Columbia Wastewater and Stormwater IMP

Attachment E

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Our Columbia Waters
Integrated Management Plan
Wastewater & Stormwater

Technical Memorandum 1

Surface Water Quality and Biological Conditions

Columbia Wastewater and Stormwater Integrated Management Plan

Columbia, Missouri
February 2, 2017

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Section 1. Introduction and Objectives

The City of Columbia, Missouri (City) is working to develop an Integrated Management Plan (IMP) for the City's wastewater and stormwater utilities. The goal of the IMP is to develop an adaptable and affordable long-term plan that addresses the City's wastewater and stormwater management needs and meets Clean Water Act requirements. The IMP will be developed based on guidance presented in US Environmental Protection Agency's (EPA) *Integrated Municipal Stormwater and Wastewater Planning Approach Framework* (Stoner 2012).

A critical step in the IMP includes evaluating the City's environmental resources and infrastructure assets to better define the existing condition, performance, and needs of its systems. This evaluation is important because it forms the basis for identifying priorities and developing alternatives in subsequent phases of the IMP. To develop a comprehensive understanding of existing conditions, the City and their project team compiled and evaluated existing surface water, wastewater, and stormwater data. These data, as well as current operation and maintenance practices and procedures, were then reviewed and discussed in a series of workshops. Results from these efforts are documented in the following technical memoranda:

- Technical Memorandum 1 – Surface Water Quality and Biological Conditions
- Technical Memroandum 2 – Wastewater Collection System Assessment
- Technical Memorandum 3 – Wastewater Treatment System Assessment
- Technical Memorandum 4 – Stormwater System Assessment

Columbia is widely known for its urban area streams and lakes. These streams and lakes are prominent natural features that support wildlife habitat and recreational opportunities. The State of Missouri has established water quality standards for streams and lakes, including those in Columbia. These standards are implemented by the Missouri Department of Natural Resources (MDNR) and specify surface water quality that is considered protective of both aquatic life and public health. If surface water quality standards are not met in a stream or lake, the City may be required to take corrective action if the impairment is attributed to activities within the City's jurisdictional area. Therefore, understanding current water quality conditions in Columbia area streams is critical for establishing priorities through the IMP process.

Surface water quality has been measured in many of Columbia's streams and lakes. The purpose of this memorandum is to summarize surface water quality data collected in the Columbia area and compare these measurements to Missouri's applicable water quality standards. This comparison will inform the IMP process by identifying observed water quality challenges or potential impairments that may be addressed through future corrective actions or water quality management strategies. It can also be used to help prioritize projects, including projects that may help protect existing water quality.

Section 2. Surface Water Resources and Current Impairments

There are approximately 300 miles of streams and more than 100 public and private lakes[1] within the 200 square miles (128,000 acres) of watersheds that adjoin or intersect the City (**Attachment A**). There are six major streams in the Columbia area (Hinkson Creek, Hominy Branch, Grindstone Creek, Gans Creek, Little Bonne Femme, and Flat Branch) which support various forms of recreation and aquatic life.

Section 303(d) of the federal Clean Water Act requires each state to periodically identify waters not meeting water quality standards that protect designated beneficial uses. Designated beneficial uses associated with waters in the Columbia area include: whole body contact recreation (e.g., swimming), secondary contact recreation (e.g., fishing, wading), protection of warm water aquatic life, human health-fish consumption and livestock and wildlife watering. The most recent MDNR 303(d) list of impaired waters (MDNR 2016) includes several lakes and streams within and around the Columbia area (**Table 1**). The most common designated beneficial use impairment in Columbia area waters is whole body contact recreation, or swimming.

Table 1. Waterbodies with Existing Water Quality Impairments.

Listing Year	WBID	Water Body	Class	Impaired Size (miles/*acres)	Pollutant	Source	Impaired Uses	Status
2016	1007	Hinkson Creek	P	7.6	*E. coli*	Nonpoint source	WBC-B	TMDL Needed
1998	1007	Hinkson Creek	P	6	Unknown	Urban Runoff	AQL	[1]TMDL Approved
2012	1008	Hinkson Creek	C	18.8	*E. coli*	Runoff from: Forest/Grassland/Parkland/Rural, Residential Areas	WBC-A	TMDL Needed
1998	1008	Hinkson Creek	C	6.3	Unknown	Urban Nonpoint Source	AQL	[1]TMDL Approved
2012	1011	Hominy Branch	C	1.0	*E. coli*	Runoff from: Forest/Grassland/Parkland/Rural, Residential Areas, Urban Runoff/Storm Sewers	WBC-B	TMDL Needed
2006	1009	Grindstone Creek	C	2.5	*E. coli*	Runoff from: Forest/Grassland/Parkland/Rural, Residential Areas, Urban Runoff/Storm Sewers	WBC-A	TMDL Needed
2012	1004	Gans Creek	C	5.5	*E. coli*	Rural Nonpoint Source	WBC-A	TMDL Needed
2012	1003	Little Bonne Femme Creek	P	9.0	*E. coli*	Source Unknown	WBC-B	TMDL Needed
2008	7628	Perry Phillips Lake	UL	*32.0	Mercury in Fish Tissue	Atmospheric Deposition - Toxics	GEN	TMDL Needed
2002	7436	Lake of the Woods	L3	*3.0	Mercury in Fish Tissue	Atmospheric Deposition - Toxics	HHP	TMDL Needed

[1]Hinkson Creek TMDL (MO_1007 and _1008) Dated 01/28/2011
Class P = Streams that maintain permanent flow even in drought periods.
Class C = Streams that may cease flow in dry periods but maintain permanent pools which support aquatic life.
Class UL = Unclassified Lake
Class L3= Other lakes which are waters of the state. These include both public and private lakes. For effluent regulation purposes, publicly-owned L3 lakes are those for which a substantial portion of the surrounding lands are publicly owned or managed.
WBC-A = Whole Body Contact Recreation A
WBC-B = Whole Body Contact Recreation B
GEN = General Criteria
HHP = Human Health Protection
AQL = Protection of Aquatic Life

[1] U.S. Geological Survey, 2007-2014, National Hydrography Dataset available on the World Wide Web (http://nhd.usgs.gov), accessed 8/11/2016.

As a means to restore beneficial uses, MDNR schedules and develops a Total Maximum Daily Load (TMDL) to address each impairment. The TMDL calculates the amount of the identified pollutant (load) a waterbody can assimilate while still being protective of the beneficial uses. Load allocations for the pollutant are then assigned to each identified point or non-point source, and an implementation plan to reduce loads is established.

In 1998, two segments of Hinkson Creek were placed on the 303(d) list for an aquatic life (AQL) impairment. A phased and adaptive TMDL was developed and approved by the US Environmental Protection Agency (EPA) in January 2011. MDNR, EPA, the City of Columbia, Boone County, and the University of Missouri entered into a "Collaborative Adaptive Management" (CAM) agreement to holistically approach the complexities and uncertainties of the Hinkson Creek aquatic life impairment.

Other impairments include *Escherichia coli* (*E. coli*) and mercury in fish tissue. These have been added to the list over the last 10 years and are currently scheduled to have TMDLs developed before the end of 2017 (MDNR 2016), although the timing is subject to change.

Section 3. Point Source Discharges

Point source discharges include wastewater treatment plant, industrial treatment, and stormwater outfall discharges that require a National Pollutant Discharge Elimination System (NPDES) permit issued by MDNR. Point sources may potentially contribute to diminished water quality and are therefore important to this surface water quality evaluation.

NPDES permits are issued for both urbanized area stormwater and wastewater. Within the Columbia area, there are 259 NPDES permitted stormwater outfalls for land disturbance activities such as road construction or development. Fifty-two permitted stormwater outfalls associated with industrial activities are located throughout the area. There are 46 NPDES permitted outfalls[2] classified as industrial (8) or domestic wastewater treatment (38) in the area (**Attachment B**), with 4 of the domestic wastewater outfalls located within City limits. Of the 38 domestic wastewater treatment NPDES permits, 11 are in the process of decommissioning and joining either the City or Boone County Regional Sewer Districts systems.

The City is also responsible for operation and maintenance of a Municipal Separate Storm Sewer System (MS4). This system collects stormwater from streets, yards and parking lots and conveys this stormwater to streams located throughout the City.

[2] 2015 MDNR NPDES Outfall Layer. *MO_2015_NPDES_Outfalls_shp*. Missouri Spatial Data Information Service. University of Missouri - Columbia.

