bacteria, SM 9223 B

Units	[MPN]/100mL	Analyzed In	Coralville
Date Analyzed	2016-05-16 10:36	Date Verified	2016-05-17 12:05
Analyst	JAO, CCC	Verifier	JAO

Analyte	Result	Quant Limit
E.coli	1900	10

Chloride, EPA 300.0

Units	mg/L	Analyzed In	Ankeny
Date Analyzed	2016-06-08 05:38	Date Verified	2016-06-14 13:32
Analyst	PMR, BRW	Verifier	BRW

Analyte	Result	Quant Limit
Chloride	88	1

Sulfate, EPA 300.0

Units	mg/L	Analyzed In	Ankeny
Date Analyzed	2016-06-03 23:31	Date Verified	2016-06-10 22:28
Analyst	BER, PMR	Verifier	BRW

Analyte	Result	Quant Limit
Sulfate	22	1

Nitrate + Nitrite as N, LAC 10-107-04-1J

Units	mg/L	Analyzed In	Ankeny
Date Analyzed	2016-05-24 12:10	Date Verified	2016-05-25 13:31
Analyst	RWR	Verifier	JAE

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Analyte	Result	Quant Limit
Nitrate + Nitrite nitrogen as N	0.42	0.1

ortho-Phosphate as P, LAC 10-115-01-1A

Units	mg/L	Analyzed In	Ankeny
Date Analyzed	2016-05-17 14:41	Date Verified	2016-05-17 15:57
Analyst	RWR	Verifier	JAE

Analyte	Result	Quant Limit
ortho-Phosphate as P	0.76	0.02

Total Phosphorus as P, LAC 10-115-01-1C

Units	mg/L	Analyzed In	Ankeny
Date Analyzed	2016-05-24 12:56	Date Verified	2016-05-25 13:16
Analyst	MGB	Verifier	JAE

Analyte	Result	Quant Limit
Total Phosphorus as P	1.3	0.1

Total Suspended Solids, USGS I-3765-85

Units	mg/L	Analyzed In	Ankeny
Date Analyzed	2016-05-18 09:01	Date Verified	2016-05-25 12:38
Analyst	AMJ	Verifier	JAE

Analyte	Result	Quant Limit
Total Suspended Solids	340	1

Oil and Grease (Hexane Extractable Material), EPA 1664

Units	ppm	Analyzed In	Coralville
Date Analyzed	2016-05-19 07:45	Date Verified	2016-05-20 13:54
Analyst	KB	Verifier	GHJ

Analyte	Result	Quant Limit
Hexane Extractable Material (HEM)	7.5	5.0

Total Extractable Hydrocarbons, Iowa OA-2

Units	ug/L	Analyzed In	Coralville
Date Analyzed	2016-05-18 00:16	Date Verified	2016-05-24 12:20
Analyst	PM	Verifier	SJM
Analysis Prep	Prep by Separatory Funnel, Iowa OA-2		

Analyte	Result	Quant Limit
Gasoline	<1000	1000

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Analyte	Result	Quant Limit
Mineral spirits	<1000	1000
Kerosene	<1000	1000
Diesel fuel	<1000	1000
Motor oil	5300	1000
Total Extractable Hydrocarbons	5300	1000

Note: The chromatographic profile of the sample extract did not match this laboratory's fuel or oil standards. Quantitation is based on this laboratory's motor oil standard.

Prep by Separatory Funnel, Iowa OA-2

Units	ug/L	Analyzed In	Coralville
Date Analyzed	2016-05-17 07:40	Date Verified	2016-05-18 07:45
Analyst	KB	Verifier	GHJ

Description of Units used within this report

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ppm = Parts per Million
ug/L = Micrograms per Liter

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Accession Number	383095
Date Sample Finalized	2016-06-29 14:21
Date Received	2016-05-28 10:04
Sample Source	Non-Drinking Water
Project	
Date Collected	2016-05-27 23:30
Collection Site	cr01 outfall
Collection Address	CORALVILLE,
Sample Description	non drinking water
Client Reference	bioretention researc
Collector	betts
Phone	319/541-1763

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Note: Upon arrival, sample met container and preservation requirements for the analysis requested. Please review carefully your sample results for additional analyte comments or method exceptions.

Results of Analyses

E.coli Bacteria, SM 9223 B

Units	[MPN]/100mL	Analyzed In	Coralville
Date Analyzed	2016-05-28 12:09	Date Verified	2016-05-31 08:36
Analyst	CAL, KFO	Verifier	KFO

Analyte	Result	Quant Limit
E.coli	100	100

Chloride, EPA 300.0

Units	mg/L	Analyzed In	Ankeny
Date Analyzed	2016-06-15 18:04	Date Verified	2016-06-21 10:39
Analyst	BER	Verifier	BRW

Analyte	Result	Quant Limit
Chloride	55	1

Sulfate, EPA 300.0

Units	mg/L	Analyzed In	Ankeny
Date Analyzed	2016-06-23 08:55	Date Verified	2016-06-29 14:21
Analyst	BER	Verifier	BRW

Analyte	Result	Quant Limit
Sulfate	41	1

Nitrate + Nitrite as N, LAC 10-107-04-1J

Units	mg/L	Analyzed In	Ankeny
Date Analyzed	2016-06-02 16:31	Date Verified	2016-06-03 09:59
Analyst	JAE	Verifier	DLS

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Analyte	Result	Quant Limit
Nitrate + Nitrite nitrogen as N	0.36	0.1

ortho-Phosphate as P, SM 4500-P E

Units	mg/L	Analyzed In	Coralville
Date Analyzed	2016-05-28 14:10	Date Verified	2016-06-02 09:52
Analyst	DMM	Verifier	MAM

