TOOLS FOR MS4s: USING GIS FOR *E. COLI* SOURCE INVESTIGATIONS AND CONTROLS

INTRODUCTION

Approximately 90 stream segments in Colorado are either impaired for recreational use due to elevated *E. coli* concentrations or identified as needing additional monitoring and evaluation of *E. coli* to assess impairment. Local health departments, municipal separate storm sewer system (MS4) permit managers, public works officials and others are increasingly faced with the challenge of identifying the sources of *E. coli* loading to streams and correcting those sources. These requirements may be voluntary, required under MS4 discharge permits or based on a Total Maximum Daily Load (TMDL) for *E. coli*. This fact sheet provides basic guidance and resources that local governments can use to organize information pertinent to *E. coli* source investigations. This "desktop" information can be combined with field investigations and monitoring programs, including microbial source tracking efforts, to support *E. coli* source identification and corrective measures. Ideally, tools such as Geographic Information Systems (GIS) are used to support hypothesis formation regarding sources, to organize initial investigations and then to track activities and improvements over time. Typically, these efforts require coordination across city departments; therefore, understanding how various types of data and information fit together is important. This fact sheet proves a brief overview of how GIS can be used to support *E. coli* source investigations and track corrective measures to reduce loading.

INVENTORYING POTENTIAL *E. COLI* SOURCES

One of the challenges of *E. coli* source identification is that there are many diffuse sources of *E. coli* in both urban and natural watersheds. The starting point for effective *E. coli* source identification and load reduction is developing a reasonable understanding of the sources of *E. coli* in the watershed, as well as understanding sources of flows transporting *E. coli* to receiving waters. Table 1 provides a list of sources of *E. coli* in urban areas. Not all sources will be present in all urban areas, but the table provides an initial checklist of potential sources. From a regulatory perspective, MS4 permittees are not required to address all of these sources (e.g., non-point sources); however, it is beneficial for MS4 permittees to have a broad understanding of the diverse sources of bacteria that may be present in impaired waterbodies that receive discharges from the MS4.

The next step is to begin compiling and reviewing information available in the study area of interest. This includes integrating available water quality data with other relevant information geospatially. GIS can be used as a tool to overlay various types of geolocated information in a manner than can help support field investigations of sources contributing to MS4 outfalls. By mapping water quality data with other geospatial information, hypotheses can be formed regarding potential sources, and areas in need of additional monitoring (data gaps) can be identified.

TABLE 1. POTENTIAL SOURCES OF FIB IN URBANIZED AREAS AND ADJOINING WATERSHEDS

GENERAL CATEGORY	*Source/Activity*
MUNICIPAL SANITARY INFRASTRUCTURE (PIPED)	*Sanitary sewer overflows (SSOs)*
	Leaky sewer pipes (Exfiltration)
	Illicit Sanitary Connections to MS4
	WWTPs (if inadequate treatment or upsets)
OTHER HUMAN SANITARY SOURCES *(some also attract urban wildlife)*	*Leaky or failing septic systems*
	Homeless encampments
	Porta-Potties
	Dumpsters (e.g., diapers, pet waste, urban wildlife)
	Swimmers/bathers, boaters, trail users (e.g., hikers, runners)
	RVs (mobile)
	Trash cans
	Garbage trucks
DOMESTIC PETS	*Dogs, cats, etc.*
URBAN WILDLIFE *(naturally-occurring and human attracted)*	*Rodents/vectors (rats, raccoons, squirrels, opossums)*
	Birds (gulls, geese, ducks, pigeons, swallows, etc.)
	Open space (coyotes, foxes, beavers, feral cats, etc.)
OTHER URBAN SOURCES *(including areas that attract vectors)*	*Landfills*
	Food processing facilities
	Outdoor dining
	Restaurant grease bins
	Bars/stairwells (washdown areas)
	Green waste, compost/mulch
	Animal-related facilities (e.g., pet boarding, zoos, off-leash parks)
URBAN NON-STORMWATER DISCHARGES *(potentially mobilizing surface-deposited FIB)*	*Power washing*
	Excessive irrigation/overspray
	Car washing
	Pools/hot tubs
	Reclaimed water/graywater (if not properly managed)
MS4 INFRASTRUCTURE	*Illegal dumping*
	Illicit sanitary connections to MS4 (also listed above)
	Leaky sewer pipes (exfiltration) (also listed above)
	Biofilms/regrowth
	Decaying plant matter, litter and sediment in the storm drain system
AGRICULTURAL SOURCES *(potentially including ranchettes within MS4 boundaries or areas in urban growth boundaries)*	*Livestock, manure storage*
	Livestock, pasture
	Livestock, corrals
	Livestock, confined animal feeding operations (CAFO) (NPDES-regulated)
	Manure spreading, pastures/crops
	Municipal biosolids re-use
	Reclaimed water (if not properly managed)
	Irrigation tailwater
	Slaughterhouses (NPDES-regulated)
NATURAL OPEN SPACE/FORESTED AREAS	*Wildlife populations*
	Grazing
	Natural area parks, off-leash areas
OTHER NATURALIZED SOURCES	*Decaying plants/algae, sand, soil (naturalized FIB)*

