9954 Mayland Drive
Suite 2400
Richmond
Virginia 23233
Tel 804 740 0181
Fax 804 217 8292

MEMO

To:
Scott Smedley
Director of Environmental Engineering

Copies:
Tom Gallo, Kristian Doerken, Noelle Slater, Peter Yakimowich

From:
Fernando Pasquel
Roger Hart

Date:
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ARCADIS Project No.:
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Subject:
Chesapeake Bay TMDL Stormwater Capital Improvement Projects

This memorandum presents the preliminary conceptual capital cost estimates for stormwater projects recommended to be included in the County Capital Improvement Program (CIP) from fiscal year (FY) 2015 through FY 2030. These stormwater retrofit projects are aligned with the County's Municipal Separate Stormwater System (MS4) permit requirements to meet the conditions of the Chesapeake Bay Total Maximum Daily Load (TMDL). The Chesapeake Bay TMDL includes mandatory MS4 load reductions for nitrogen, phosphorus, and total suspended solids to be implemented over three permit cycles. Each permit cycle lasts 5 years. The County's first MS4 permit cycle is scheduled to begin with permit issuance in 2014.

1. CAPITAL COST ESTIMATES

The estimated range of capital improvement costs to meet the required pollutant load reductions associated with the Chesapeake Bay TMDL for all three permit cycles is between approximately $90M - $150M for all scenarios. Narrower ranges of costs could be identified based on the selection of the most feasible scenarios. The selection of scenarios will evolve as the MS4 permit is finalized and the Compliance Plan is completed and implemented.

Successfully implementing the recommend projects and restoring/dredging Falling Creek Reservoir with load reduction credits approved by Virginia Department of Environmental Quality (DEQ) will result in a range of cost estimates between $90M - $110M.

The methodology and supporting analysis for the capital cost estimates is provided below.

2. METHODOLOGY

The methodology for estimating capital costs was based on a multi-step process that included:

- Estimating the **required load reductions** for total nitrogen, total phosphorus, and total suspended solids based on the targets in the draft MS4 permit;
- Identifying best management practices (BMPs) and developing estimated load reductions based on **selected BMPs** with DEQ approved and/or estimated unit removal efficiencies and costs.
- Generating **alternative compliance scenarios** with varying mixes of BMPs that comply with the TMDL load reductions and estimating their associated capital costs.

2.1 Required Load Reductions

MS4 Area. The required load reductions are based on the size and extent of the regulated MS4 as of June 30th, 2009. Regulated areas within the MS4 include both pervious and impervious land cover, each with different pollutant loads. DEQ has indicated that Phase I MS4 permittees, including Chesterfield County, may use the census designated urbanized areas and jurisdictional boundaries as a conservative estimate of the area of the MS4. According to DEQ, the MS4 may also exclude:

(1) Forested lands
(2) Lands regulated under the Industrial Stormwater General Permit (ISGP).
(3) Lands regulated under another MS4 permit (*i.e.* Virginia Department of Transportation [VDOT] right-of-ways)

Using the 2010 census urban areas within Chesterfield County and excluding forested lands and VDOT right-of-ways (which are regulated under a separate MS4 permit) the estimated* size and extent of the County MS4 includes approximately:

- 14,000 acres of regulated urban impervious area and
- 52,288 acres regulated urban pervious area.

Loading Rates and Load Reductions. The required load reductions are also based on the per acre loading and removal rates specified in the Chesterfield County draft MS4 permit which includes the assumptions and specifications presented in **Table 1**. The calculated required load reductions for each regulated land use in the first permit cycle are presented in **Table 2**, while the overall required load reductions for each permit cycle are presented in **Table 3** below.

* A more accurate estimate of the size of the County MS4 will be prepared as soon as the mapping of stormwater outfalls is completed and will likely result in smaller regulated acreages. Therefore, the current estimate is conservative and reasonable for the purpose of the cost estimate.