Analyte	Result	Quant Limit
ortho-Phosphate as P	0.11	0.02

Total Phosphorus as P, LAC 10-115-01-1C

Units	mg/L	Analyzed In	Ankeny
Date Analyzed	2016-06-08 11:15	Date Verified	2016-06-09 10:35
Analyst	MGB	Verifier	RWR

Analyte	Result	Quant Limit
Total Phosphorus as P	0.81	0.1

Total Suspended Solids, USGS I-3765-85

Units	mg/L	Analyzed In	Ankeny
Date Analyzed	2016-06-01 13:00	Date Verified	2016-06-07 09:35
Analyst	AMJ	Verifier	JAE

Analyte	Result	Quant Limit
Total Suspended Solids	670	1

Oil and Grease (Hexane Extractable Material), EPA 1664

Units	ppm	Analyzed In	Coralville
Date Analyzed	2016-06-01 13:09	Date Verified	2016-06-03 15:43
Analyst	RAD	Verifier	KB

Analyte	Result	Quant Limit
Hexane Extractable Material (HEM)	<5.0	5.0

Note: Sample exceeded required temperature upon receipt.

Total Extractable Hydrocarbons, Iowa OA-2

Units	ug/L	Analyzed In	Coralville
Date Analyzed	2016-06-01 16:16	Date Verified	2016-06-10 10:47
Analyst	PM	Verifier	SJM
Analysis Prep	Prep by Separatory Funnel, Iowa OA-2		

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Accession Number | 383095

Analyte	Result	Quant Limit
Gasoline	<100	100
Mineral spirits	<100	100
Kerosene	<100	100
Diesel fuel	<100	100
Motor oil	440	100
Total Extractable Hydrocarbons	440	100

Note: The chromatographic profile of the sample extract did not match this laboratory's fuel or oil standards. Quantitation is based on this laboratory's motor oil standard.

Prep by Separatory Funnel, Iowa OA-2

Units	ug/L	Analyzed In	Coralville
Date Analyzed	2016-05-31 09:00	Date Verified	2016-06-01 07:35
Analyst	KB	Verifier	GHJ

Description of Units used within this report

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ppm = Parts per Million
ug/L = Micrograms per Liter

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Accession Number	383096
Date Sample Finalized	2016-06-29 14:21
Date Received	2016-05-28 10:04
Sample Source	Non-Drinking Water
Project	
Date Collected	2016-05-27 23:45
Collection Site	cr02 outfall
Collection Address	
Sample Description	non drinking water
Client Reference	bioretention researc
Collector	bua
Phone	

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Note: Upon arrival, sample met container and preservation requirements for the analysis requested. Please review carefully your sample results for additional analyte comments or method exceptions.

Results of Analyses

E.coli Bacteria, SM 9223 B

Units	[MPN]/100mL	Analyzed In	Coralville
Date Analyzed	2016-05-28 12:09	Date Verified	2016-05-31 08:36
Analyst	CAL, KFO	Verifier	KFO

Analyte	Result	Quant Limit
E.coli	<100	100

Chloride, EPA 300.0

Units	mg/L	Analyzed In	Ankeny
Date Analyzed	2016-06-15 18:22	Date Verified	2016-06-21 10:39
Analyst	BER	Verifier	BRW

Analyte	Result	Quant Limit
Chloride	16	1

Sulfate, EPA 300.0

Units	mg/L	Analyzed In	Ankeny
Date Analyzed	2016-06-23 11:05	Date Verified	2016-06-29 14:21
Analyst	BER	Verifier	BRW

Analyte	Result	Quant Limit
Sulfate	14	1

Nitrate + Nitrite as N, LAC 10-107-04-1J

Units	mg/L	Analyzed In	Ankeny
Date Analyzed	2016-06-02 16:31	Date Verified	2016-06-03 09:59
Analyst	JAE	Verifier	DLS

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Analyte	Result	Quant Limit
Nitrate + Nitrite nitrogen as N	0.22	0.1

ortho-Phosphate as P, SM 4500-P E

Units	mg/L	Analyzed In	Coralville
Date Analyzed	2016-05-28 14:10	Date Verified	2016-06-02 09:52
Analyst	DMM	Verifier	MAM

Analyte	Result	Quant Limit
ortho-Phosphate as P	0.07	0.02

Total Phosphorus as P, LAC 10-115-01-1D

Units	mg/L	Analyzed In	Ankeny
Date Analyzed	2016-06-08 09:17	Date Verified	2016-06-09 12:56
Analyst	MGB	Verifier	RWR

Analyte	Result	Quant Limit
Total Phosphorus as P	0.14	0.02

Total Suspended Solids, USGS I-3765-85

Units	mg/L	Analyzed In	Ankeny
Date Analyzed	2016-06-01 13:00	Date Verified	2016-06-07 09:35
Analyst	AMJ	Verifier	JAE

Analyte	Result	Quant Limit
Total Suspended Solids	36	1

Oil and Grease (Hexane Extractable Material), EPA 1664

Units	ppm	Analyzed In	Coralville
Date Analyzed	2016-06-01 13:09	Date Verified	2016-06-03 15:43
Analyst	RAD	Verifier	KB

Analyte	Result	Quant Limit
Hexane Extractable Material (HEM)	<5.0	5.0

Note: Sample exceeded required temperature upon receipt.

Total Extractable Hydrocarbons, Iowa OA-2

Units	ug/L	Analyzed In	Coralville
Date Analyzed	2016-06-01 18:13	Date Verified	2016-06-10 10:49
Analyst	PM	Verifier	SJM
Analysis Prep	Prep by Separatory Funnel, Iowa OA-2		

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Analyte	Result	Quant Limit
Gasoline	<100	100
Mineral spirits	<100	100
Kerosene	<100	100
Diesel fuel	<100	100
Motor oil	1100	100
Total Extractable Hydrocarbons	1100	100

Note: The chromatographic profile of the sample extract did not match this laboratory's fuel or oil standards. Quantitation is based on this laboratory's motor oil standard.