NOTE *This table is a Colorado adaptation of work by San Diego County (Armand Ruby Consulting 2011)*

ACCESSING PUBLICLY AVAILABLE DATA FOR GIS

Most local governments have some level of GIS capability that provides basic land use and infrastructure mapping. This can be supplemented by GIS data from regional entities such as Denver Regional Council of Governments (DRCOG) and other sources and can be used to begin organizing information for *E. coli* source investigations. Examples of pertinent data and sources of data include:

- **BASIC LAND USE AND HYDROLOGIC MAPPING** The Colorado Division of Water Resources provides GIS data for all river basins in Colorado. GIS layers include HydroBase data such as points of water diversion, wells, streams/rivers, stream gages, canals, and climate stations. Irrigated acreages for various years and other relevant layers are also provided, which may be of interest when *E. coli* impairments cross from urban areas into agricultural areas. The data can be downloaded and used directly in ArcGIS. *Colorado's Decision Support Systems*

- **STORM DRAIN SYSTEM** Under Colorado's MS4 permits, illicit discharge detection and elimination (IDDE) requirements include mapping of storm drain system outfalls. MS4s are required to maintain mapping of all MS4 outfalls within the permit area, and the names and location of all state waters that receive discharges from those outfalls. These data along with other storm drain infrastructure mapping provide valuable information relevant to *E. coli* source investigations. Data such as pipe age and material are also relevant.

- **SANITARY SEWER SYSTEM** Most public works departments have sanitary sewer mapping. Electronic availability, level of detail and accuracy varies. This can be overlaid with the storm drain system to identify potential areas of sanitary exfiltration into storm drains. In addition to pipe locations, pipe age and materials as well as maintenance activities are useful information. This can also include sanitary sewer overflow (SSO) occurrence records, which are an obvious, though intermittent, source of bacteria loading to the storm drain system.

- **ENVIRONMENTAL PROTECTION AGENCY (EPA) ENFORCEMENT AND COMPLIANCE HISTORY ONLINE (ECHO) DATABASE** For comprehensive information on permitted dischargers in watersheds and compliance and enforcement history, EPA's Echo Database is a key tool to inventory major and minor wastewater treatment facilities (POTWs), confined animal feeding operations (CAFOs), biosolids permits, stormwater permits, and other discharges. While major POTWs are often well known, smaller facilities such as trailer parks and campgrounds can also be identified through ECHO. Compliance history searches can help identify potential problem areas. Additionally, searches on EPA's Permit Compliance System (PCS) and Integrated Compliance Information System (ICIS) databases on EPA's Envirofacts website may provide additional information on these facilities. *EPA ECHO* or *EPA PCS-ICIS Search*

- **ONSITE WASTEWATER TREATMENT SYSTEM (OWTS, SEPTIC SYSTEMS)** Availability of OWTS mapping varies substantially; however, some counties and local health departments have this information. Data may be incomplete; however, even limited OWTS mapping is relevant to bacteria source investigations.

