Final Hydrologic and Hydraulic Design Report
D0103030109 and D0103030110

Submitted To:

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1. INTRODUCTION

1.1. Project Description

This report details the basis for final stormwater design for the addition of a second Midtown Tunnel and extension of Martin Luther King (MLK) Expressway with a connection to Interstate 264 in Norfolk and Portsmouth, Virginia. The intention of this stormwater report and associated drainage plans is to provide drainage analysis and design for the purpose of pricing, final right-of-way acquisition and construction. Provided herein are the following:

- Drainage criteria
- Summary of the methodology for stormwater design on the Project
- Stormwater management pre-final plan
- Stormwater management calculations
- Discussion of major stormwater issues on the Project
- Culvert calculations

The purpose of this report is to analyze the stormwater management design of the project area and determine necessary measures to comply with Virginia Department of Conservation and Recreation (DCR) and Virginia Department of Transportation (VDOT) requirements.

2. STORM SEWER

Due to the urban environment in the surrounding area, the primary method of storm water conveyance on the Project is storm sewer, ditches and culverts. The storm sewer is designed per the drainage criteria, located in Appendix A, and VDOT Drainage Manual (Revised September 2011). All storm sewers on primary roadways are designed to the twenty-five year rainfall event and storm sewers on local streets are designed for the ten year rainfall event. In the case that one continuous storm drain system is located on primary roads and local streets, the higher storm event governs.

Stormwater runoff from the boat sections of the Midtown Tunnel is conveyed through modified inlets and ductile iron storm sewer to a pump station at either end of the boat section. The pump stations will release this runoff directly to the Elizabeth River. These pump stations are addressed in detail in the Portal Pump Stations Report (Revision 1) dated February 2013.

There are two extremely large existing closed systems within the project limits which are modified as a result of the proposed roadway improvements. The limits of these two existing closed systems extend well beyond the proposed construction and survey limits associated with this project. The following justifications have been prepared to support not developing a comprehensive hydraulic analysis of these systems.

48-inch RCP in King Street (Using Existing Structure 39-18 as the point of analysis)

The existing stormwater flow rate in the existing 48-inch pipe running in King Street is not expected to increase after completion of the proposed roadway project due to the following reasons:

1. In the existing condition, stormwater runoff from the section of Harbor Drive, approximately between Stations 1034+00 and 1039+50, is collected and conveyed via a storm sewer system

to the existing 48-inch pipe in King Street. However, in the proposed system, runoff from the proposed MLK Expressway section between approximately Stations 1034+00 to 1039+50 will be collected, routed through proposed Pond 25 before it is discharged back into the 48-inch pipe.

2. No new drainage contributory area has been added to the existing drainage area of the 48-inch pipe in King Street.

3. The Turnpike Road project will remove a significant contributory area from the existing 42-inch line from the former Cassel Avenue, which will remain connected to the existing 48-inch culvert in King Street.

36-inch RCP north of London Boulevard (using Existing Structure 50-9 as the point of analysis)

The existing stormwater flow rate in the existing 36-inch pipe that runs parallel to MLK Expressway and drains towards the north is not expected to increase after completion of the proposed roadway project due to the following reasons:

1. In the existing condition, the 36-inch pipe collects runoff from Ramp A, runoff from portions of the Ramp B infield area collected via existing structures 46-5 and 46-7, and the section of the existing MLK Expressway between approximately stations 1046+00 and 1056+00. The 36-inch storm pipe eventually discharges into an existing 7' x 6' box culvert at structures 50-6, 50-9 and via structure 50-13. In the proposed system, the 36-inch pipe continues to receive runoff from Ramp A and the section of the existing MLK Expressway between approximately stations 1046+00 and 1056+00. However runoff the Ramp B infield area, in the proposed condition, will be collected and routed through Pond 30 prior to discharge into the 7'x6' box culvert.

2. No new drainage contributory area has been added to the existing drainage area of the 36-inch pipe.

Stormwater runoff from the proposed bridges on MLK Expressway and ramps has been designed per the drainage criteria and VDOT Bridge Manual, Volume V – Part 2, Chapter 22. All bridge drainage is being conveyed through storm drain systems on the structures to central drop points at bridge supports. The runoff is then either dropped directly into stormwater management facilities or directed through underground storm sewer to outfalls in nearby stormwater management facilities or ditches.

3. DITCHES

Proposed ditches are located along the existing Interstate 264 corridor and both proposed tunnel approaches. Ditches are designed to convey the ten year storm and checked for stability with the two year storm, per the drainage criteria and VDOT Drainage Manual (Revised September 2011). A few ditches along MLK have also been designed to convey the twenty-five year storm. Ditches with high velocity flows require protection either using EC-2 matting, EC-3 matting or concrete depending on design velocities. Ditch calculations are located in Appendix G and ditch protection is shown on the Erosion and Sediment Control Plans.