Prep by Separatory Funnel, Iowa OA-2

Units	ug/L	Analyzed In	Coralville
Date Analyzed	2016-05-31 09:00	Date Verified	2016-06-01 07:35
Analyst	KB	Verifier	GHJ

Description of Units used within this report

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ppm = Parts per Million
ug/L = Micrograms per Liter

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Accession Number	383097
Date Sample Finalized	2016-06-29 14:21
Date Received	2016-05-28 10:04
Sample Source	Non-Drinking Water
Project	
Date Collected	2016-05-28 00:00
Collection Site	cr03 outfall
Collection Address	
Sample Description	non drinking water
Client Reference	bioretention researc
Collector	betts
Phone	

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Note: Upon arrival, sample met container and preservation requirements for the analysis requested. Please review carefully your sample results for additional analyte comments or method exceptions.

Results of Analyses

E.coli Bacteria, SM 9223 B

Units	[MPN]/100mL	Analyzed In	Coralville
Date Analyzed	2016-05-28 12:09	Date Verified	2016-05-31 08:36
Analyst	CAL, KFO	Verifier	KFO

Analyte	Result	Quant Limit
E.coli	3400	100

Chloride, EPA 300.0

Units	mg/L	Analyzed In	Ankeny
Date Analyzed	2016-06-15 18:40	Date Verified	2016-06-21 10:39
Analyst	BER	Verifier	BRW

Analyte	Result	Quant Limit
Chloride	11	1

Sulfate, EPA 300.0

Units	mg/L	Analyzed In	Ankeny
Date Analyzed	2016-06-23 11:37	Date Verified	2016-06-29 14:21
Analyst	BER	Verifier	BRW

Analyte	Result	Quant Limit
Sulfate	14	1

Nitrate + Nitrite as N, LAC 10-107-04-1J

Units	mg/L	Analyzed In	Ankeny
Date Analyzed	2016-06-02 16:31	Date Verified	2016-06-03 09:59
Analyst	JAE	Verifier	DLS

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Analyte	Result	Quant Limit
Nitrate + Nitrite nitrogen as N	0.16	0.1

ortho-Phosphate as P, SM 4500-P E

Units	mg/L	Analyzed In	Coralville
Date Analyzed	2016-05-28 14:10	Date Verified	2016-06-02 09:52
Analyst	DMM	Verifier	MAM

Analyte	Result	Quant Limit
ortho-Phosphate as P	0.18	0.02

Total Phosphorus as P, LAC 10-115-01-1D

Units	mg/L	Analyzed In	Ankeny
Date Analyzed	2016-06-08 09:17	Date Verified	2016-06-09 12:56
Analyst	MGB	Verifier	RWR

Analyte	Result	Quant Limit
Total Phosphorus as P	0.28	0.02

Total Suspended Solids, USGS I-3765-85

Units	mg/L	Analyzed In	Ankeny
Date Analyzed	2016-06-01 13:00	Date Verified	2016-06-07 09:35
Analyst	AMJ	Verifier	JAE

Analyte	Result	Quant Limit
Total Suspended Solids	28	1

Oil and Grease (Hexane Extractable Material), EPA 1664

Units	ppm	Analyzed In	Coralville
Date Analyzed	2016-06-01 13:09	Date Verified	2016-06-09 15:26
Analyst	RAD	Verifier	KB

Analyte	Result	Quant Limit
Hexane Extractable Material (HEM)	<5.0	5.0

Note: There was an error in sample collection date/time (e.g. missing, mismatched, postdated or incorrect).

Total Extractable Hydrocarbons, Iowa OA-2

Units	ug/L	Analyzed In	Coralville
Date Analyzed	2016-06-01 20:11	Date Verified	2016-06-10 10:50
Analyst	PM	Verifier	SJM
Analysis Prep	Prep by Separatory Funnel, Iowa OA-2		

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State Hygienic Laboratory

The University of Iowa

Accession Number | 383097

Analyte	Result	Quant Limit
Gasoline	<100	100
Mineral spirits	<100	100
Kerosene	<100	100
Diesel fuel	<100	100
Motor oil	890	100
Total Extractable Hydrocarbons	890	100

Note: The chromatographic profile of the sample extract did not match this laboratory's fuel or oil standards. Quantitation is based on this laboratory's motor oil standard.

Prep by Separatory Funnel, Iowa OA-2

Units	ug/L	Analyzed In	Coralville
Date Analyzed	2016-05-31 09:00	Date Verified	2016-06-01 07:35
Analyst	KB	Verifier	GHJ

Description of Units used within this report

[MPN]/100mL = Most Probable Number per 100 Milliliters
mg/L = Milligrams per Liter
ppm = Parts per Million
ug/L = Micrograms per Liter

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Accession Number	383098
Date Sample Finalized	2016-06-29 14:22
Date Received	2016-05-28 10:04
Sample Source	Non-Drinking Water
Project	
Date Collected	2016-05-28 01:45
Collection Site	crw-4
Collection Address	CORALVILLE,
Sample Description	non drinking water
Client Reference	bioretention researc
Collector	betis
Phone	319/541-1763

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JOHNSON COUNTY SWCD
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IOWA CITY, IA 52240

Note: Upon arrival, sample met container and preservation requirements for the analysis requested. Please review carefully your sample results for additional analyte comments or method exceptions.