Table 1: Chesterfield County MS4 Permit

Pollutant	Subsource	Loading Rate [lbs/ac/yr]	First Permit Cycle Load Reduction (5% of total) [lbs/ac/yr]
Nitrogen	Regulated Urban Impervious	9.39	0.04
	Regulated Urban Pervious	6.99	0.02
Phosphorus	Regulated Urban Impervious	1.76	0.01
	Regulated Urban Pervious	0.5	0.002
Total Suspended Solids	Regulated Urban Impervious	676.94	6.67
	Regulated Urban Pervious	101.08	0.44

Table 2: Calculations for Determining Total Pollutant Reductions Required During the First Permit Cycle

Pollutant	Subsource	Total Existing Acres Served by MS4 (6/30/09)	First Permit Cycle Required Reduction in Loading Rate [lbs/acre/year]	Total Reduction Required First Permit Cycle [lbs/year]
Nitrogen	Regulated Urban Impervious	14,000	0.04	560
	Regulated Urban Pervious	52,288	0.02	1,046
Phosphorus	Regulated Urban Impervious	14,000	0.01	140
	Regulated Urban Pervious	52,288	0.002	105
Total Suspended Solids	Regulated Urban Impervious	14,000	6.67	93,380
	Regulated Urban Pervious	52,288	0.44	23,007

Table 3: Permit Cycle and Target Pollutant Reductions (lbs)

Permit Cycle	1	2	3	Total Reduction
Percent Removal Requirement / Pollutant	5%	35%	60%	
Nitrogen	1,606	11,240	19,269	32,115
Phosphorus	245	1,712	2,935	4,892
Total Suspended Sediment	116,387	814,707	1,396,640	2,327,734

2.2 Selected BMPs

A list of stormwater BMPs applicable to the County MS4 area was compiled from published studies and reports and based on previous ARCADIS staff studies and experience. Standard unit treatment efficiencies for Nitrogen, Phosphorus, and TSS as well as unit capital costs (generally including design, permitting, planning, and construction costs) were compiled into **Table 4** using four primary sources of information:

1) Center for Watershed Protection (CWP) 2007. *Urban Stormwater Retrofit Practices, Version 1.0.* Urban Subwatershed Restoration Manual Series - Manual 3. August, 2007.

2) CWP, 2013. *Cost-Effectiveness Study of Urban Stormwater BMPs in the James River Basin (Revised)*. June 2013.

3) King and Hagan, 2011. *Costs of Stormwater Management Practices in Maryland Counties*. University of Maryland Center for Environmental Science. [UMCES] CBL 11-043. October 10, 2011.

4) Virginia Department of Environmental Quality (DEQ), 2013. *Draft TMDL Action Plan Guidance Document (Version 3)*. November, 2013.

Twelve types of BMPs were selected for inclusion in the analysis (**Table 4**), of which ten are approved by DEQ and/or the Chesapeake Bay Program through, in most cases, the Virginia Stormwater BMP Clearinghouse or Expert Panel Reports. This Technical Memorandum describes the status of these BMPs as “Approved by the Chesapeake Bay Program”. The remaining two were based on planning-level estimates derived using a combination of published values, reasonable assumptions, and professional judgment. Where applicable, published unit costs for each of the selected BMPs were adjusted to 2013 dollar values at an annual compound rate of 3%.