Section 4. Surface Water Quality Characterization

Surface water quality and hydrological data were gathered from available sources including the MDNR water quality database, the City and Boone County Health Department records, US Geological Survey (USGS) gauging stations, and the Missouri Spatial Data Information Service (MSDIS). Data were then compiled into databases for further analysis. Water quality data were reviewed to determine whether data were suitable and of sufficient quantity to include in the water quality evaluation. Monitoring stations (**Attachment C, Table 2**) were considered suitable and sufficient if more than one measurement was collected from a site within the last 10 years[3].

Table 2. Surface Water Quality Data Summary.

Parameter	Monitoring Stations	Number of Samples
E. coli	50	1,080
Dissolved Oxygen	79	380
Chloride	44	201
Ammonia	59	180
Total Nitrogen	49	255
Total Phosphorus	49	255

4.1. Bacteria

E. coli is a type of fecal coliform bacteria present in the intestines of animals and humans. The presence of *E. coli* in water serves as an indicator of potential human or animal waste contamination and is measured in colonies per 100 milliliters (CFU/100mL). Human and animal waste has the potential to contain many types of disease-causing pathogens (Kander, 2014). The levels of these indicator bacteria for which MDNR has determined that there is a low risk of illness from ingestion or contact are set as the water quality standard or criterion (**Table 3**). The bacteria criterion for each waterbody (streams and lakes) is based on the applicable contact recreation uses, which are assigned based on waterbody conditions and public accessibility (Kander, 2014). In addition, the bacteria criteria for Missouri, which are expressed as a seasonal geometric mean, are only applicable during the established recreational season (April 1 to October 31).

[3] An exception was made to the 10-year timeframe suitability to include chloride data collected between 1994 and 1995 for a University of Missouri research project (Perkins1995) that illustrated seasonal variations. Data from Hinkson Creek and Flat Branch collected on May 29, 2012 in response to the Brookside Apartment fires were also excluded from the evaluation.

Table 3. E. coli Criteria for Recreational Beneficial Use Designations (10 CSR 20-7.031 Water Quality Standards).

Beneficial Use	Beneficial Use Description	Recreational Season Criterion[1] (CFU/100mL)
Whole Body Contact - A	Waters that have been established by the property owner as public swimming areas welcoming access by the public for swimming purposes and waters with documented existing whole body contact recreational use(s) by the public.	126
Whole Body Contact - B	Waters designated for whole body contact recreation not contained within category A	206
Secondary Contact	Uses include fishing, wading, commercial and recreational boating, any limited contact incidental to shoreline activities, and activities in which users do not swim or float in the water.	1,134

[1]Criterion expressed as a recreational season (April 1 thru October 31) geometric mean.

Consistent with observations that fecal indicator bacteria are pervasive in streams (UWRRC, 2014), *E. coli* was detected in all stream samples included in this evaluation. Data were grouped by monitoring location to assess annual variability in Hinkson Creek and Little Bonne Femme Creek and their primary tributaries (**Figure 1**), and long-term trends in individual stream segments (**Figure 2**) and lakes (**Figure 3**). *E. coli* data along Hinkson Creek indicate an upward trend from upstream to downstream, and express annual variability over the last three years (**Figure 3**). UWRRC (2014) noted bacteria data in urban stormwater were highly variable in urban streams over time. Flat Branch Creek, a tributary of Hinkson Creek, typically exhibits higher annual bacteria levels than other locations in the Hinkson Creek watershed.

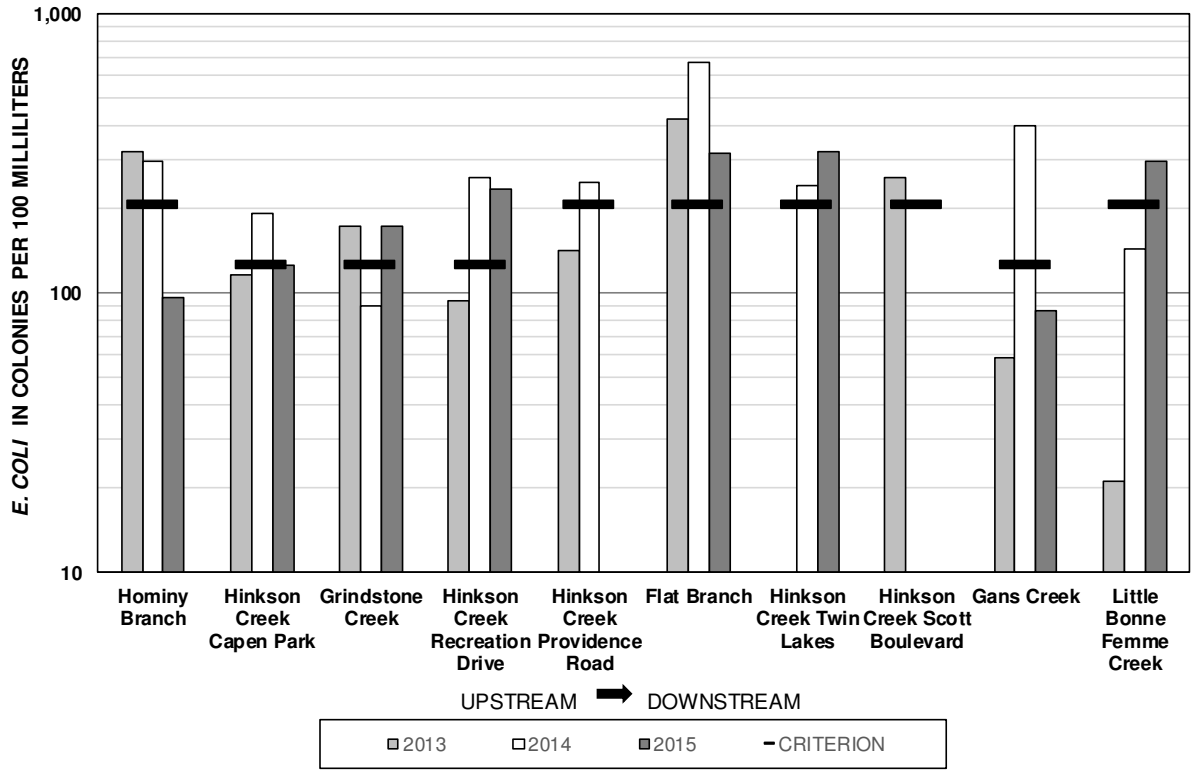

Figure 1. Geometric Mean Bacteria Levels Measured in Local Watersheds from Upstream to Downstream from 2013 to 2015. Hominy Branch (2013), Hinkson Creek at Capen Park (2013 and 2014), Hinkson Creek at Recreation Drive (2013), Hinkson Creek at Providence Road (2013 and 2014), Hinkson Creek at Scott Boulevard (2013), and Gans Creek (2013) data are represented by less than 5 data points.

Bacteria levels are typically elevated during wet weather flows in all rivers and streams and may be attributed to sources such as stormwater discharges from MS4s, sanitary sewer overflows, illicit discharges to storm sewer systems, failing or improperly located onsite septic systems, wastewater treatment plants, wildlife, domestic pets, agriculture, and other sources. A summary of bacteria measurements during wet and dry weather conditions was developed for Hinkson Creek and Little Bonne Femme Creek watersheds (**Figure 2**). The distinction between wet and dry weather was based on Hinkson Creek flow data as measured at the USGS gauge station below Providence Road. Periods when the daily average flow was greater than the long term median (50th percentile) flow value were considered wet weather influenced. Nearly all streams met the designated contact recreation criterion during dry weather flows. However, wet weather measurements were several orders of magnitude higher. Flat Branch Creek did not express this same characteristic. In fact, dry weather bacteria levels were greater than wet weather levels.