4. STORMWATER MANAGEMENT

The Stormwater Management design has been undertaken from a project wide perspective. Since there is lack of available right-of-way around the Midtown Tunnel on both the Norfolk and Portsmouth sides, water quality mitigation for these areas will be achieved through overtreatment in areas around the MLK extension and Interstate 264 Interchange. *Table 1* provides the pre- and post-development land use for the entire project by outfall. Total project area includes offsite contributing areas treated by Stormwater Management Facilities (SWMFs).

Outfalls	Pre-development C factor	Area (Ac)	Post-development C factor	Area (Ac)
Basin 5	0.52	5.55	0.67	5.55
Pond 7	0.47	3.41	0.68	3.41
Ramp C Basin	0.70	0.71	0.83	0.71
Ramp EN Basin	0.52	0.87	0.72	0.87
Pond 8	0.49	4.96	0.61	4.96
Pond 14	0.43	11.28	0.63	11.28
Pond 19	0.79	21.90	0.84	21.90
Pond 20	0.49	38.54	0.54	38.54
Pond 24	0.85	7.70	0.89	7.70
Pond 25	0.70	6.00	0.67	6.00
Pond 30	0.52	12.60	0.62	12.60
MTT Norfolk	0.70	17.15	0.80	17.15
MTT Portsmouth	0.85	14.82	0.86	14.82
Total Project	**0.63**	**145.49**	**0.70**	**145.49**

Table 1 – Overall Pre- and Post-Development Land Use

The drainage outfalls adjacent to the Midtown Tunnel convey directly to the Elizabeth River. Thus, the channel is deemed to be adequate in regards to any additional flow from increased impervious area from the proposed Project.

Existing drainage patterns have been maintained in the proposed design, with runoff being mitigated using SWMFs including detention and retention ponds to meet water quality and quantity requirements. In some areas, stormwater runoff has been mitigated for more than just the additional runoff that is being generated by the Project to help lower flows into existing undersized storm sewer systems. *Table 2* presents the pre- and post-development flows for all SWMFs on this Project. In every scenario, the post-development flows are significantly lower than the pre-development flows thus existing outfalls are considered adequate.

BMP	PRE-DEV 2-YR (cfs)	POST-DEV 2-YR (cfs)	PRE-DEV 25-YR (cfs)	POST-DEV 25-YR (cfs)	PRE-DEV 100-YR (cfs)	POST-DEV 100-YR (cfs)
Basin 5	14.63	3.82	22.50	8.06	32.20	11.88
Pond 7	7.49	3.23	12.73	5.11	19.57	7.08
Pond 8	8.27	1.07	13.39	3.71	19.52	8.92
Pond 14	14.08	0.15	26.09	0.23	33.35	0.26
Pond 19	18.77	12.20	36.15	26.92	72.95	35.83
Pond 20	34.56	2.82	66.58	24.03	107.15	47.66
Pond 24	38.30	0.14	57.20	0.17	82.35	0.22
Pond 25	13.35	1.05	19.16	2.18	27.84	3.03
Pond 30	25.21	0.18	47.29	0.21	67.67	0.26
Ramp C Basin	2.79	0.22	3.81	1.52	6.02	2.55
Ramp EN Basin	2.95	0.26	4.45	3.29	6.36	4.67

Table 2 – Pre- and Post-Development Flows for Stormwater Management Facilities

Existing systems have been identified that are undersized for the existing conditions and are prone to flooding. The first example is a thirty inch trunk line under Frederick Boulevard, which runs in a southeast direction from the Frederick Boulevard, Interstate 264 Interchange and eventually outfalls near Elliot Avenue. Another example of an undersized existing system is an existing thirty inch culvert that crosses Interstate 264 at station 1446+45. Calculations for the existing and proposed scenarios are located in Appendix H – Existing Culvert Analysis

4.1. Existing 30” Culvert under Interstate 264

An area of concern is an undersized existing thirty inch culvert under Interstate 264 at around station 1446+45 (shown in *Figure 1*) that conveys significant existing drainage area from the graveyard as well as stormwater from Pond 14, across the Interstate from south to north. Pond 14 has been sized large enough to mitigate increased flows from the additional impervious area as well as to mitigate the existing flows. Still, the existing thirty inch culvert has been determined to be inadequate. As a result, an additional thirty inch reinforced concrete pipe is proposed to be jacked under I-264 alongside the existing thirty inch culvert.