Results of Analyses

E.coli Bacteria, SM 9223 B

Units	[MPN]/100mL	Analyzed In	Coralville
Date Analyzed	2016-05-28 12:09	Date Verified	2016-05-31 08:36
Analyst	CAL, KFO	Verifier	KFO

Analyte	Result	Quant Limit
E.coli	100	100

Chloride, EPA 300.0

Units	mg/L	Analyzed In	Ankeny
Date Analyzed	2016-06-16 23:10	Date Verified	2016-06-21 15:34
Analyst	BER	Verifier	DLS

Analyte	Result	Quant Limit
Chloride	3.5	1

Sulfate, EPA 300.0

Units	mg/L	Analyzed In	Ankeny
Date Analyzed	2016-06-23 12:42	Date Verified	2016-06-29 14:22
Analyst	BER	Verifier	BRW

Analyte	Result	Quant Limit
Sulfate	1.3	1

Nitrate + Nitrite as N, LAC 10-107-04-1J

Units	mg/L	Analyzed In	Ankeny
Date Analyzed	2016-06-02 16:31	Date Verified	2016-06-03 09:59
Analyst	JAE	Verifier	DLS

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Accession Number | 383098

Analyte	Result	Quant Limit
Nitrate + Nitrite nitrogen as N	<0.10	0.1

ortho-Phosphate as P, SM 4500-P E

Units	mg/L	Analyzed In	Coralville
Date Analyzed	2016-05-28 14:10	Date Verified	2016-06-02 09:53
Analyst	DMM	Verifier	MAM

Analyte	Result	Quant Limit
ortho-Phosphate as P	0.28	0.02

Total Phosphorus as P, LAC 10-115-01-1D

Units	mg/L	Analyzed In	Ankeny
Date Analyzed	2016-06-08 09:17	Date Verified	2016-06-09 12:56
Analyst	MGB	Verifier	RWR

Analyte	Result	Quant Limit
Total Phosphorus as P	0.33	0.02

Total Suspended Solids, USGS I-3765-85

Units	mg/L	Analyzed In	Ankeny
Date Analyzed	2016-06-01 13:00	Date Verified	2016-06-07 09:35
Analyst	AMJ	Verifier	JAE

Analyte	Result	Quant Limit
Total Suspended Solids	12	1

Oil and Grease (Hexane Extractable Material), EPA 1664

Units	ppm	Analyzed In	Coralville
Date Analyzed	2016-06-01 13:09	Date Verified	2016-06-09 15:31
Analyst	RAD	Verifier	KB

Analyte	Result	Quant Limit
Hexane Extractable Material (HEM)	<5.0	5.0

Note: There was an error in sample collection date/time (e.g. missing, mismatched, postdated or incorrect).

Total Extractable Hydrocarbons, Iowa OA-2

Units	ug/L	Analyzed In	Coralville
Date Analyzed	2016-06-01 22:08	Date Verified	2016-06-10 10:52
Analyst	PM	Verifier	SJM
Analysis Prep	Prep by Separatory Funnel, Iowa OA-2		

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Accession Number | 383098

Analyte	Result	Quant Limit
Gasoline	<100	100
Mineral spirits	<100	100
Kerosene	<100	100
Diesel fuel	<100	100
Motor oil	410	100
Total Extractable Hydrocarbons	410	100

Note: The chromatographic profile of the sample extract did not match this laboratory's fuel or oil standards. Quantitation is based on this laboratory's motor oil standard.

Prep by Separatory Funnel, Iowa OA-2

Units	ug/L	Analyzed In	Coralville
Date Analyzed	2016-05-31 09:00	Date Verified	2016-06-01 07:36
Analyst	KB	Verifier	GHJ

Description of Units used within this report

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Accession Number	383099
Date Sample Finalized	2016-06-29 14:23
Date Received	2016-05-28 10:04
Sample Source	Non-Drinking Water
Project	
Date Collected	2016-05-28 00:30
Collection Site	cr05 outfall
Collection Address	
Sample Description	non drinking water
Client Reference	bioretention researc
Collector	
Phone	

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Note: Upon arrival, sample met container and preservation requirements for the analysis requested. Please review carefully your sample results for additional analyte comments or method exceptions.

Results of Analyses

E.coli Bacteria, SM 9223 B

Units	[MPN]/100mL	Analyzed In	Coralville
Date Analyzed	2016-05-28 12:09	Date Verified	2016-05-31 08:36
Analyst	CAL, KFO	Verifier	KFO

Analyte	Result	Quant Limit
E.coli	<100	100

Chloride, EPA 300.0

Units	mg/L	Analyzed In	Ankeny
Date Analyzed	2016-06-15 19:16	Date Verified	2016-06-21 10:39
Analyst	BER	Verifier	BRW

Analyte	Result	Quant Limit
Chloride	11	1

Sulfate, EPA 300.0

Units	mg/L	Analyzed In	Ankeny
Date Analyzed	2016-06-23 13:47	Date Verified	2016-06-29 14:23
Analyst	BER	Verifier	BRW

Analyte	Result	Quant Limit
Sulfate	13	1

Nitrate + Nitrite as N, LAC 10-107-04-1J

Units	mg/L	Analyzed In	Ankeny
Date Analyzed	2016-06-02 16:31	Date Verified	2016-06-03 09:59
Analyst	JAE	Verifier	DLS

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Analyte	Result	Quant Limit
Nitrate + Nitrite nitrogen as N	<0.10	0.1

ortho-Phosphate as P, SM 4500-P E

Units	mg/L	Analyzed In	Coralville
Date Analyzed	2016-05-28 14:10	Date Verified	2016-06-02 09:53
Analyst	DMM	Verifier	MAM