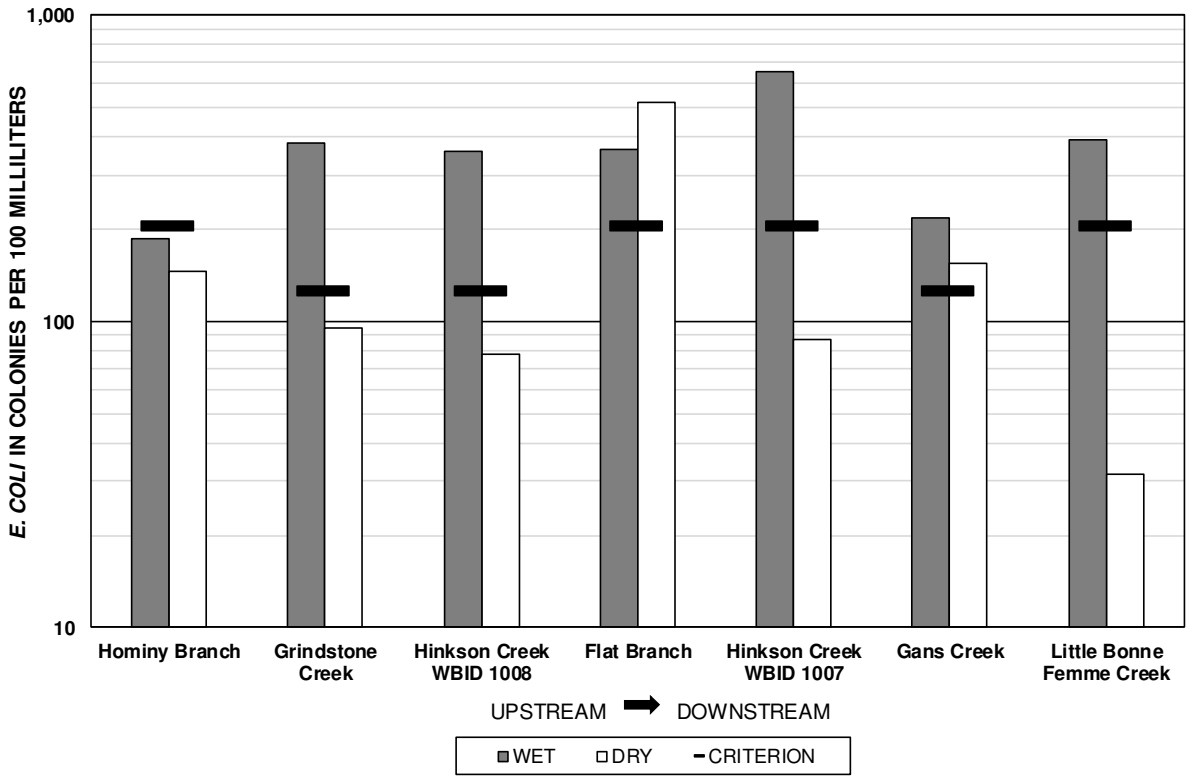

Figure 2. Long Term Wet Weather Characterization of Seasonal Geometric Mean Bacteria Levels in Streams, 2006-2015. Data assessment includes all available data within the last 10 years.

As previously discussed, *E. coli* criteria are expressed as a recreational season geometric mean. However, MDNR also advises against swimming at public beaches (lakes and streams) when a measurement exceeds 190 CFU/100 mL. East Hulen Lake, Finger Lakes, Katy Lake, Shalimar Gardens, and Stephens Lake have had single sample bacteria levels above the MDNR maximum advisory threshold for public swimming beaches (**Figure 3**).

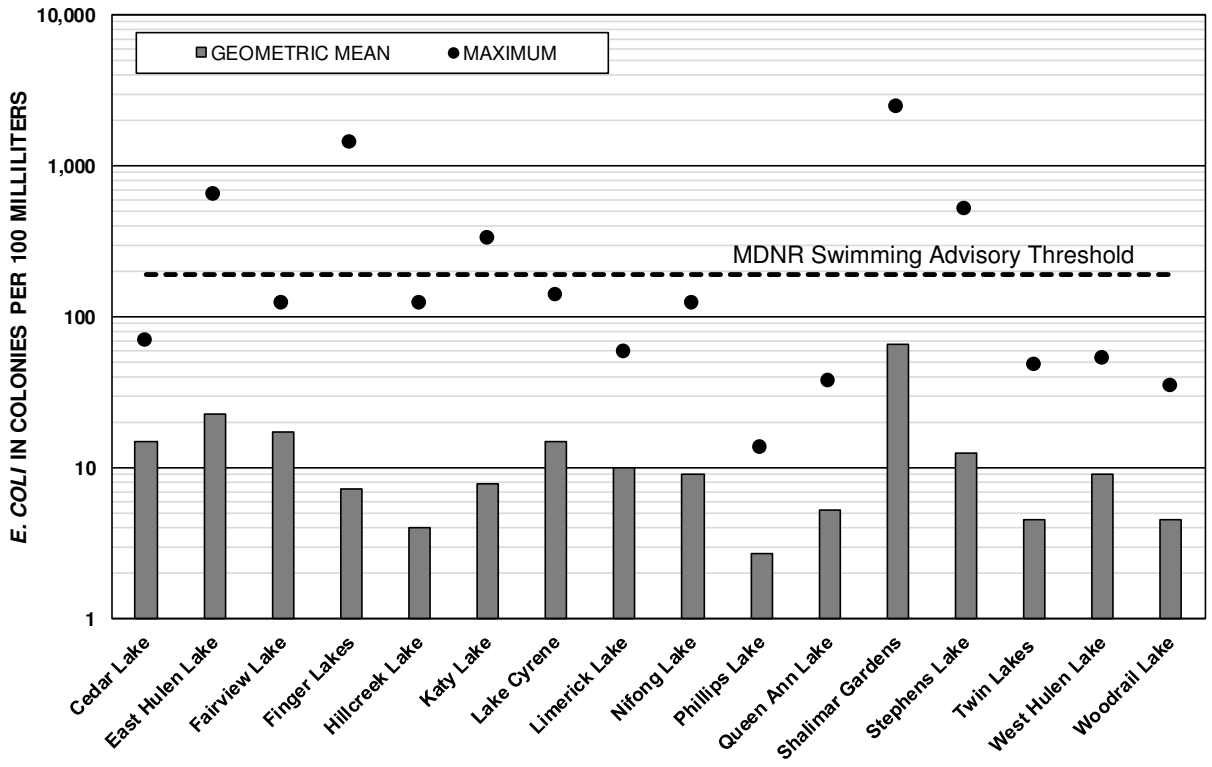

Figure 3. Seasonal Bacteria Levels in City and Local Watershed Lakes, 2006-2015.

4.2. Dissolved Oxygen

Dissolved oxygen (DO) is necessary in streams and lakes to support aquatic life. MDNR has established a water quality standard of 5.0 milligram per liter (mg/L) as a minimum concentration (10 CSR 20-7.031) for the protection of aquatic life in warm water fisheries. However, EPA's suggested criteria for ambient water quality (EPA, 1987) indicate DO levels can drop below 5 mg/L at times and not adversely affect aquatic organisms. MDNR considers a stream impaired for DO when more than 10% of collected DO measurements fall below this water quality criterion (MDNR LMD 2018).

DO data from the past 10 years were evaluated against the criterion. This evaluation indicated that 335 of 363 (92%) individual lake and stream DO samples were at or above 5.0 mg/L. Dissolved oxygen measurements below 5.0 mg/L most often occurred during the summer seasons when low stream flows and high water temperatures naturally limit a waterbody's ability to maintain high DO levels, although DO levels are impacted by a number of other factors such as organic matter, flow conditions, stream shading, and others.

Average DO concentrations from streams in the Columbia area ranged from 6.1 mg/L (Little Bonne Femme) to 9.7 mg/L (Hinkson Creek WBID 1008, **Figure 4**). Flat Branch Creek and Little Boone Femme Creek 10th percentile DO concentrations (90% of the data exceed this value) were below the 5 mg/L DO criterion. Hinkson Creek exhibits higher DO concentrations in the upper segment (WBID 1008) compared to the lower segment (WBID 1007).

