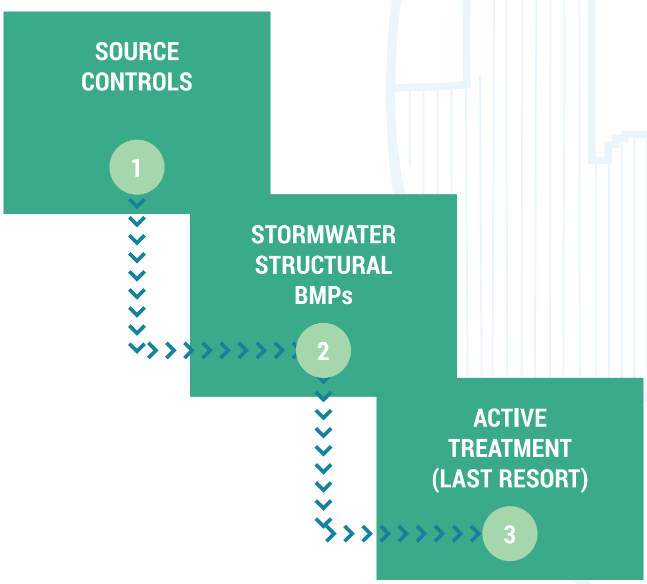
TOOLS FOR MS4s: STORMWATER BMPs FOR *E. COLI*

INTRODUCTION

Local governments with municipal storm sewer systems (MS4s) discharging to waterbodies that are impaired due to elevated *E. coli* are often faced with the challenge of reducing *E. coli* loading to these waterbodies. Source controls are an essential step for reducing *E. coli*. Structural control practices to reduce *E. coli* loading from wet weather flows include options for treating urban runoff through "passive" stormwater best management practices (BMPs) such as those included in the Urban Drainage and Flood Control District's (UDFCD's) Urban Storm Drainage Criteria Manual Volume 3. Active treatment options, which are typically considered a last resort for managing dry weather flows, include low-flow diversions to the sanitary sewer and active treatment using disinfection at the outfall. This fact sheet provides information on approaches to reducing *E. coli* loads from MS4s, expectations for stormwater BMP performance and various treatment options.



WHAT IS THE BEST APPROACH FOR REDUCING *E. COLI* LOADING FROM MS4S?

The first step is source controls, which benefit both dry and wet weather discharges from MS4s. This typically requires an investigation of dry weather discharges to identify the causes of elevated *E. coli* and correct these sources. These efforts can be implemented as part of Illicit Discharge Detection and Elimination (IDDE) programs already required under MS4 permits. One of the most important source control measures is identifying sanitary sewer leaks intercepted by the storm drain system and, in some cases, erroneous plumbing of the sanitary sewer to the storm drain. More diffuse sources can include transient encampments, drainage from dumpsters, and wildlife and pets. (See Colorado *E. coli* Toolbox for a complete list to consider as part of IDDE and source investigations.)

Implementation of structural stormwater BMPs to improve water quality under wet weather conditions is also a fundamental part of stormwater management programs. Stormwater BMPs can help reduce *E. coli* loading to streams, although consistent attainment of instream primary contact recreation standards at end of pipe under wet weather conditions is typically not realistic. This is one of the reasons some communities nationally have focused on green infrastructure approaches that encourage runoff volume reduction to reduce pollutant loads.

WHICH STORMWATER BMPS WORK BEST FOR REMOVING *E. COLI*?

In Volume 3 of the Urban Storm Drainage Criteria Manual, UDFCD provides BMP selection, design, construction and maintenance guidance for structural BMPs suitable for use in urban areas in most of Colorado. The menu of structural BMPs in Volume 3 is summarized in Table 1 along with general characterization of expected effectiveness for fecal indicator bacteria (FIB) (e.g., *E. coli*, enterococcus, fecal coliform) and a summary of unit treatment process, or removal mechanisms, provided by the BMP. Actual performance at a given site is affected by proper maintenance and other site-specific and design factors.