Analyte	Result	Quant Limit
ortho-Phosphate as P	0.08	0.02

Total Phosphorus as P, LAC 10-115-01-1D

Units	mg/L	Analyzed In	Ankeny
Date Analyzed	2016-06-08 09:17	Date Verified	2016-06-09 12:56
Analyst	MGB	Verifier	RWR

Analyte	Result	Quant Limit
Total Phosphorus as P	0.37	0.02

Total Suspended Solids, USGS I-3765-85

Units	mg/L	Analyzed In	Ankeny
Date Analyzed	2016-06-01 13:00	Date Verified	2016-06-07 09:35
Analyst	AMJ	Verifier	JAE

Analyte	Result	Quant Limit
Total Suspended Solids	190	1

Oil and Grease (Hexane Extractable Material), EPA 1664

Units	ppm	Analyzed In	Coralville
Date Analyzed	2016-06-01 13:09	Date Verified	2016-06-09 15:31
Analyst	RAD	Verifier	KB

Analyte	Result	Quant Limit
Hexane Extractable Material (HEM)	<5.0	5.0

Note: There was an error in sample collection date/time (e.g. missing, mismatched, postdated or incorrect).

Total Extractable Hydrocarbons, Iowa OA-2

Units	ug/L	Analyzed In	Coralville
Date Analyzed	2016-06-02 00:06	Date Verified	2016-06-10 10:53
Analyst	PM	Verifier	SJM
Analysis Prep	Prep by Separatory Funnel, Iowa OA-2		

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Accession Number | 383099

Analyte	Result	Quant Limit
Gasoline	<100	100
Mineral spirits	<100	100
Kerosene	<100	100
Diesel fuel	<100	100
Motor oil	1000	100
Total Extractable Hydrocarbons	1000	100

Note: The chromatographic profile of the sample extract did not match this laboratory's fuel or oil standards. Quantitation is based on this laboratory's motor oil standard.

Prep by Separatory Funnel, Iowa OA-2

Units	ug/L	Analyzed In	Coralville
Date Analyzed	2016-05-31 09:00	Date Verified	2016-06-01 07:36
Analyst	KB	Verifier	GHJ

Description of Units used within this report

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ug/L = Micrograms per Liter

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Accession Number	383100
Date Sample Finalized	2016-06-29 14:23
Date Received	2016-05-28 10:04
Sample Source	Non-Drinking Water
Project	
Date Collected	2016-05-28 00:15
Collection Site	cr04 outfall
Collection Address	
Sample Description	non drinking water
Client Reference	bioretention researc
Collector	betis
Phone	

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Note: Upon arrival, sample met container and preservation requirements for the analysis requested. Please review carefully your sample results for additional analyte comments or method exceptions.

Results of Analyses

E.coli Bacteria, SM 9223 B

Units	[MPN]/100mL	Analyzed In	Coralville
Date Analyzed	2016-05-28 12:09	Date Verified	2016-05-31 08:37
Analyst	CAL, KFO	Verifier	KFO

Analyte	Result	Quant Limit
E.coli	<100	100

Chloride, EPA 300.0

Units	mg/L	Analyzed In	Ankeny
Date Analyzed	2016-06-15 19:34	Date Verified	2016-06-21 10:39
Analyst	BER	Verifier	BRW

Analyte	Result	Quant Limit
Chloride	10	1

Sulfate, EPA 300.0

Units	mg/L	Analyzed In	Ankeny
Date Analyzed	2016-06-23 14:19	Date Verified	2016-06-29 14:23
Analyst	BER	Verifier	BRW

Analyte	Result	Quant Limit
Sulfate	15	1

Nitrate + Nitrite as N, LAC 10-107-04-1J

Units	mg/L	Analyzed In	Ankeny
Date Analyzed	2016-06-02 16:31	Date Verified	2016-06-03 09:59
Analyst	JAE	Verifier	DLS

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Accession Number | 383100

Analyte	Result	Quant Limit
Nitrate + Nitrite nitrogen as N	0.23	0.1

ortho-Phosphate as P, SM 4500-P E

Units	mg/L	Analyzed In	Coralville
Date Analyzed	2016-05-28 14:10	Date Verified	2016-06-02 09:53
Analyst	DMM	Verifier	MAM

Analyte	Result	Quant Limit
ortho-Phosphate as P	0.33	0.02

Total Phosphorus as P, LAC 10-115-01-1C

Units	mg/L	Analyzed In	Ankeny
Date Analyzed	2016-06-08 11:15	Date Verified	2016-06-09 10:35
Analyst	MGB	Verifier	RWR

Analyte	Result	Quant Limit
Total Phosphorus as P	0.63	0.1

Total Suspended Solids, USGS I-3765-85

Units	mg/L	Analyzed In	Ankeny
Date Analyzed	2016-06-01 13:00	Date Verified	2016-06-07 09:35
Analyst	AMJ	Verifier	JAE

Analyte	Result	Quant Limit
Total Suspended Solids	26	1

Oil and Grease (Hexane Extractable Material), EPA 1664

Units	ppm	Analyzed In	Coralville
Date Analyzed	2016-06-01 15:50	Date Verified	2016-06-09 15:33
Analyst	RAD	Verifier	KB

Analyte	Result	Quant Limit
Hexane Extractable Material (HEM)	<5.0	5.0

Note: There was an error in sample collection date/time (e.g. missing, mismatched, postdated or incorrect).

Total Extractable Hydrocarbons, Iowa OA-2

Units	ug/L	Analyzed In	Coralville
Date Analyzed	2016-06-02 02:03	Date Verified	2016-06-10 10:54
Analyst	PM	Verifier	SJM
Analysis Prep	Prep by Separatory Funnel, Iowa OA-2		

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The University of Iowa

Accession Number | 383100

Analyte	Result	Quant Limit
Gasoline	<100	100
Mineral spirits	<100	100
Kerosene	<100	100
Diesel fuel	<100	100
Motor oil	450	100
Total Extractable Hydrocarbons	450	100

Note: The chromatographic profile of the sample extract did not match this laboratory's fuel or oil standards. Quantitation is based on this laboratory's motor oil standard.