Table 4: Selected BMP Unit Treatment Efficiencies and Unit Costs

BMP Type	Status	Unit Size		Unit Capital Cost [$ / basis unit]	Cost Effectiveness [$/lb removed]			Notes	Source
		Basis	Unit		TN	TP	TSS		
Bioswale	Approved	EIA	ac	46,680	8,895	81,241	262	Average Cost (inflated from $2011), O&M Excluded	King and Hagan, 2011
BMP Outfalls	Approved	EIA	ac	17,403	6,109	45,890	137	Average Cost (inflated from $2006), O&M Excluded, (average of wetlands and bioretention pond)	CWP, 2007
Dredging	Potentially allowable based on interpretation of TMDL implementation guidance document	Vol	cu ft	3.704	1,955	1,754	1.37	Assumed $70/cy dredge, haul and dispose (not HTRW) + $30/cy planning and permitting	Preliminary estimate based on assumptions and professional judgement
Dry Detention Ponds	Approved	EIA	ac	46,680	124,531	609,305	2,096	Average Cost (inflated from $2011), O&M Excluded	King and Hagan, 2011
Filterra	Approved (Proprietary)	EIA	ac	32,000	10,163	69,616	169	Average Cost from Filterra Presenation Available on Internet	Inferred from Filterra Website
Rainwater Harvesting	Approved	IA	ac	74,057	10,976	107,407	--	based on 75$/barrel, 50% treatment	Preliminary estimate based on assumptions and professional judgement
Urban Stream Restoration (recommended interim efficiencies)	Approved	Len	ft	684	3,421	10,063	13	Average Cost (inflated from $2011), O&M Excluded	King and Hagan, 2011
Urban Tree Planting	Approved	IA	ac	35,010	14,587	27,785	61	Average Cost (inflated from $2011), O&M Excluded	King and Hagan, 2011
Wet Pond 1 (Coastal Plain)	Approved	EIA	ac	44,965	23,992	130,429	337	Average Cost (inflated from $2011), O&M Excluded	King and Hagan, 2011
Wet Pond 2 (Coastal Plain)	Approved	EIA	ac	44,965	19,993	90,297	337	Average Cost (inflated from $2011), O&M Excluded	King and Hagan, 2011
Wet Ponds and Wetlands	Approved	EIA	ac	19,112	12,747	55,438	143	50th percentile capital costs (inflated from $2006) + 40% design and permitting costs, O&M excluded	CWP, 2007
Wetlands (retrofit)	CBP panel recommendations approved by Water Quality Goal Implementation Team	EIA	ac	19,112	10,197	62,368	168	50th percentile capital costs (inflated from $2006) + 40% design and permitting costs, O&M excluded	CWP, 2007

Assumptions:

- 3% inflation rate to normalize costs to 2013 dollars.

Basis Acronyms

EIA = equivalent impervious area = (0.368 x Pervious acreage) + (1.0 x Impervious acreage).
[Based on the assumption that the runoff from 1 pervious acre is equivalent to the runoff from 0.368 impervious acres using runoff coefficients of 0.95 for impervious areas and 0.35 for pervious areas]
IA = impervious area
Vol = volume of wet bottom sediments
Len = stream length

Units

ac = acres
cu ft = cubic feet
cft = feet

2.3 Alternative Scenarios

Three alternative scenarios groups were developed in order to estimate a reasonable range of costs for the CIP projects required to meet the estimated TMDL pollutant load reductions requirements associated with MS4 permit. Each scenario included Baseline BMPs and differing mixes of primary, secondary and tertiary BMPs as described below.

Baseline BMPs

Each of the scenarios includes costs and pollutant reductions associated with the following baseline BMPs:

- Existing BMPs completed and/or certified after June 30th, 2009,
- Planned BMPs recommended through CIP projects (FY15 – FY19) to be implemented during the first permit cycle

Existing and planned BMPs (Baseline BMPs) allow the County to comply with the load reduction requirements in the **first permit cycle**. The Baseline BMP load reductions were included in each of the three alternative scenarios and are summarized in **Table 5**.

Existing BMPs are currently tracked in the County's StormWater InFormation Tracking (SWIFT) database. As of October 2013, there were 86 BMPs entered into SWIFT that were completed and/or certified after June 30th, 2009. Of the 86 BMPs, 65 have sufficient information to estimate associated pollutant load reductions (Table 5, Category: SWIFT). Although the remaining 21 BMPs in SWIFT will have associated pollutant load reductions, their exclusion from the analysis due to data gaps (*e.g.* contributing drainage area) is conservative and acceptable for deriving planning-level CIP cost estimates. Similarly, there are also 14 recent BMPs (Table 5, Category: NEW) that have not yet been entered into SWIFT that are owned or maintained by the County and are located at eight public schools and on one home-owners association common area.

Planned BMPs submitted in the FY2015 CIP include six identified projects and six generalized projects as documented in the ARCADIS technical memorandum submitted to the County on December 11, 2013.