Nationally, performance monitoring for stormwater BMPs for FIB is relatively limited and results can be difficult to interpret due to the highly variable nature of *E. coli* monitoring results. Nonetheless, available data suggest that several BMP types can significantly reduce *E. coli* concentrations. Generally, green infrastructure practices that infiltrate and evapotranspire runoff, such as bioretention, can help to reduce the frequency and magnitude of *E. coli* loads discharged to streams. Additionally, practices such as retention (wet) ponds, wetland basins and media (sand) filters also demonstrate the ability to reduce FIB. Findings from the International Stormwater BMP Database for FIB are summarized in Table 2. Colorado's recreational water quality criteria are based on *E. coli*, with the primary contact recreation standard based on a 61-day rolling geometric mean of 126 cfu/100 mL.

BMP TYPE	EXPECTED EFFECTIVENESS FOR E. COLI	DOMINANT REMOVAL PROCESSES FOR FIB FOR BMP TYPE	ADDITIONAL CONSIDERATIONS
Grass Buffers and Grass Swales	*Poor*	*Infiltration*	*Swales may increase bacteria concentrations if frequented by urban wildlife and pets.*
Bioretention	*Moderate to High*	*Infiltration Filtration Biological Processes*	*High infiltration rates, excessive hydraulic loading, and shallow media depth can all negatively impact FIB reduction performance.*
Green Roof	*Not Well Characterized*	*Evaporation Filtration*	*The primary benefit of green roofs is volume reduction.*
Extended Detention Basin	*Poor to Moderate*	*Sedimentation Infiltration (limited)*	*The performance of EDBs for FIB reduction varies widely.*
Sand Filter	*Moderate*	*Filtration*	*Media enhancements may help to reduce FIB.*
Retention Pond (Wet Pond)	*Moderate*	*Sedimentation Biological Processes (predation)*	*Many wet ponds demonstrate significant FIB reductions.*
Constructed Wetland Pond	*Moderate*	*Sedimentation Biological Processes (predation)*	*Some wetlands may export FIB when birds and other wildlife utilize these areas for habitat.*
Constructed Wetland Channel	*Poor to High, depending on design*	*Sedimentation Biological Processes (predation)*	*Consider subsurface constructed wetland channel designs to enhance performance.*
Permeable Pavement	*Not Well Characterized*	*Infiltration Filtration*	*The primary benefit of permeable pavement is volume reduction.*
Underground BMPs (Proprietary Practices)	*Variable*	*Device-dependent*	*Proprietary practice designs continue to evolve. Effectiveness depends on the practice.*

TABLE 1. EXPECTED EFFECTIVENESS OF USDCM VOLUME 3 BMPs FOR FIB

BMP CATEGORY	BMPs		EMCs		25th		MEDIAN			75th	
	IN	OUT	IN	OUT	IN	OUT	IN	OUT	DIFFERENCE	IN	OUT
E. coli (MPN/100 mL)											
Bioretention	7	7	97	96	110	18	1,200 (200-2,100)	240 (77-280)	◇◆◆	5,900	1,100
Grass Swale	5	6	39	46	410	1,200	3,500 (410-5,600)	4,400 (2,600-5,900)	◇◇◇	11,000	11,000
Retention Pond	4	4	69	65	580	10	2,000 (990-3,100)	80 (24-170)	◆◆◆	5,500	700
Wetland Basin	6	6	77	76	650	260	2,800 (870-6,900)	1,000 (550-1,500)	◇◆◆	15,000	3,800
Wetland Basin/ Retention Pond	10	10	146	141	580	41	2,300 (1,400-3,500)	450 (200-700)	◆◆◆	11,000	1,600
Enterococcus (MPN/100 mL)											
Bioretention	3	3	48	49	180	32	590 (220-920)	220 (58-440)	◇◆◆	2,400	2,200
Wetland Basin	4	4	53	53	230	30	840 (250-1,500)	330 (100-630)	◇◆◆	4,000	1,800
Wetland Basin/ Retention Pond	6	6	86	86	210	20	780 (350-1,500)	170 (80-390)	◇◆◆	4,300	1,700
Fecal Coliform (MPN/100 mL)											
Composite	4	4	64	56	5,500	4,100	15,000 (9,500-19,000)	12,000 (6,800-17,000)	◇◇◇	37,000	21,000
Detention Basin	15	15	170	194	400	60	1,800 (1,100-2,800)	640 (370-1,500)	◇◆◆	12,000	7,100
Grass Swale	12	11	91	82	1,100	1,000	4,900 (2,500-7,000)	4,400 (2,400-6,200)	◇◇◇	22,000	17,000
Media Filter	15	15	184	169	120	33	900 (400-1,500)	400 (200-800)	◇◆◆	10,000	5,600
Retention Pond	10	12	121	161	300	50	3,400 (1,500-5,000)	1,400 (360-2,300)	◇◆◆	23,000	8,500
Wetland Basin	5	5	42	39	2,400	180	12,000 (3,200-15,000)	900 (230-1,900)	◆◆◆	23,000	7,200
Wetland Basin/ Retention Pond	15	17	163	200	610	79	5,000 (2,600-7,300)	1,200 (450-1,800)	◆◆◆	23,000	8,500
Wetland Channel	3	3	21	20	3,500	1,700	6,000 (2,300-7,500)	4,000 (1,600-11,000)	◇◇◇	12,000	12,000