Prep by Separatory Funnel, Iowa OA-2

Units	ug/L	Analyzed In	Coralville
Date Analyzed	2016-05-31 09:00	Date Verified	2016-06-01 07:36
Analyst	KB	Verifier	GHJ

Description of Units used within this report

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ug/L = Micrograms per Liter

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Accession Number	383102
Date Sample Finalized	2016-06-29 14:23
Date Received	2016-05-28 10:04
Sample Source	Non-Drinking Water
Project	
Date Collected	2016-05-28 01:15
Collection Site	crw-2
Collection Address	
Sample Description	non drinking water
Client Reference	bioretention researc
Collector	
Phone	

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Note: Upon arrival, sample met container and preservation requirements for the analysis requested. Please review carefully your sample results for additional analyte comments or method exceptions.

Results of Analyses

E.coli Bacteria, SM 9223 B

Units	[MPN]/100mL	Analyzed In	Coralville
Date Analyzed	2016-05-28 12:09	Date Verified	2016-05-31 08:37
Analyst	CAL, KFO	Verifier	KFO

Analyte	Result	Quant Limit
E.coli	<100	100

Chloride, EPA 300.0

Units	mg/L	Analyzed In	Ankeny
Date Analyzed	2016-06-15 20:09	Date Verified	2016-06-21 10:40
Analyst	BER	Verifier	BRW

Analyte	Result	Quant Limit
Chloride	8.1	1

Sulfate, EPA 300.0

Units	mg/L	Analyzed In	Ankeny
Date Analyzed	2016-06-23 14:51	Date Verified	2016-06-29 14:23
Analyst	BER	Verifier	BRW

Analyte	Result	Quant Limit
Sulfate	13	1

Nitrate + Nitrite as N, LAC 10-107-04-1J

Units	mg/L	Analyzed In	Ankeny
Date Analyzed	2016-06-02 16:31	Date Verified	2016-06-03 09:59
Analyst	JAE	Verifier	DLS

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Analyte	Result	Quant Limit
Nitrate + Nitrite nitrogen as N	0.29	0.1

ortho-Phosphate as P, SM 4500-P E

Units	mg/L	Analyzed In	Coralville
Date Analyzed	2016-05-28 14:10	Date Verified	2016-06-02 09:54
Analyst	DMM	Verifier	MAM

Analyte	Result	Quant Limit
ortho-Phosphate as P	0.79	0.02

Total Phosphorus as P, LAC 10-115-01-1C

Units	mg/L	Analyzed In	Ankeny
Date Analyzed	2016-06-08 11:15	Date Verified	2016-06-09 10:35
Analyst	MGB	Verifier	RWR

Analyte	Result	Quant Limit
Total Phosphorus as P	1.5	0.1

Total Suspended Solids, USGS I-3765-85

Units	mg/L	Analyzed In	Ankeny
Date Analyzed	2016-06-01 13:00	Date Verified	2016-06-07 09:35
Analyst	AMJ	Verifier	JAE

Analyte	Result	Quant Limit
Total Suspended Solids	110	1

Oil and Grease (Hexane Extractable Material), EPA 1664

Units	ppm	Analyzed In	Coralville
Date Analyzed	2016-06-01 15:50	Date Verified	2016-06-09 15:35
Analyst	RAD	Verifier	KB

Analyte	Result	Quant Limit
Hexane Extractable Material (HEM)	<5.0	5.0

Note: There was an error in sample collection date/time (e.g. missing, mismatched, postdated or incorrect).

Total Extractable Hydrocarbons, Iowa OA-2

Units	ug/L	Analyzed In	Coralville
Date Analyzed	2016-06-02 05:58	Date Verified	2016-06-10 11:08
Analyst	PM	Verifier	SJM
Analysis Prep	Prep by Separatory Funnel, Iowa OA-2		

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Accession Number | 383102

Analyte	Result	Quant Limit
Gasoline	<100	100
Mineral spirits	<100	100
Kerosene	<100	100
Diesel fuel	<100	100
Motor oil	370	100
Total Extractable Hydrocarbons	370	100

Note: The chromatographic profile of the sample extract did not match this laboratory's fuel or oil standards. Quantitation is based on this laboratory's motor oil standard.

Prep by Separatory Funnel, Iowa OA-2

Units	ug/L	Analyzed In	Coralville
Date Analyzed	2016-05-31 09:00	Date Verified	2016-06-01 07:36
Analyst	KB	Verifier	GHJ

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ppm = Parts per Million
ug/L = Micrograms per Liter

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State Hygienic Laboratory

The University of Iowa

Accession Number	383103
Date Sample Finalized	2016-06-29 14:23
Date Received	2016-05-28 10:04
Sample Source	Non-Drinking Water
Project	
Date Collected	2016-05-28 01:00
Collection Site	crw1 north median well
Collection Address	
Sample Description	non drinking water
Client Reference	bioretention researc
Collector	
Phone	

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IOWA CITY, IA 52240

Note: Upon arrival, sample met container and preservation requirements for the analysis requested. Please review carefully your sample results for additional analyte comments or method exceptions.