- **NATIONAL WATER QUALITY DATA PORTAL** The Water Quality Portal (WQP) is a cooperative service sponsored by the United States Geological Survey (USGS), EPA, and the National Water Quality Monitoring Council (NWQMC). It hosts data collected by over 400 state, federal, tribal, and local agencies, including the Colorado Water Quality Control Division, Colorado Parks and Wildlife's Riverwatch program. The portal is a good source of information on watershed monitoring and local governments can utilize it to supplement their own monitoring programs. *National Water Quality Data Portal*

- **COLORADO DATA SHARING NETWORK (CDSN)** The purpose of the CDSN is to allow for simple GIS queries to support evaluation of geospatial relationships to impaired waters, hydrologic unit code areas (e.g., HUC 8 and HUC 12), ecoregions, waterbodies, and basins. The CDSN can be a source of monitoring data by others that supplements a local government's monitoring data. *CDSN Web GIS*

- **COLORADO WATER QUALITY CONTROL DIVISION GIS RESOURCES** The Division provides stream segment mapping which can be useful when local governments are addressing *E. coli* impairments on multiple regulatory stream segments. *CDPHE Clean Water GIS*

- **URBAN DRAINAGE AND FLOOD CONTROL DISTRICT (UDFCD) GIS RESOURCES** UDFCD provides open access to useful stream and stormwater-related infrastructure mapping through Colorado Open Data and UDFCD's website. Examples includes storm drainage basin boundaries, detention basin locations, storm drains and pipes, and other information. Additionally, UDFCD's master-planned improvements, BMP research and Joint Task Force monitoring locations can be accessed on UDFCD's mapping and data webpage. *UDFCD GIS*

- **COLORADO OPEN DATA** Colorado Open Data is a good general source of information for various data provided by local governments. Although local governments presumably have access to their own data internally, where watersheds cross multiple jurisdictions, Colorado Open Data may be a resource to access other data sets. For example, some local governments provide open access to land use and sewer main and/or storm drain mapping through this site. *Data Open Colorado*

- **ERAMS** Colorado State University's eRAMS geospatial platform provides access to a variety of geospatial data, water quality data and flow data. Additionally, various tools accessible on this website can be useful for exploratory data analysis. For example, in Colorado, Load Duration Curves are a common technique used to support *E. coli* TMDLs. The eRAMS "Flow Analysis" tools allow user to either utilize publicly available data sets or their own data sets to generate load duration curves. These outputs allow users to see how *E. coli* loading varies under a range of flow conditions and seasons in comparison to load targets. *eRams*

- **OTHER DATA** In addition to data sources listed above, features such as dog parks, hobby farms, stables and other sources are relevant. If these features are not available in other data sets, simple review of satellite imagery on publicly available sites such as Google can be used to identify features. Additionally, documentation of areas irrigated with reclaimed water can be valuable, particularly if DNA-based microbial source tracking is planned. (Although reclaimed water is disinfected, human DNA may still be detected and confound source investigations.)

In addition to being useful to support *E. coli* source investigations, the information above can be used to support other MS4 permit-related requirements such as identifying IDDE Permit Priority Areas that have a higher likelihood of having illicit discharges

PRIORITIZING SOURCES FOR INVESTIGATION

Based on the combination of water quality and geospatial data, initial hypotheses regarding bacteria source loading areas can be formulated and further investigated using a range of simple to advanced microbial source tracking approaches. Given the many sources of bacteria in urban areas and some of the challenges associated with definitively determining sources, it is helpful to develop a source prioritization process. Water quality data, geospatial information and community input can be combined to prioritize areas for further investigation considering factors such as:

- Human health risk (e.g., Sanitary sources are of more concern than birds.)
- Magnitude of loading
- Geographical distribution relative to recreational use locations
- Controllability/ability to implement/ability to leverage other planned projects
- Frequency of standards exceedances[1]

As sources are identified and/or eliminated, GIS can also be used to track additional data and corrective measures as it is collected.