TABLE 2. INFLUENT-EFFLUENT SUMMARY STATISTICS FOR VARIOUS BMPs FOR FIB

TABLE 2 NOTES

Numbers provided for In and Out columns represent the number of inflow and outflow BMPs and event mean concentrations (EMCs) for each BMP type. Values in parenthesis represent the 95% confidence interval for the median concentrations. "Difference" is interpreted based on the table below. For more detail, see www.bmpdatabase.org.

◆◇◇	*95% confidence intervals around influent/effluent medians do not overlap.*
◇◆◇	*P-value of the Mann-Whitney test is less than 0.05.*
◇◇◆	*P-value of the Wilcoxon test is less than 0.05.*
◇◇◇	*Results are not statistically different.*

INFLOW-OUTFLOW CONCENTRATION DIFFERENCES

HOW DO I EVALUATE EXPECTED PERFORMANCE OF PROPRIETARY BMPs?

The proprietary market for stormwater controls is continually evolving. A systematic evaluation of manufactured devices designed to reduce FIB and pathogens was not completed for purposes of this fact sheet. Basic guidance for reviewing proprietary device performance claims for FIB includes:

- **VERIFY USE OF "REAL" STORMWATER IN STUDIES** "Real" stormwater includes natural organic matter (NOM) and suspended sediment. If synthetic stormwater without these characteristics is used in studies, performance results may not be representative of installed conditions. If synthetic stormwater is used, NOM and suspended solids should be added to mimic "real" stormwater. Influent FIB concentrations should also be representative of typical stormwater runoff concentrations.

- **REVIEW EFFLUENT CONCENTRATIONS** Review independently measured quantitative results for each monitored event (including effluent concentrations), rather than simplified percent removal tabulations. Effluent concentration tends to be a more robust predictor of performance than percent removals.

- **REQUEST INDEPENDENTLY CONDUCTED OR VERIFIED FIELD-BASED STUDIES** Field demonstration test results are preferred over or in combination with laboratory studies.

- **REVIEW STUDY DESIGN DETAILS AND DATA SETS** A robust and transparent study will include influent and effluent concentrations for the monitored storm events, precipitation and flow data associated with monitored events, and information on the sampling plans.

- **VERIFY ANTIMICROBIAL CHEMICAL ACCEPTANCE** Some proprietary devices with antimicrobial chemicals may be subject to registration with regulatory agencies (e.g., the USEPA or possibly the Colorado Department of Agriculture). Proper registration and review may be legally required and will aid in protecting the environment from exports of potentially toxic material.

Examples of detailed proprietary device evaluations based on field installations can be obtained from the New Jersey Cooperative for Advance Technology (NJCAT) program (*njcat.org*), the Technology Acceptance Reciprocity Program (TARP), the International Stormwater BMP Database (*bmpdatabase.org*), and other sources such as in-depth academic dissertations and publications.

As with any BMP, after a proprietary device is installed, care should be taken to ensure proper maintenance, since they are often underground (out-of-sight). When proper maintenance is not conducted, sediment and organic materials captured in the device can become a source of FIB. Similarly, if devices allow resuspension and scouring of sediment, then export of FIB may be an issue.