Table 5: Baseline BMPs

Status	Category	N	P	TSS	Future Capital Cost
Existing BMPs	SWIFT	1,540 (4.8%)	371 (7.6%)	90,036 (3.9%)	N/A
	NEW	107 (0.3%)	17 (0.3%)	3,933 (0.2%)	N/A
Planned BMPs Included in CIP (FY 2015-19)	Identified	1,124 (3.5%)	284 (5.8%)	187,376 (8.0%)	4,100,000
	Generalized	2,268 (7.1%)	696 (14.2%)	538,385 (23.1%)	4,600,000
Total		5,038 (15.7%)	1,368 (28%)	819,729 (35.2%)	8,700,000

Scenario Development

Three alternative scenarios were developed to estimate a planning-level range of CIP project costs required to meet the load reduction requirements over the **second and third permit cycles** following the implementation of the Baseline BMPs, described above, during the **first permit cycle**. These three alternative scenarios included differing mixes of the following BMPs:

- Primary BMPs – Stream Restoration
- Secondary BMPs – Lake Restoration (New Retrofit)
- Tertiary BMPs – Various combinations of BMPs that include Stormwater Outfall BMPs (e.g., sheetflow to vegetated filter), Green Streets, Bioswales (e.g., bioretention, infiltration, swales, filtering practices), Pond Retrofits (e.g., BMP conversions and enhancements), Tree Planting, and Rain Barrels.

The alternative scenarios were based on selecting a mix of capital improvement BMPs (*i.e.* projects with a structural and/or construction component) grouped by the proportion of primary, secondary and tertiary BMPs used to meet the required load reductions. These scenarios are presented in **Table 6**.

Based on available data, the required nitrogen load reductions are anticipated to be the most costly stormwater pollutant to meet over the three permit cycles. Therefore, the primary, secondary and tertiary BMPs were selected based on their efficacy at reducing nitrogen and regulatory acceptance.

Primary BMP – Stream Restoration

Stream restoration was selected as the primary BMP used to meet load reductions for two reasons – it is the second-most cost-effective of the selected BMPs (particularly for nitrogen, see Table 4) and it is approved by USEPA and DEQ (DEQ, 2013). Scenarioss1, 2, and 3 (**Table 6**) included a total of 11 miles, 14 miles, and 17 miles of stream restoration projects, respectively. The 11 miles, 14 miles, and 17 miles of stream restoration projects correspond to meeting 40%, 50% and 60%, respectively, of the total required nitrogen load reduction through the end of the third permit cycle (estimated to be 32,115 lbs nitrogen per year).

There are approximately 1,100 miles of streams in the County that include approximately 210 miles of impaired streams. There are also a total of approximately 340 miles of third and lower order* stream in Chesterfield County, of which 28 miles are on County-owned lands. Given that the County may control more areas through easements and the precedent for public/private partnership stream restoration projects in the County, the upper limit of 17 miles of stream restoration projects appears reasonable. The lower limit of 11 miles of stream restoration projects may be the minimum required as less than this

* Third and lower order streams are typically used for stream restoration projects when claiming credit for pollutant load reductions. Zero order streams are ephemeral and intermittent streams segments. First order streams are perennial stream segments with no perennial tributaries. Second and higher order streams are stream segments that begin at the confluence of two stream segments of the next lower order (i.e. two first order streams combine into a second order stream, two second order streams combine into a third order stream, etc.).

threshold may significantly increase required costs because other evaluated BMP technologies are currently less cost effective with respect to pollutant removal, particularly nitrogen.