[1] *List adopted from the Source Prioritization Process prepared by Armand Ruby Consulting (2011) for the San Diego County MS4 co-permittees.*

USING GIS TO TRACK SOURCE INVESTIGATIONS AND CORRECTIVE MEASURES

Once initial mapping and information has been compiled to formulate hypotheses and initiate investigations and corrective measures, it is important to track activities and monitoring data in an organized manner that is integrated with GIS. A common problem with water quality investigations is the lack of systematic storage of data collected from individual studies in a meaningful manner for use in GIS over the long term. Each monitoring location associated with special studies or investigations should be geolocated and stored systematically so that information is not lost over time (e.g., due to staff turnover). At a minimum, water quality data should be stored in a single database that includes a table of monitoring locations with geospatial data (e.g., decimal latitude and longitude) and a table of compiled monitoring data. This requirement should apply to internal studies and special studies conducted by academic institutions or consultants to the local government. This information can be overlaid with actions implemented to reduce *E. coli* loading.

Examples of information that should be tracked in GIS include:

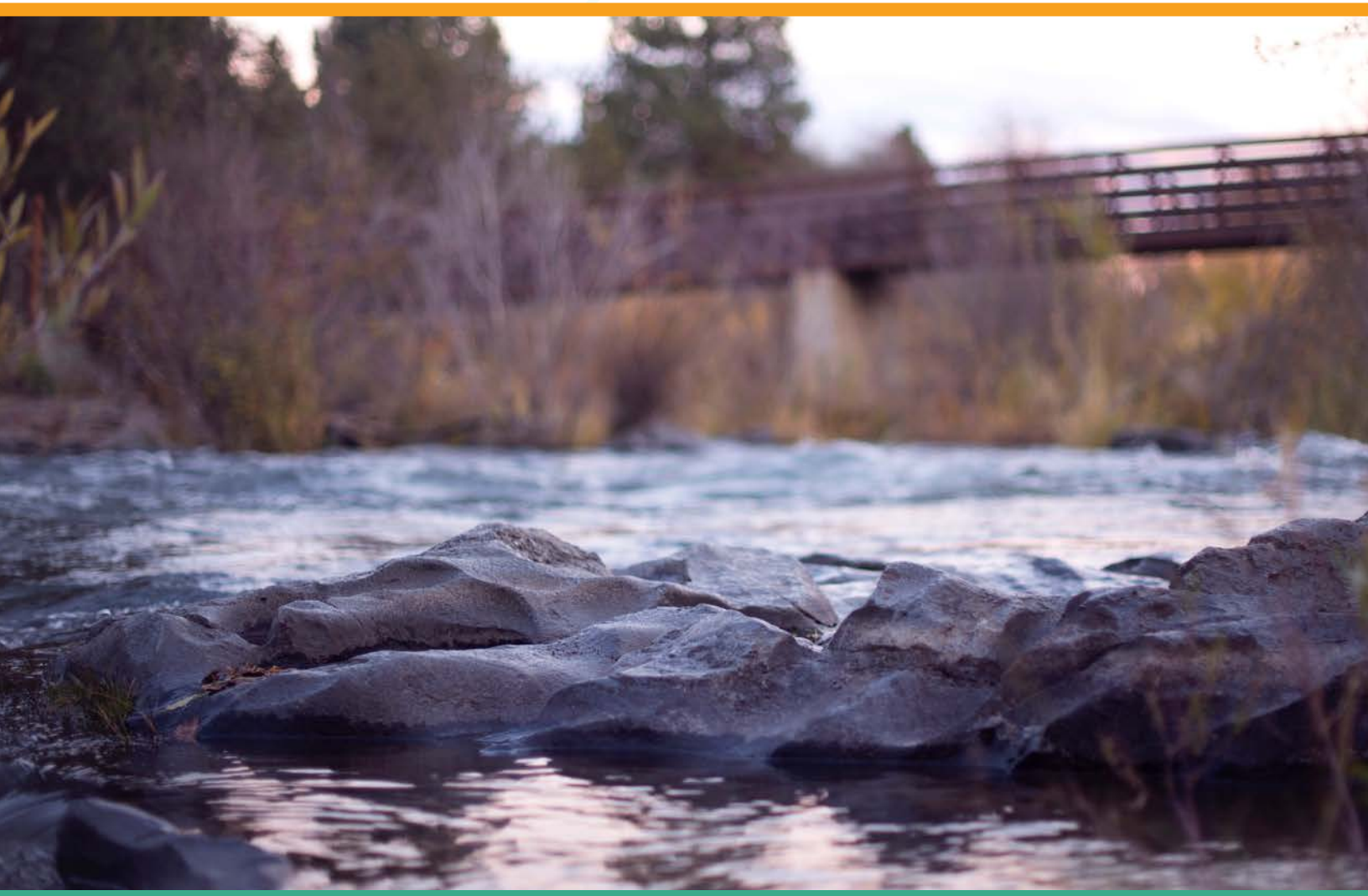
- **SANITARY SEWER AND STORM DRAIN SYSTEM MAINTENANCE** Aging and leaking sanitary sewer and stormwater conveyance pipes can introduce pollutants to the MS4 through SSOs caused by blockages, line breaks, or other sewer defects; exfiltration of sewage from sanitary sewers; and infiltration of groundwater when the storm drain lies below the water table. Upgrading, repairing, or slip-lining faulty sanitary sewer pipes can reduce pollutant loads by eliminating the leaks in those pipes. Additionally, upgrading or repairing storm drains can minimize the infiltration of contaminated groundwater into the MS4. Many communities have implemented "Asset Management Programs" that provide a systematic strategy to manage, maintain and operate infrastructure. Data from Asset Management Systems, particularly related to CCTV investigations and maintenance such as cleaning, slip-lining or replacement, can be particularly helpful to overlay on GIS maps along with sampling data.