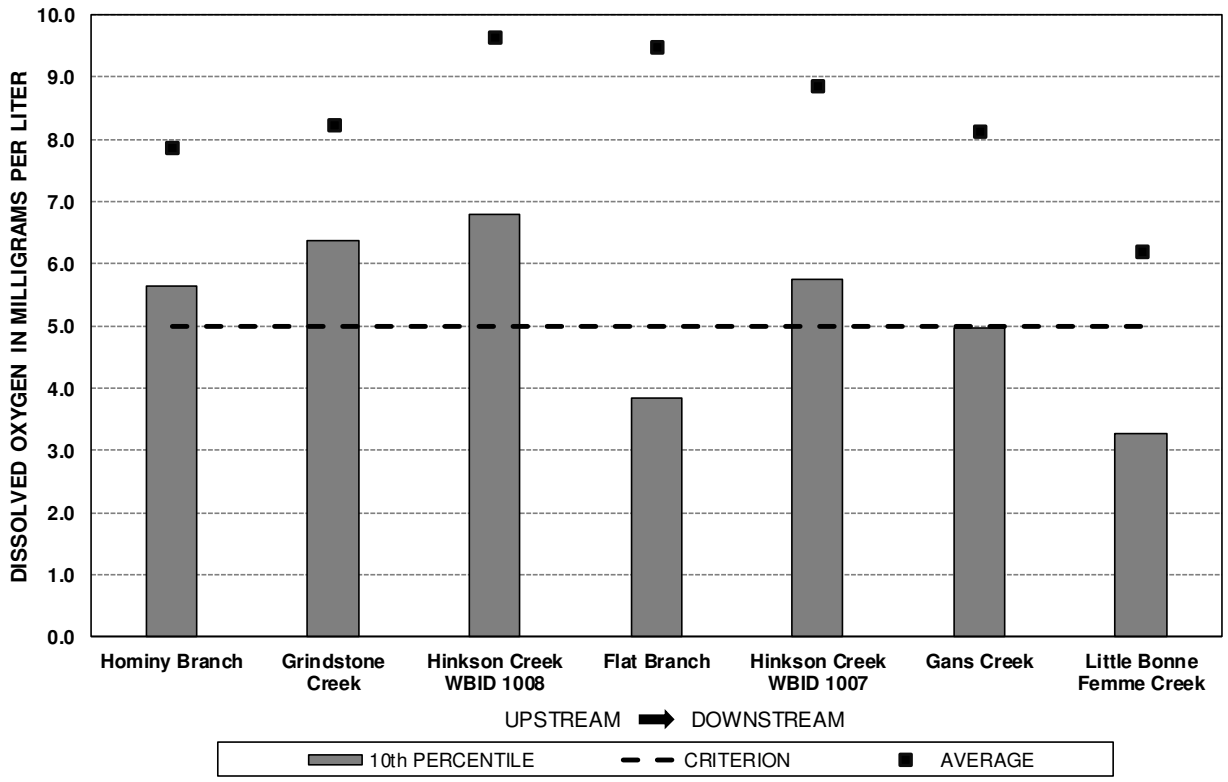

Figure 4. Summary of DO Concentration Measurements in the Hinkson Creek and Little Bonne Femme Creek Watersheds. Hinkson Creek locations were grouped according to their appropriate WBID to evaluate potential longitudinal differences in DO concentrations.

4.3. Chloride

Chloride concentrations in urban streams often become elevated from runoff associated with de-icing materials applied to roads during the winter months (MDNR, 2004). Calcium and Sodium chloride are the typical de-icing compounds applied to private and public sidewalks, roadways and parking lots. Elevated chloride concentrations may adversely affect aquatic biological communities and alter species composition (Starke et al., 2000). The water quality criterion for acute and chronic chloride is 860 mg/L and 230 mg/L, respectively. MDNR considers more than one chronic and/or acute criterion exceedance within the last three years as impairment for aquatic life protection.

Nearly 200 chloride samples from streams and lakes in the Columbia area were evaluated. Chloride measurements were collected during a year-long study conducted on Hinkson Creek below Providence Road from 1994 to 1995 by the University of Missouri (Perkins 1995). Overall, monthly chloride concentrations are below applicable criteria, with increasing concentrations during the winter season (**Figure 5**). Measured chloride concentrations exhibit seasonal trends related to winter road treatment. This observation is further supported by a 2010 – 2011 Hinkson Creek study (Nichols et al., 2016) where average chloride concentrations measured from October to March (range 50 mg/L to 128 mg/L) were appreciably greater than averages observed from April to September (range 15 to 55 mg/L).

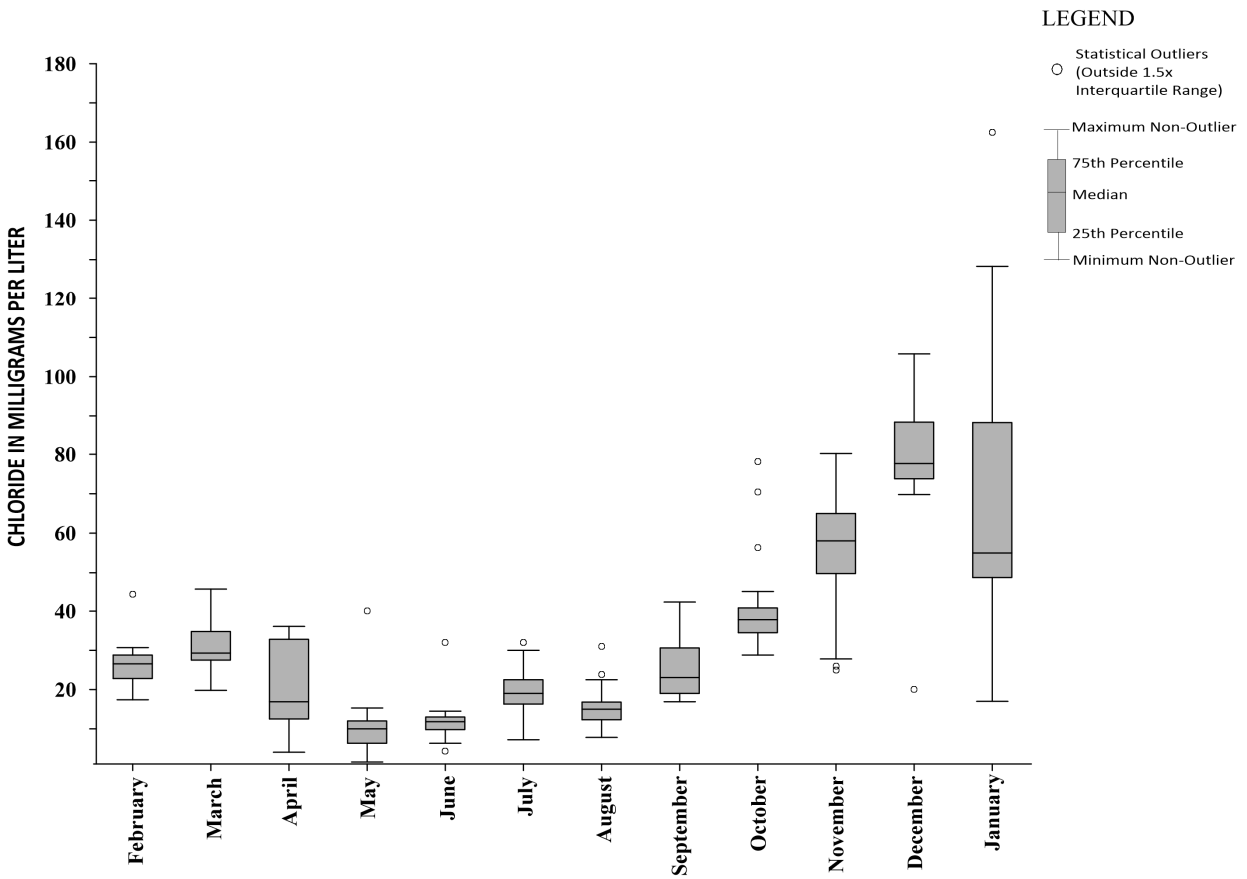

Figure 5. Monthly Chloride Concentration Ranges as Measured in Hinkson Creek below Providence Road between 1994 and 1995 (Perkins 1995).

Chloride concentrations within the last 10 years were also evaluated for trends in other streams in the Hinkson Creek watershed. Available data were not sufficient to discern temporal trends. However, average and maximum concentrations (**Figure 6**) indicate an increasing gradient from the upstream segment (WBID 1008) to the downstream segment (WBID 1007) of Hinkson Creek (Nichols et al., 2016). The same trend is evident when comparing maximum chloride concentrations from upstream to downstream in tributaries along Hinkson Creek. Overall, average chloride concentrations were low, with Flat Branch having the highest average concentrations. Recently, a University of Missouri study (as cited in Hooper, 2015) concluded that maximum chloride concentrations in Hinkson Creek may exceed the acute and chronic criterion during winter and spring runoff events.