Results of Analyses

E.coli Bacteria, SM 9223 B

Units	[MPN]/100mL	Analyzed In	Coralville
Date Analyzed	2016-05-28 12:09	Date Verified	2016-05-31 08:37
Analyst	CAL, KFO	Verifier	KFO

Analyte	Result	Quant Limit
E.coli	200	100

Chloride, EPA 300.0

Units	mg/L	Analyzed In	Ankeny
Date Analyzed	2016-06-15 21:03	Date Verified	2016-06-21 10:42
Analyst	BER	Verifier	BRW

Analyte	Result	Quant Limit
Chloride	18	1

Sulfate, EPA 300.0

Units	mg/L	Analyzed In	Ankeny
Date Analyzed	2016-06-23 16:29	Date Verified	2016-06-29 14:23
Analyst	BER	Verifier	BRW

Analyte	Result	Quant Limit
Sulfate	27	1

Nitrate + Nitrite as N, LAC 10-107-04-1J

Units	mg/L	Analyzed In	Ankeny
Date Analyzed	2016-06-02 16:31	Date Verified	2016-06-03 09:59
Analyst	JAE	Verifier	DLS

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Accession Number | 383103

Analyte	Result	Quant Limit
Nitrate + Nitrite nitrogen as N	0.47	0.1

ortho-Phosphate as P, SM 4500-P E

Units	mg/L	Analyzed In	Coralville
Date Analyzed	2016-05-28 14:10	Date Verified	2016-06-02 09:54
Analyst	DMM	Verifier	MAM

Analyte	Result	Quant Limit
ortho-Phosphate as P	0.34	0.02

Total Phosphorus as P, LAC 10-115-01-1C

Units	mg/L	Analyzed In	Ankeny
Date Analyzed	2016-06-08 11:15	Date Verified	2016-06-09 10:35
Analyst	MGB	Verifier	RWR

Analyte	Result	Quant Limit
Total Phosphorus as P	0.83	0.1

Total Suspended Solids, USGS I-3765-85

Units	mg/L	Analyzed In	Ankeny
Date Analyzed	2016-06-01 13:00	Date Verified	2016-06-07 09:35
Analyst	AMJ	Verifier	JAE

Analyte	Result	Quant Limit
Total Suspended Solids	52	1

Oil and Grease (Hexane Extractable Material), EPA 1664

Units	ppm	Analyzed In	Coralville
Date Analyzed	2016-06-01 15:50	Date Verified	2016-06-09 15:35
Analyst	RAD	Verifier	KB

Analyte	Result	Quant Limit
Hexane Extractable Material (HEM)	<5.0	5.0

Note: There was an error in sample collection date/time (e.g. missing, mismatched, postdated or incorrect).

Total Extractable Hydrocarbons, Iowa OA-2

Units	ug/L	Analyzed In	Coralville
Date Analyzed	2016-06-02 07:55	Date Verified	2016-06-10 11:10
Analyst	PM	Verifier	SJM
Analysis Prep	Prep by Separatory Funnel, Iowa OA-2		

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Accession Number | 383103

Analyte	Result	Quant Limit
Gasoline	<100	100
Mineral spirits	<100	100
Kerosene	<100	100
Diesel fuel	<100	100
Motor oil	300	100
Total Extractable Hydrocarbons	300	100

Note: The chromatographic profile of the sample extract did not match this laboratory's fuel or oil standards. Quantitation is based on this laboratory's motor oil standard.

Prep by Separatory Funnel, Iowa OA-2

Units	ug/L	Analyzed In	Coralville
Date Analyzed	2016-05-31 09:00	Date Verified	2016-06-01 07:36
Analyst	KB	Verifier	GHJ

Description of Units used within this report

[MPN]/100mL = Most Probable Number per 100 Milliliters
mg/L = Milligrams per Liter
ppm = Parts per Million
ug/L = Micrograms per Liter

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Accession Number	383104
Date Sample Finalized	2016-06-29 14:54
Date Received	2016-05-28 10:04
Sample Source	Non-Drinking Water
Project	
Date Collected	2016-05-28 00:45
Collection Site	cr06 outfall
Collection Address	
Sample Description	non drinking water
Client Reference	bioretention researc
Collector	
Phone	

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Note: Upon arrival, sample met container and preservation requirements for the analysis requested. Please review carefully your sample results for additional analyte comments or method exceptions.

Results of Analyses

E.coli Bacteria, SM 9223 B

Units	[MPN]/100mL	Analyzed In	Coralville
Date Analyzed	2016-05-28 12:09	Date Verified	2016-05-31 08:37
Analyst	CAL, KFO	Verifier	KFO

Analyte	Result	Quant Limit
E.coli	100	100

Chloride, EPA 300.0

Units	mg/L	Analyzed In	Ankeny
Date Analyzed	2016-06-15 21:21	Date Verified	2016-06-21 10:42
Analyst	BER	Verifier	BRW

Analyte	Result	Quant Limit
Chloride	12	1

Sulfate, EPA 300.0

Units	mg/L	Analyzed In	Ankeny
Date Analyzed	2016-06-23 18:06	Date Verified	2016-06-29 14:54
Analyst	BER	Verifier	BRW

Analyte	Result	Quant Limit
Sulfate	24	1

Nitrate + Nitrite as N, LAC 10-107-04-1J

Units	mg/L	Analyzed In	Ankeny
Date Analyzed	2016-06-02 16:31	Date Verified	2016-06-03 09:59
Analyst	JAE	Verifier	DLS

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Analyte	Result	Quant Limit
Nitrate + Nitrite nitrogen as N	0.28	0.1

ortho-Phosphate as P, SM 4500-P E

Units	mg/L	Analyzed In	Coralville
Date Analyzed	2016-05-28 14:10	Date Verified	2016-06-02 09:54
Analyst	DMM	Verifier	MAM

Analyte	Result	Quant Limit
ortho-Phosphate as P	0.56	0.02

Total Phosphorus as P, LAC 10-115-01-1C

Units	mg/L	Analyzed In	Ankeny
Date Analyzed	2016-06-08 11:15	Date Verified	2016-06-09 10:35
Analyst	MGB	Verifier	RWR