- **STORM DRAIN CLEANING** Storm drains can accumulate trash, sediment, organic matter and animal waste over time. As a result, they can become secondary reservoirs of bacteria and other pollutants. Cyclical storm drain cleaning using water jetting and vacuuming of jetted water is one tool that some communities have implemented as a source control BMP. Storm drain cleaning is typically done on a several year cycle and can be done more frequently in "priority basins" where elevated bacteria at storm drains is identified. Sampling results may be used to help target areas in need of more frequent cleaning such as siphon conditions.

- **CATCHBASIN CLEANING** Catchbasins and drain inlets play an important role in the prevention of trash and other sediment from entering the storm drain system. Catchbasin cleaning is an important institutional BMP. For bacteria, catchbasin cleaning may be most beneficial in commercial areas.

- **STRUCTURAL STORMWATER BMP MAINTENANCE** Maintenance of structural stormwater quality BMPs can also help to remove secondary reservoirs of bacteria in urban areas. Routine sediment removal from extended detention basins, manufactured devices, and other BMPs can reduce the likelihood of sediment resuspension and bacteria release during storm events. Maintenance dates and activities can be tracked within GIS attributes.

- **OWTS/SEPTIC SYSTEM ACTIVITIES** If septic systems are identified as a source of bacteria loading, activities such as maintenance, replacement and/or connection to sanitary sewers are representative activities to track in GIS.



CONCLUSION AND ADDITIONAL INFORMATION

GIS-based approaches that integrate water quality data with geospatial data can be a key tool for bacteria source investigations and corrective measures to reduce bacteria loading. The Colorado *E. coli* Toolbox and references below provide additional guidance intended to be used with this fact sheet.

- Colorado *E. coli* Toolbox: A Practical Guide for Colorado MS4s, available on UDFCD's website. *Colorado E. coli Toolbox*
- Illicit Discharge Detection and Elimination: A Guidance Manual for Program Development and Technical Assessments: *IDDE Guidance Manual for Program Development and Technical Assessments*
- The California Microbial Source Identification Manual: A Tiered Approach to Identifying Fecal Pollution Sources to Beaches: *California Microbial Source Identification Manual*

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