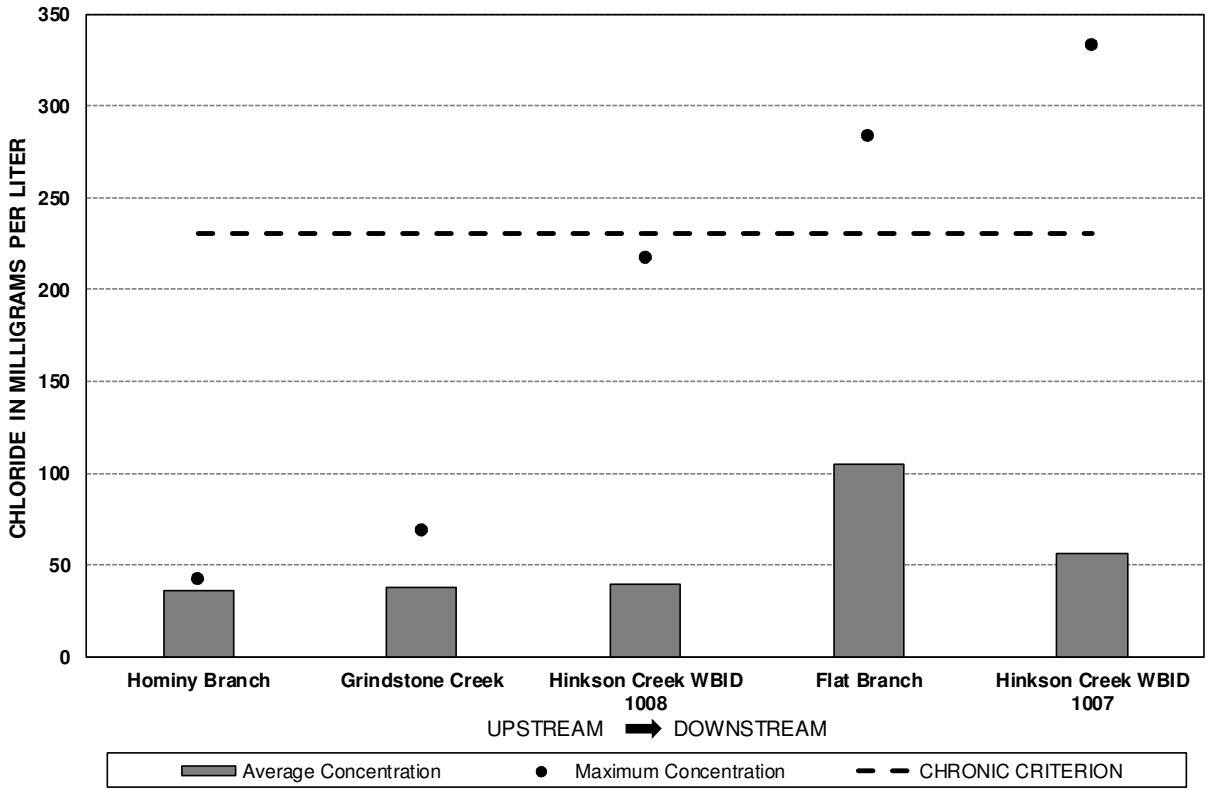

Figure 6. Chloride Concentrations in the Hinkson Creek Watershed.

4.4. Ammonia

Ammonia is a form of nitrogen that exists in aquatic environments and can have toxic effects to aquatic life. Ammonia sources can include fertilizers, industrial applications, decomposition of organic matter, animal and human waste. The default criteria for acute and chronic ammonia are 12 mg/L and 1.5 mg/L. However, actual criteria are based on the pH and temperature of the surface water at the time of sample collection. MDNR considers more than one chronic or acute ammonia criterion exceedance within the last three years as impaired for aquatic life protection.

There were 180 ammonia samples evaluated for temporal and spatial trends but results were inconclusive. Samples in the Columbia area were infrequently high with maximum values typically associated with special stream studies conducted by MDNR for evaluation of small point source discharges outside of the City limits. With the exception of the special stream studies, the maximum ammonia concentration in the Columbia area was 0.64 mg/L. Overall average ammonia concentrations were relatively low, ranging from 0.02 mg/L (multiple locations) to 0.16 mg/L (Hinkson Creek below Forum Blvd). This is consistent with other ammonia data collected on Hinkson Creek (Zeiger and Hubbart, 2015).

4.5. Nutrients

Nutrients, including total nitrogen (TN) and total phosphorus (TP), are natural and necessary elements of aquatic ecosystems. However, when nutrients become over abundant they can cause significant negative impacts to lakes and streams (EPA Nutrient Pollution website).

Currently, Missouri does not have nutrient water quality criteria for most stream, rivers, and most lakes. However, EPA has developed suggested thresholds based on monitoring data from high quality streams and the geographical locations of those waterbodies throughout the United States. EPA recommends that states develop numeric nutrient criteria for different water body types, but recognizes the difficulty of developing scientifically-defensible criteria (EPA, 2011). For streams in the Columbia area (Ecoregion 9, Sub-Ecoregion 72[4]), suggested thresholds are 0.75 mg/L for total nitrogen and 0.083 mg/L for total phosphorus (EPA, 2000).

Average TN concentrations at individual monitoring stations ranged from 0.28 mg/L at Hinkson Creek near Highway 63 to 1.02 mg/L at Hinkson Creek below Forum Boulevard. Stream segment average TN concentrations (**Figure 7**) ranged from 0.3 mg/L (Flat Branch) to 0.61 mg/L (Hominy Branch). Average TN concentrations in Columbia area streams were generally below EPA's suggested threshold values except for those observed at Hinkson Creek at North Rogers Road (Zeiger and Hubbart, 2015).

Average TP concentrations measured at individual monitoring stations in the Columbia area range from 0.02 mg/L (Hinkson Creek at Broadway) to 0.11 mg/L (Hinkson Creek near I-70) . Between 2010 to 2013, Zeiger and Hubbart (2015) observed average TP concentrations in Hinkson Creek also fell within this range. Stream average TP concentrations (**Figure 8**) ranged from 0.05 mg/L (Lower Hinkson Creek, WBID 1007) to 0.07 mg/L (Flat Branch). Average and maximum TP concentrations were below EPA's suggested thresholds in evaluated Columbia area streams.

[4] The City of Columbia is split between Sub-Ecoregion 40 and 72. Sub-Ecoregion 72 values were chosen because the intersection of the Upper Hinkson Creek (WBID 1008) and Lower Hinkson Creek (WBID 1007) fall within it.

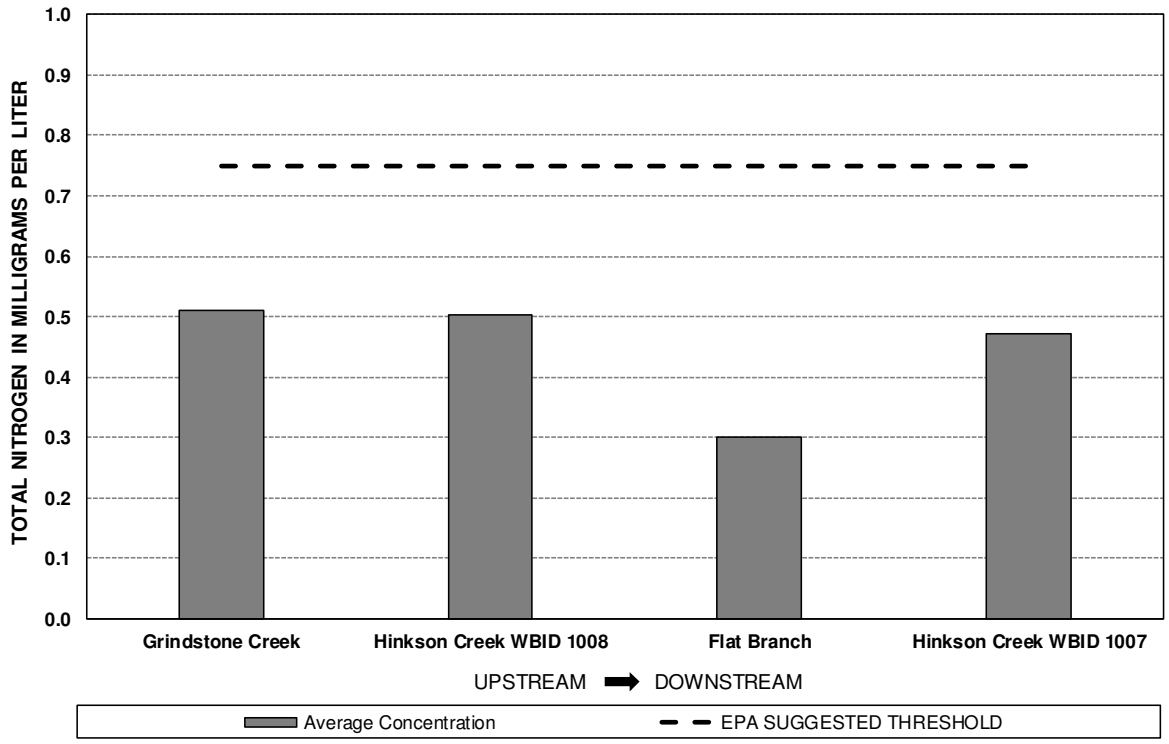

Figure 7. Total Nitrogen Concentration in Columbia Area Streams.