Analyte	Result	Quant Limit
Total Phosphorus as P	1.0	0.1

Total Suspended Solids, USGS I-3765-85

Units	mg/L	Analyzed In	Ankeny
Date Analyzed	2016-06-01 13:00	Date Verified	2016-06-07 09:35
Analyst	AMJ	Verifier	JAE

Analyte	Result	Quant Limit
Total Suspended Solids	28	1

Oil and Grease (Hexane Extractable Material), EPA 1664

Units	ppm	Analyzed In	Coralville
Date Analyzed	2016-06-01 15:50	Date Verified	2016-06-09 15:36
Analyst	RAD	Verifier	KB

Analyte	Result	Quant Limit
Hexane Extractable Material (HEM)	<5.0	5.0

Note: There was an error in sample collection date/time (e.g. missing, mismatched, postdated or incorrect).

Total Extractable Hydrocarbons, Iowa OA-2

Units	ug/L	Analyzed In	Coralville
Date Analyzed	2016-06-02 09:53	Date Verified	2016-06-10 11:11
Analyst	PM	Verifier	SJM
Analysis Prep	Prep by Separatory Funnel, Iowa OA-2		

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Accession Number | 383104

Analyte	Result	Quant Limit
Gasoline	<100	100
Mineral spirits	<100	100
Kerosene	<100	100
Diesel fuel	<100	100
Motor oil	300	100
Total Extractable Hydrocarbons	300	100

Note: The chromatographic profile of the sample extract did not match this laboratory's fuel or oil standards. Quantitation is based on this laboratory's motor oil standard.

Prep by Separatory Funnel, Iowa OA-2

Units	ug/L	Analyzed In	Coralville
Date Analyzed	2016-05-31 09:00	Date Verified	2016-06-01 07:36
Analyst	KB	Verifier	GHJ

Description of Units used within this report

[MPN]/100mL = Most Probable Number per 100 Milliliters
mg/L = Milligrams per Liter
ppm = Parts per Million
ug/L = Micrograms per Liter

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Accession Number	387173
Date Sample Finalized	2016-07-01 14:26
Date Received	2016-06-09 09:50
Sample Source	Non-Drinking Water
Project	
Date Collected	2016-06-09 09:15
Collection Site	cr-06
Collection Address	CORALVILLE,
Sample Description	non drinking water
Client Reference	bioretention researc
Collector	beebe charles & sewell kelly
Phone	563/590-2165

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Note: Upon arrival, sample met container and preservation requirements for the analysis requested. Please review carefully your sample results for additional analyte comments or method exceptions.

Results of Analyses

E.coli Bacteria, SM 9223 B

Units	[MPN]/100mL	Analyzed In	Coralville
Date Analyzed	2016-06-09 11:54	Date Verified	2016-06-10 11:51
Analyst	BEC, CCC	Verifier	BEC

Analyte	Result	Quant Limit
E.coli	63	10

Chloride, EPA 300.0

Units	mg/L	Analyzed In	Ankeny
Date Analyzed	2016-06-30 03:28	Date Verified	2016-07-01 14:24
Analyst	BER	Verifier	BRW

Analyte	Result	Quant Limit
Chloride	4.8	1

Sulfate, EPA 300.0

Units	mg/L	Analyzed In	Ankeny
Date Analyzed	2016-06-30 03:28	Date Verified	2016-07-01 14:26
Analyst	BER	Verifier	BRW

Analyte	Result	Quant Limit
Sulfate	21	1

Nitrate + Nitrite as N, LAC 10-107-04-1J

Units	mg/L	Analyzed In	Ankeny
Date Analyzed	2016-06-14 08:35	Date Verified	2016-06-14 14:33
Analyst	RWR	Verifier	JAE

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Accession Number | 387173

Analyte	Result	Quant Limit
Nitrate + Nitrite nitrogen as N	0.12	0.1

ortho-Phosphate as P, LAC 10-115-01-1A

Units	mg/L	Analyzed In	Ankeny
Date Analyzed	2016-06-10 15:07	Date Verified	2016-06-13 08:43
Analyst	MGB	Verifier	JAE

Analyte	Result	Quant Limit
ortho-Phosphate as P	0.19	0.02

Total Phosphorus as P, LAC 10-115-01-1D

Units	mg/L	Analyzed In	Ankeny
Date Analyzed	2016-06-16 14:02	Date Verified	2016-06-17 08:59
Analyst	MGB	Verifier	DLS

Analyte	Result	Quant Limit
Total Phosphorus as P	0.22	0.02

Total Suspended Solids, USGS I-3765-85

Units	mg/L	Analyzed In	Ankeny
Date Analyzed	2016-06-13 10:30	Date Verified	2016-06-14 15:31
Analyst	AMJ	Verifier	JAE

Analyte	Result	Quant Limit
Total Suspended Solids	4	1

Oil and Grease (Hexane Extractable Material), EPA 1664

Units	ppm	Analyzed In	Coralville
Date Analyzed	2016-06-14 10:22	Date Verified	2016-06-20 07:45
Analyst	RAD	Verifier	GHJ

Analyte	Result	Quant Limit
Hexane Extractable Material (HEM)	<5.0	5.0

Total Extractable Hydrocarbons, Iowa OA-2

Units	ug/L	Analyzed In	Coralville
Date Analyzed	2016-06-10 10:22	Date Verified	2016-06-13 15:06
Analyst	PM	Verifier	SJM
Analysis Prep	Prep by Separatory Funnel, Iowa OA-2		

Analyte	Result	Quant Limit
Gasoline	<100	100

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