Table 6: Alternative Scenarios and Results

Scenario		Primary BMP[1]	Secondary BMP[2]	Tertiary Generalized BMP[3]	CIP Cost[4]	Notes
1	A	Stream Restoration (11 Miles) *Provides 40% of Nitrogen Reduction Requirement*	2ft Dredge	Outfall BMPs, Green Streets	$89,000,000	$10 million of Tertiary Generalized BMPs
	B		1ft Dredge	Outfall BMPs, Green Streets, Bioswales	$120,000,000	$57 million of Tertiary Generalized BMPs
	C		0ft Dredge	Outfall BMPs, Green Streets, Bioswales, Pond Retrofits, Tree Planting, Rain Barrels	$150,000,000 +	Does not achieve total compliance at $150,000,000 with only 91% achievement on nitrogen
2	A	Stream Restoration (14 Miles) *Provides 50% of Nitrogen Reduction Requirement*	1.9ft Dredge	None Needed	$90,000,000	1.9 feet of dredging. No need for Tertiary Generalized BMPs
	B		1ft Dredge	Outfall BMPs, Green Streets, Bioswales	$108,000,000	$31 million on Tertiary Generalized BMPs
	C		0ft Dredge	Outfall BMPs, Green Streets, Bioswales, Pond Retrofits, Tree Planting	$150,000,000	$99 million on Tertiary Generalized BMPs
3	A	Stream Restoration (17 Miles) *Provides 60% of Nitrogen Reduction Requirement*	1.6ft Dredge	None Needed	$98,000,000	1.6 feet of dredging. No need for Tertiary Generalized BMPs
	B		1ft Dredge	Outfall BMPs, Green Streets	$106,000,000	$17 million on Tertiary Generalized BMPs
	C		0ft Dredge	Outfall BMPs, Green Streets, Bioswales, Pond Retrofits	$146,000,000	$71 million on Tertiary Generalized BMPs

Notes:

1 *Primary BMP: stream restoration projects*

2 *Secondary BMP: Lake restoration / dredging of Falling Creek Reservoir*

3 *Tertiary BMP: various BMP technologies defined in* ***Table 7*** *and required to achieve compliance through the end of the third permit cycle*

4 *CIP Costs include:*

- *Assumed no future CIP costs for baseline projects constructed and/or accredited on or after July 1, 2009 (based on information in the SWIFT database and information provided by County Staff).*
- *Proposed FY2015 - FY2019 CIP projects ($8.7M) to complete first permit cycle requirements*
- *25% Contingency on 2nd and 3rd permit cycle projects*

Secondary BMP – Lake Restoration (New Retrofit)

The Falling Creek Watershed has a drainage area of approximately 34,000 acres. The restoration of Falling Creek Reservoir (91 acres) through a series of retrofit techniques (*e.g.*, major sediment cleanouts/dredging, aeration, forebay creation, wetland restoration, bank restoration, etc.) was selected as the secondary BMP used to meet required load reductions since it is estimated to be a cost effective BMP. Based on discussions with County staff, the Falling Creek Reservoir has not been previously reported to DCR or DEQ as a BMP and its drainage area includes portions of the County that were developed before there were any stormwater management requirements.

Cost estimates for dredging were based on costs for a dredging a similar reservoir in Virginia Beach ($70/cubic yard [cy] wet sediment) and general industry averages ($50-$150/cy). For the purposes of the cost estimation, it was assumed that the sediments would be:

- Dewatered or decanted onsite prior to hauling,
- Suitable for general land disposal (*i.e.* the sediments do not contain sufficient levels of hazardous, toxic, or radioactive waste to require special landfilling), and
- Hauled over a short distance (less than 10 miles).

A cost of $30/cy was added to the cost estimate to include planning, design, and permitting of the project for a total of $100/cy of sediment dredging. The evaluation, feasibility and recommendation of retrofit enhancements, that provide a higher level of treatment, such as sediment forebays, aeration systems, bank restoration, and constructed wetland benches, will be included in a Preliminary Engineering Report that will be initiated in 2014. This Report will also include coordination with DEQ to establish the final restoration design, removal efficiencies, and pollutant load reductions.

The load reduction credits associated with lake restoration were based on the assumption that, from a regulatory perspective, the dredging would not be considered routine maintenance and that the volume of the reservoir would be increased to accommodate further settling of sediments and nutrients, thus providing incremental treatment and transforming the silted reservoir into a BMP. The initial credit would be the mass removed applied over the fifteen year permit cycle. The concentration of pollutants (*e.g.* nitrogen, phosphorus, and sediments) in a cubic yard of (wet) sediment at the lake bottom was estimated as follows:

- Dry bulk density = 0.65 kg dry sediment / L of wet bottom sediments (Sekellick, et al., 2013)
- Total Nitrogen = 700 mg N / kg dry sediment (USGS, 2013)
- Total Phosphorus = 780 mg/kg P / kg dry sediment (USGS, 2013)

The concentration assumptions are estimates based on available data and will be refined in the upcoming Preliminary Engineering Report to more accurately quantify the pollutant load reductions associated with this BMP.