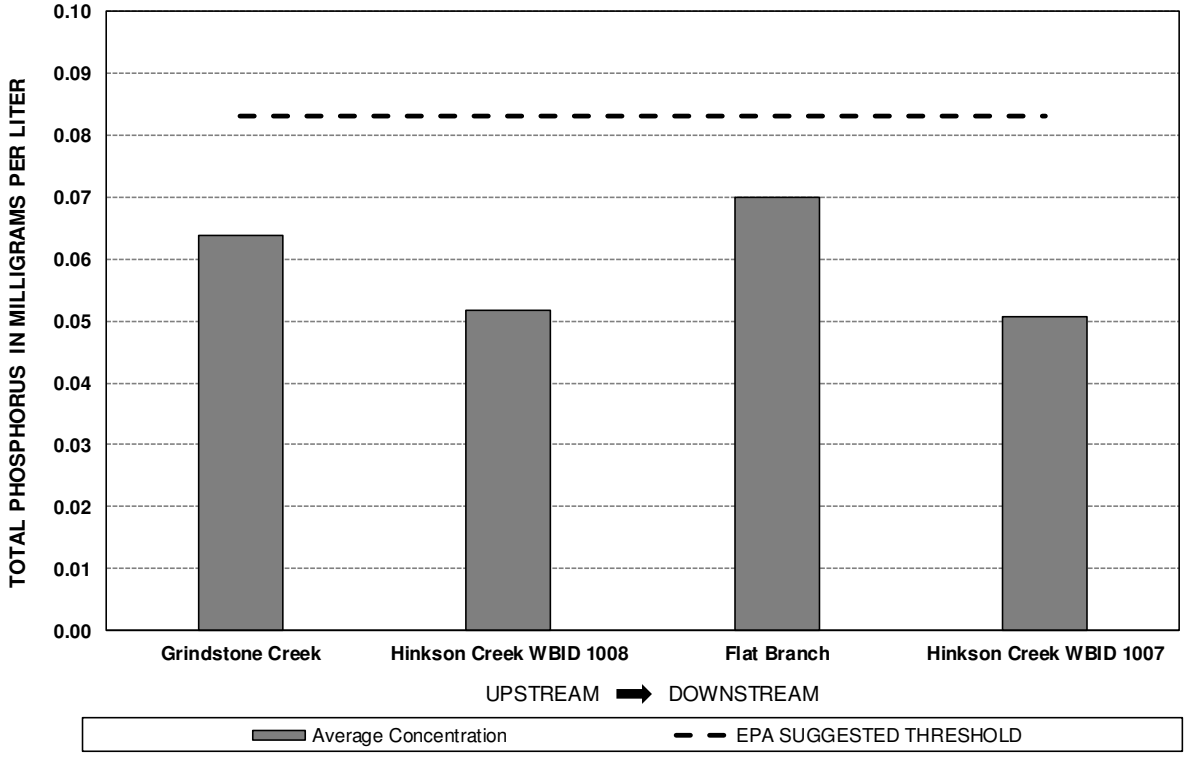

Figure 8. Total Phosphorus Concentration in Columbia Area Streams.

4.6. Macroinvertebrates

Aquatic macroinvertebrates are used as an indicator of stream water quality. Samples have been collected from Hinkson Creek since 2001. In 2012, MDNR launched a 5-year intensive monitoring program on Hinkson Creek in response to an EPA-approved aquatic life TMDL. During the 5-year study, MDNR is assessing annual spring and fall macroinvertebrate community composition (MDNR, 2012-2014).

Aquatic macroinvertebrate community evaluations are expressed as the Missouri Stream Condition Index (MSCI), which is comprised of four biological metrics: Taxa Richness (TR), Ephemeroptera/Plecoptera/Trichoptera Taxa (EPTT), Biotic Index (BI), and the Shannon Diversity Index (SDI). Together, these metrics consider stream health and adjust to changes in environmental stream conditions. In calculating the MSCI score, each of the four metrics is standardized and assigned values of 1, 3 or 5, with 5 representing optimum conditions. **Table 4** outlines the ranges and biological relevance of the metric derived MSCI scores.

Table 4. Missouri Stream Condition Index Breakdown.

Minimum Range	Maximum Range	Biological Indicator
16	20	Fully Supports Aquatic Life Uses
10	14	Partially Supports Aquatic Life Uses
4	8	Does Not Support Aquatic Life Uses

Historically, all sampling locations in the upper (WBID 1008) and lower (WBID 1007) reaches of Hinkson Creek have attained partially supporting or fully supporting MSCI scores. MSCI scores are typically higher in the upstream reach than in downstream reach however, the downstream reach did demonstrate fully supporting conditions in the Fall of 2015 (**Attachment D**). The EPTT is generally the biological metric influencing MSCI scores for both the upper and lower reaches of Hinkson Creek. MDNR uses Bonne Femme Creek as a control stream for comparing MSCI scores collected from Hinkson Creek. Since 2012, MSCI scores measured at Bonne Femme Creek have been comparable to those measured at all Hinkson Creek stations.

4.7. State Parks and Conservation Areas

Water quality data within local and state parks/conservation areas were reviewed as part of the evaluation. Several City park streams and lakes had *E. coli* maximum values above MDNR's swimming advisory level (190 CFU/100 mL) but nutrients were generally low.

Eagle Bluffs Conservation Area (Eagle Bluffs) is a 4,400 acre wetland and wildlife area managed by the Missouri Department of Conservation (MDC). Wetlands and open water comprise approximately 1,700 acres of the area. To maintain this critical wetland habitat, a near constant source of water is required. The City and MDC have an operational understanding by which the Columbia Regional Wastewater Treatment Plant (CRWWTP) provides treated effluent to constantly maintain wetland and open water habitat. This agreement represents one of the nation's most prominent projects reclaiming wastewater effluent for wildlife habitat creation. Effluent quality is described in *Technical Memorandum 3 – Wastewater Treatment System Evaluation*.

Section 5. Summary

Understanding stream and lake water quality in the Columbia area is critical for prioritization of resources and corrective actions. Water quality data for Columbia area streams and lakes were reviewed to assist in prioritizing potential water quality concerns and identifying waters which may benefit from strategies focused on water quality improvement or protection. Water quality conditions identified in the assessment include:

- Surface water quality data have been collected in a number of Columbia area streams and lakes and are sufficient for evaluating large scale patterns and trends. However, the limited quantity of data available from most sites generally prevents the robust and detailed analysis needed to identify potential pollution sources or areas of concern. Hinkson Creek's main stem has the most extensive dataset. Data for Columbia area lakes were limited and primarily included bacteria, few lakes had information related to other parameters discussed.

- Columbia area streams and lakes have several impaired beneficial uses (whole body contact recreation, aquatic life, etc). Most of the impairments are related to whole body contact recreation and the result of elevated *E. coli* levels which MDNR could address through the TMDL process. A TMDL has been developed for aquatic life use impairments in Hinkson Creek and is being implemented through the ongoing CAM process. Impairments related to atmospheric deposition of mercury are a widespread issue statewide.

- Elevated *E. coli* levels are pervasive throughout Columbia area waters, which is typical in urban waters. Seasonal geometric mean criteria for *E. coli* were exceeded during one or more of the last three years (2013, 2014, 2015) and during wet weather in all streams evaluated. Lake *E. coli* levels were typically below the seasonal criteria but individual samples occasionally exceeded advisory thresholds.

- DO in Columbia area streams and lakes typically met state water quality criteria. However, Flat Branch, Gans Creek, and Little Bonne Femme Creek data indicate that depressed DO levels are present primarily during warm weather and low-flow conditions. The impacts of depressed DO levels on aquatic organisms in these streams is unclear.

- Chloride concentrations are generally low in Columbia streams. However, levels increase during winter and early spring during runoff events. Data were not sufficient to determine if water quality criteria were attained.

- Total nitrogen and total phosphorus levels in streams were below EPA's suggested ecoregional thresholds.

- Macroinvertebrate MSCI scores for Hinkson Creek indicate the upstream segment is typically fully supporting of aquatic life uses while the downstream segment is generally partially supporting of aquatic life.

- The continued use of the CRWWTP treated effluent is critical to the management strategies being implemented at Eagle Bluffs. Without this constant source of water, MDC would have to rely on the costly and energy-intensive practice of pumping several million gallons per day of Missouri River water to maintain water levels within Eagle Bluffs.