SHOULD I IMPLEMENT ACTIVE TREATMENT SUCH AS DISINFECTION?

Active disinfection methods include techniques such as UV light irradiation, chlorination, ozonation, paracetic acid, and others. These methods are well documented as effective treatment techniques for sanitary wastewater (sewage); however, they are typically a last resort for treatment of dry and wet weather discharges and are not currently used in Colorado, although some pilot-scale testing has been conducted. The reasons that these methods are typically a last resort include:

- Disinfection does not provide benefits for reducing nutrients and other pollutants that may be associated with bacterial discharges to streams.
- Most urban streams in Colorado include multiple outfalls rather than a single combined major outfall enabling consolidation of treatment facilities in a central facility. (In contrast, most of the active disinfection examples for California beaches enable use of a single facility for a swim beach.)
- Existing outfalls are inherently located in already developed areas, which present space constraints for end-of-pipe treatment. Although disinfection of low flows may be feasible with a relatively compact treatment facility footprint, wet weather treatment facilities require a substantially greater footprint and capital cost due to the need for flow equalization basins.
- Active disinfection requires active operation and management over the long-term with significantly greater costs than passive BMPs. These costs can include electricity, parts replacement, mechanical repairs, vandalism repairs and labor.
- Although disinfection can effectively treat flows for pathogens, the downstream receiving water may not necessarily attain recreational water quality criteria since new sources of FIB (e.g., wildlife, birds) may be introduced following treatment.

For these reasons, when considering use of active treatment, it is generally recommended that source controls should be implemented as a primary stormwater treatment strategy first, followed by carefully selected passive-treatment structural stormwater controls (BMPs). In cases where these practices are not effective and high levels of recreational use are present, disinfection may be a viable alternative, particularly if human sources of *E. coli* have been confirmed and not controlled by other measures.

CAN I DIVERT MY MS4 DISCHARGES TO THE SANITARY SEWER FOR TREATMENT?

In some states, diverting dry weather flows to the sanitary sewer system for treatment has been used as an option for reducing dry-weather *E. coli* loading if such flows cannot be practically or cost-effectively controlled. This approach has been used in more than 125 cases in California for outfalls that discharge to swim beaches. The range of costs for dry-weather diversions reported by the Surfrider Foundation for 35 diversion projects in California funded under the Clean Beaches Initiative (CBI) was $200,000 to $5 million, with a median cost of approximately $750,000.

In Colorado, local governments should anticipate significant obstacles to implementing this approach for the following reasons:

- Legal prohibition of storm discharges to the sanitary sewer system.
- Possible water rights complications related to changing the point of discharge and ambiguity of flow sources.
- Concerns from WWTP operators regarding other difficult-to-treat pollutants such as selenium and arsenic that may be present in groundwater.

These challenges may be more manageable if the MS4 and the WWTP are operated by the same municipality. In cases where a municipality's wastewater is treated by a special district, this option may not be viable. When discussing potential options with WWTPs, it is important to clarify that the flows would be dry-weather discharges rather than stormwater dischargers. (See the Colorado *E. coli* Toolbox for additional considerations.)

WHERE CAN I FIND MORE INFORMATION ON BMP PERFORMANCE FOR FECAL INDICATOR BACTERIA?

For BMP selection, design, installation and maintenance guidance appropriate for Colorado, see:

- *Urban Storm Drainage Criteria Manual, Volume 3*

For more information on stormwater BMP performance see:

- *International Stormwater BMP Database and Summary Statistics*
- *Colorado E. coli Toolbox: A Practical Guide for Colorado MS4s*
- *Pathogens in Urban Stormwater Systems*

For more information on approaches to identify (and remove) bacteria sources from the MS4, see:

- *Stormwater Effects Handbook: A Tool Box for Watershed Managers, Scientists, and Engineers*
- *Illicit Discharge Detection and Elimination: A Guidance Manual for Program Development and Technical Assessments*
- *The California Microbial Source Identification Manual: A Tiered Approach to Identifying Fecal Pollution Sources to Beaches*

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