Each of the scenarios (1, 2, and 3) presented in **Table 6** was further subdivided into three sub-scenarios: A, B, and C. These sub-scenarios (A, B, and C) correspond to dredging approximately 2ft, 1ft and 0ft of bottom sediments from Falling Creek Reservoir, respectively. Having sub-scenarios with different levels of dredging provides information for the selection of other BMPs that would need to be implemented as well as flexibility in the implementation.

Tertiary BMPs

The total required pollutant load reductions not accomplished by the baseline, primary, and secondary BMPs were met by the addition of tertiary BMPs as shown in **Table 6**. Tertiary BMPs consisted of a mix of the various BMP technologies presented in **Table 7**.

The potential maximum amount of treatable acres available in the County was estimated for each tertiary BMP based on the rationale/assumptions presented in **Table 7**. The rationale/assumptions were based on estimates of the acreage where each tertiary BMP type could be readily implemented within the County. Tertiary BMP technologies were added in the order presented in **Table 7** to each alternative scenario to meet the remaining required pollutant reductions.

Table 7: Tertiary BMP Assumptions and Ceilings

Tertiary BMP Type	Estimated Upper Limit of Treatable Acres	Basis	Rationale / Assumptions
Outfall BMPs (e.g., sheetflow to vegetated filter)	1,800	GIS analysis	Residential Areas within 100 ft of a stream outfall with a drainage area less than 10 acres
Green Streets	250	Professional judgment. Assumption on a reasonable amount of roads	10 miles of streets 20 feet wide with some other contributing area
Bioswales (e.g., bioretention, infiltration, swales, filtering practices)	650	Professional judgment following a brief review of typical strip mall parking lots in the County	Retrofit 15 to 30 strip mall parking lot areas that are 90% imperviousness.
Pond Retrofits (e.g., BMP conversions and enhancements)	2,000	Professional judgment and reasonable assumptions	Retrofit existing dry ponds in older highly impervious areas (e.g. malls). Midlothian has about 200 acres, would need the equivalent of about 10 more similarly sized areas. 80% impervious.
Urban Tree Planting	100	Professional judgment and reasonable assumptions	10,000 trees; 100 trees planted = 1 acre treated
Rain Barrels	10	Professional judgment and reasonable assumptions	5,000 barrels supplied through a County program over 10 years;

3. RESULTS

The results of the analysis are as follows:

- The resulting costs estimated by the methodology presented in the previous Section for all scenarios ranged from $89 M to over $150 M (**Table 6**).

- The most cost effective scenarios (1A and 2A) include lake restoration, and stream restoration as the primary BMPs. Scenario 1A includes a small amount of less cost effective tertiary BMPs to meet the required nitrogen load reductions. Scenario 2A includes no contribution from tertiary BMPs.

- The least cost effective scenarios (1C, 2C, and 3C) did not include lake restoration. If lake restoration is not used as a BMP, the County will need at least 14 miles of stream restoration and a mix of tertiary BMPs to meet the required nitrogen load reductions.

4. RECOMMENDATIONS

The following recommendations were made based on the results and conclusions of the cost estimation analysis:

- Given the importance of lake restoration outlined by the present evaluation, the County has directed ARCADIS to complete the Preliminary Engineering Report in 2014. This Report will refine the pollutant load reduction estimates, the retrofit techniques, permitting, and the Opinion of Probable Construction Cost (OPCC).

- Operation and maintenance costs can be significant and vary between BMPs. These operating costs will be evaluated and presented as part of the Draft Compliance Plan currently being developed by ARCADIS. It is also important to note that the Primary and Secondary BMP's recommended in the previous sections have lower operations and maintenance costs than other BMPs evaluated.

- Nutrient trading was not considered in this evaluation. While nutrient trading may offer a cost-effective (but likely temporary) compliance alternative for meeting nitrogen load reductions; a regulatory-approved framework for trading has not been established for stormwater. The County should continue to track the evolution of trading alternatives and their potential applicability in future permit cycles.

- A dedicated funding source such as the proposed Stormwater Service District will provide the funds needed to comply with the regulatory requirements.

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