Section 6. References

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Technical Memorandum 1

Attachments

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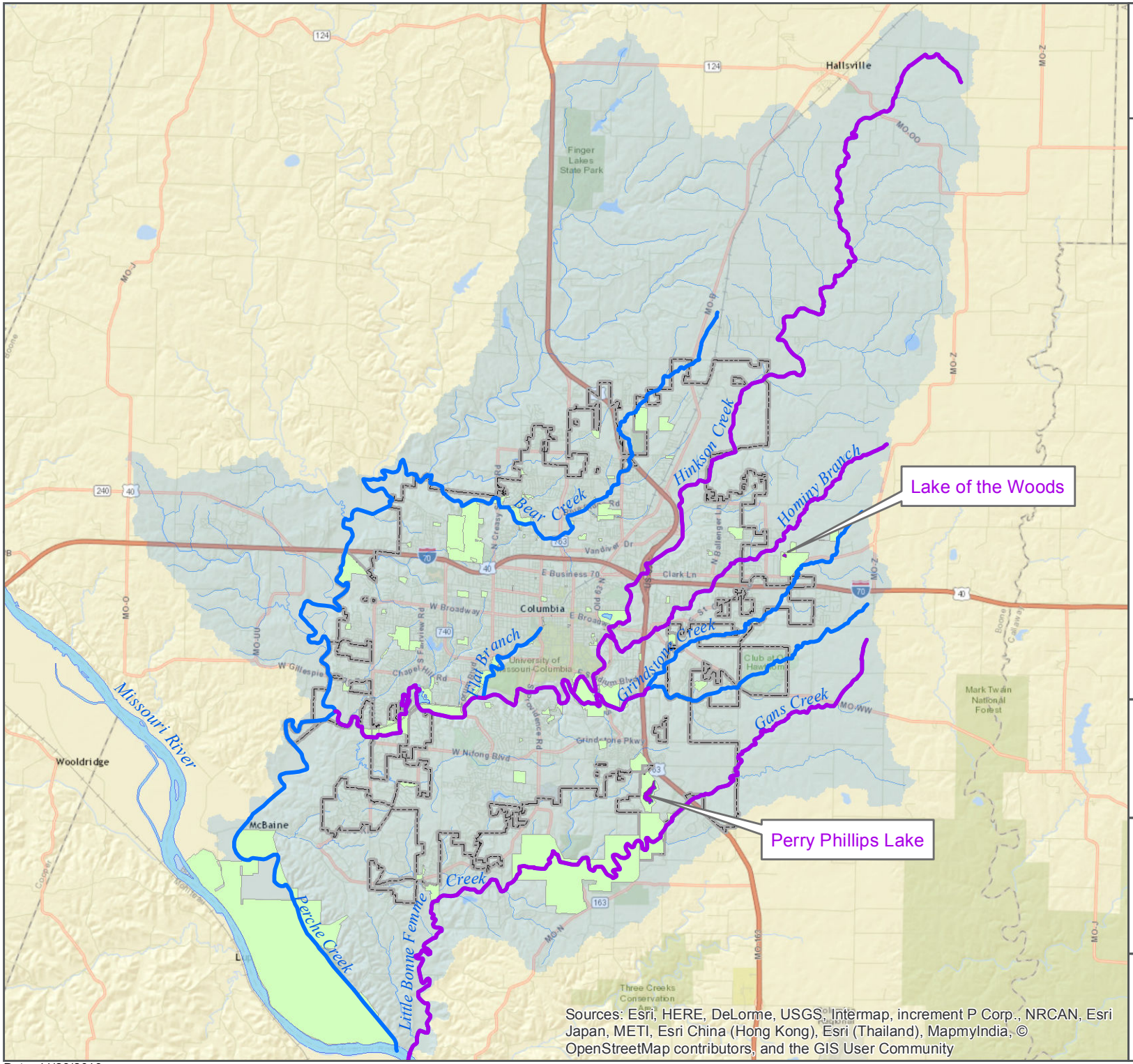


Our Columbia Waters
Integrated Management Plan
Wastewater & Stormwater

LEGEND

- Streams on 303(d) list
- Major streams
- Minor streams
- Lakes on 303(d) list
- City limit
- Watershed
- Parks

ATTACHMENT A
COLUMBIA STREAMS AND IMPAIRED WATERBODIES

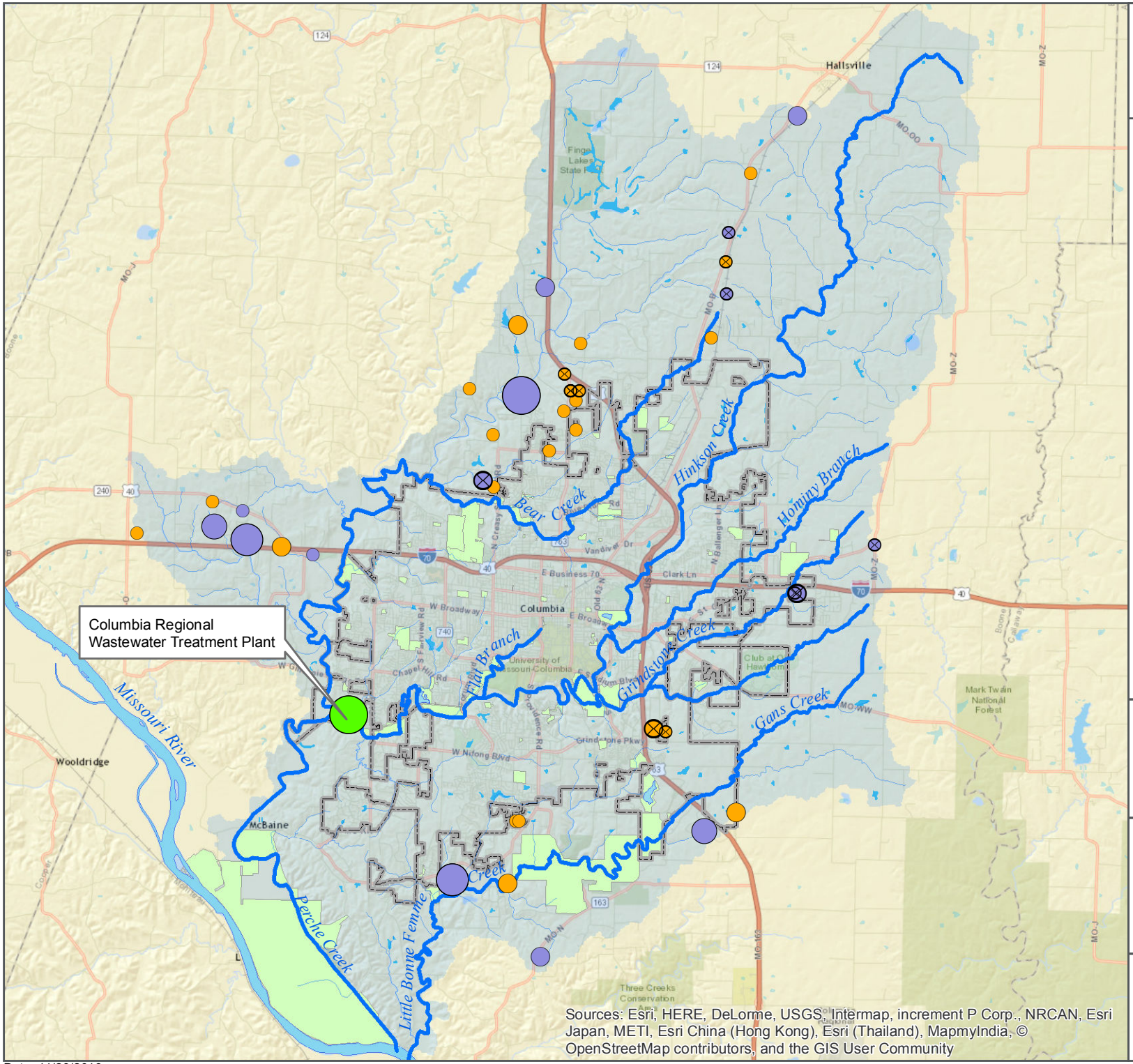
CITY OF COLUMBIA
MISSOURI

WASTEWATER & STORMWATER INTEGRATED MANAGEMENT PLAN

N

0 1.5 3 4.5
MILES

Date: 11/29/2016



Our Columbia Waters
Integrated Management Plan
Wastewater & Stormwater

LEGEND

- Major streams
- Minor streams
- Water bodies
- Watershed
- City limit
- Parks

Treatment System Owner

- Boone County Regional Sewer District
- City of Columbia
- Private Systems
- Planned to be Consolidated

Treatment System Flow (GPD)

- 0 - 10,000
- 10,001 - 50,000
- 50,001 - 100,000
- 100,001 - 250,000
- 250,001 - and greater

ATTACHMENT B
DOMESTIC WASTEWATER TREATMENT SYSTEMS

CITY OF COLUMBIA
MISSOURI

WASTEWATER & STORMWATER INTEGRATED MANAGEMENT PLAN

N

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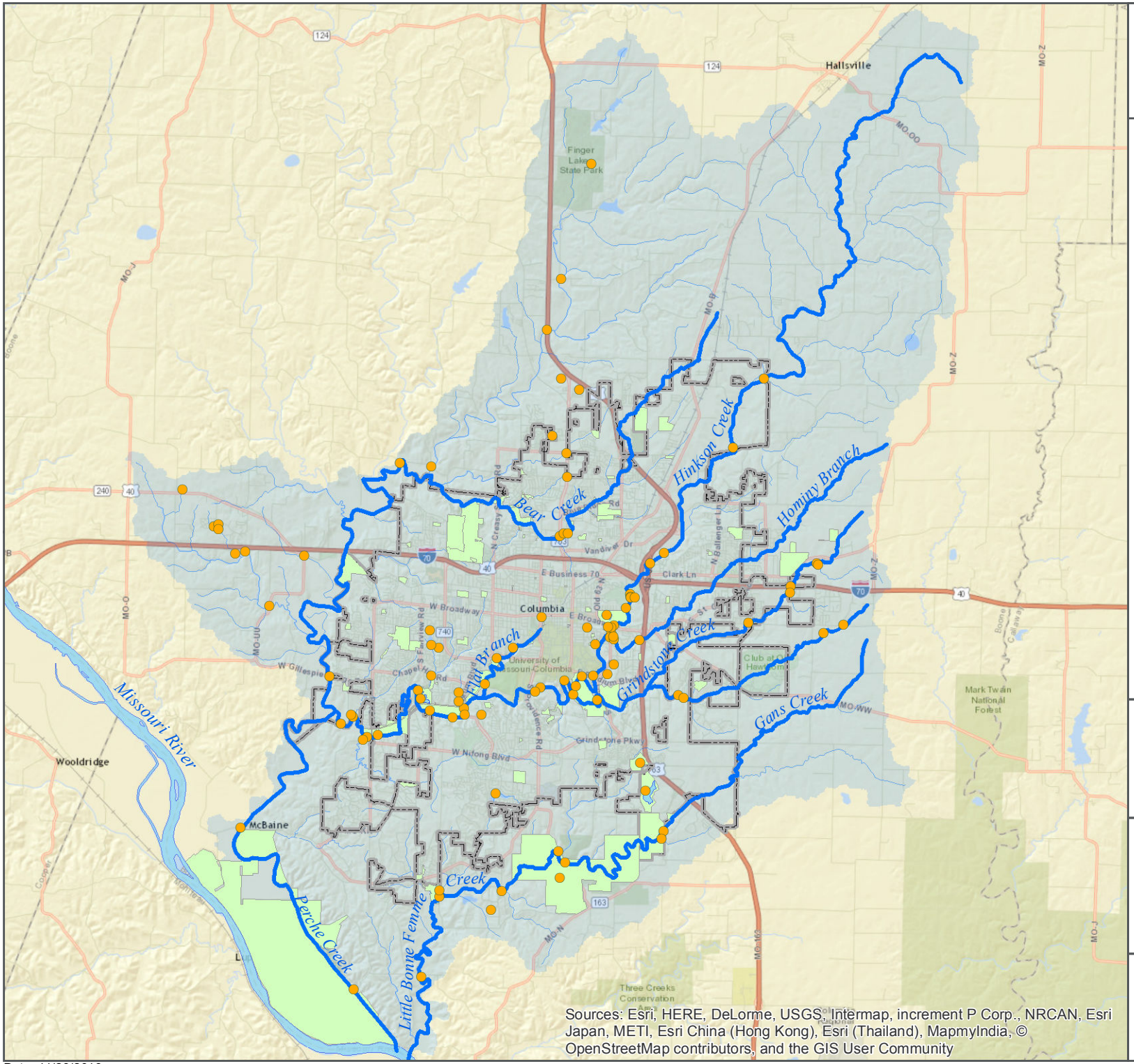
MILES

Date: 11/29/2016



Our Columbia Waters
Integrated Management Plan
Wastewater & Stormwater

LEGEND

- Water quality stations
- Major streams
- Minor streams
- City limit
- Watershed
- Parks

ATTACHMENT C
COLUMBIA WATER QUALITY MONITORING STATIONS

CITY OF COLUMBIA
MISSOURI

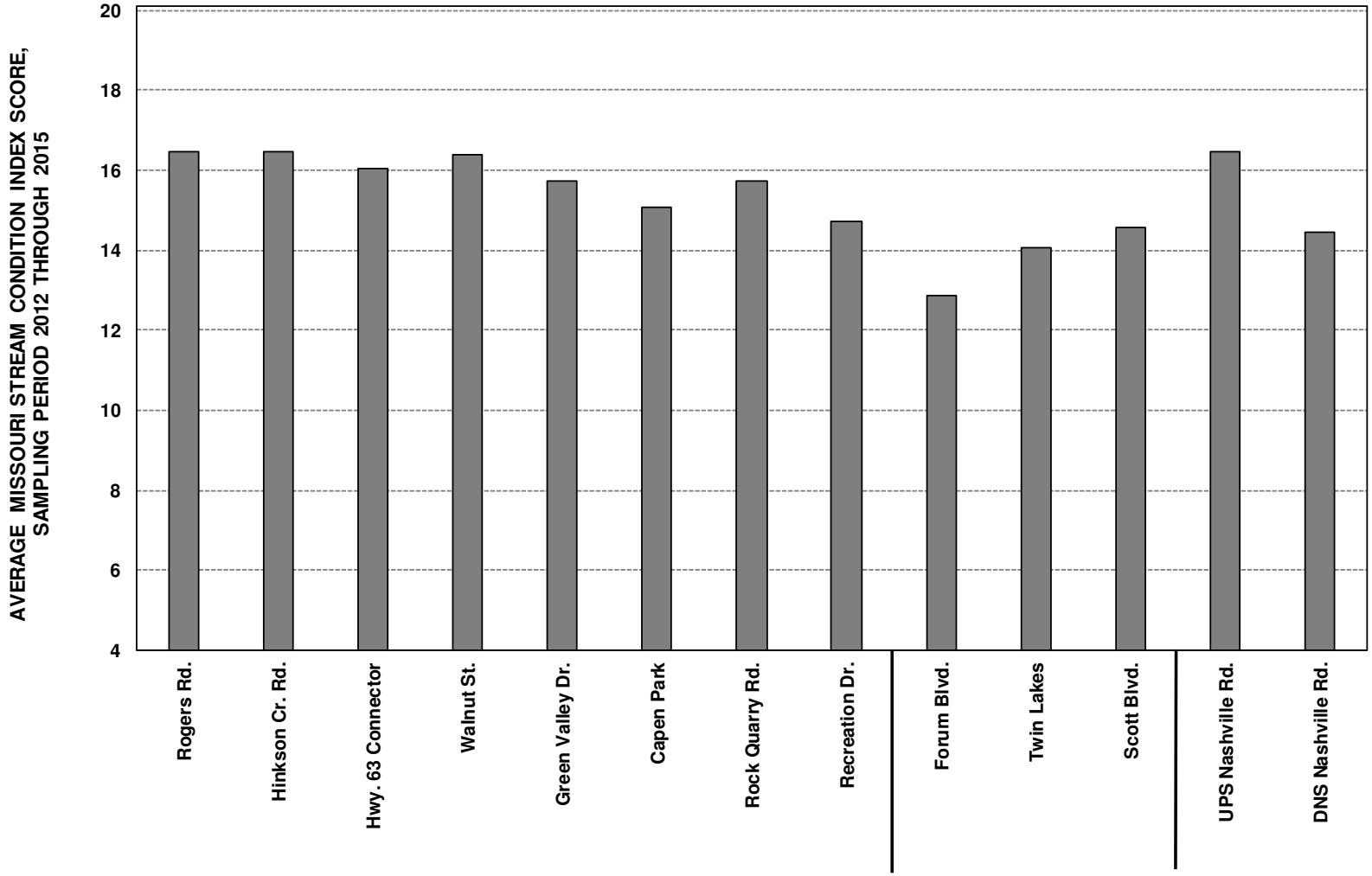
WASTEWATER & STORMWATER INTEGRATED MANAGEMENT PLAN

N

0 1.5 3 4.5
MILES

Date: 11/29/2016

Attachment D
Hinkson Creek and Bonne Femme Creek MSCI Scores



Note: Blank cells indicate that no macroinvertebrate sample was collected; **Shaded and Bolded** cells indicate a sample was collected and fully supports aquatic life; "- -" indicates a sample was collected but not included in the MDNR evaluation; Unshaded and no bold indicates partial supporting of aquatic life. Fall 2012 data have been excluded by MDNR due to drought conditions during the summer of 2012.