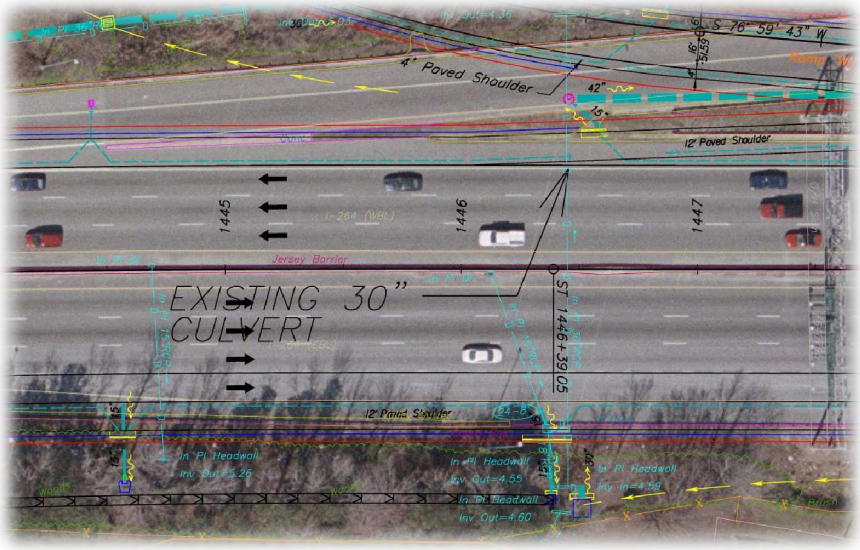


Figure 1 - Existing 30" Culvert under I-264

4.2. Frederick Boulevard/I-264 Intersection

This Project has taken great measures to assure the Frederick Boulevard area is not negatively impacted by proposed improvements. Drainage from proposed MLK Expressway Ramp EN has been directed to an existing dry detention basin (proposed Pond 7) located on the south side of I-264 at station 1404+00. To reach the detention basin, a storm sewer pipe will be jack and bored underneath an existing I-264 ramp. The existing dry detention has been modified to accommodate the additional area so that the basin continues to function correctly and contain the 100-year storm with 1' of freeboard. The proposed design is shown below in *Figure 2*.

Figure 2 – Expanded Existing Dry Detention Pond

Also, two small detention basins have been added near the intersection to minimize discharge into the existing 30” storm sewer system in Frederick Boulevard. Upstream of this Project, VDOT recently constructed two detention ponds to reduce the potential and frequency of flooding in the interchange. The combination of all these detention ponds reduces the post-development flows to less than pre-development flows. The proposed design is shown below in *Figure 3.*

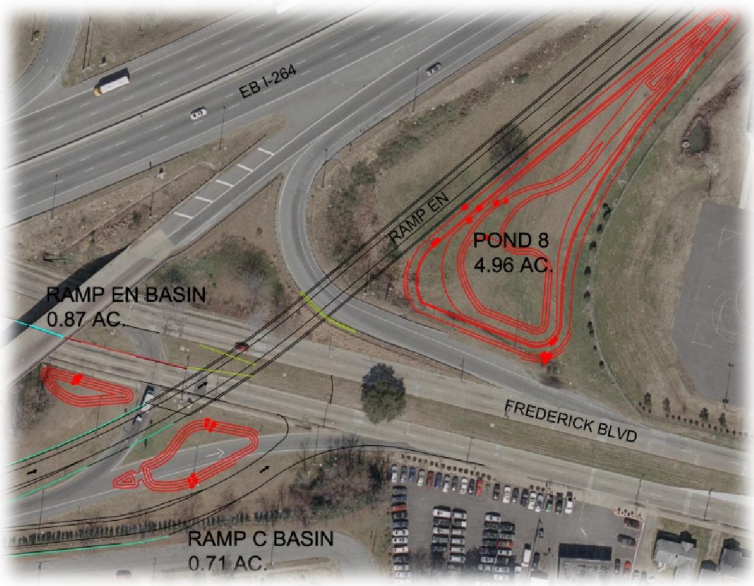


Figure 3 - Frederick Blvd Intersection

4.3. 36” Culvert under Interstate 264

The second culvert under Interstate 264 is a thirty-six inch reinforced concrete pipe located at station 1452+50 and is shown in *Figure 4*. This culvert is actually part of a storm sewer system which conveys stormwater from a large drainage area to the south of the Project. The calculations for this pipe are found in Appendix H – Existing Culvert Analysis. The Project is not adding to the runoff in this system, and although inadequate for existing flows, upgrading this culvert would lead to negative effects on the north side of I-264.

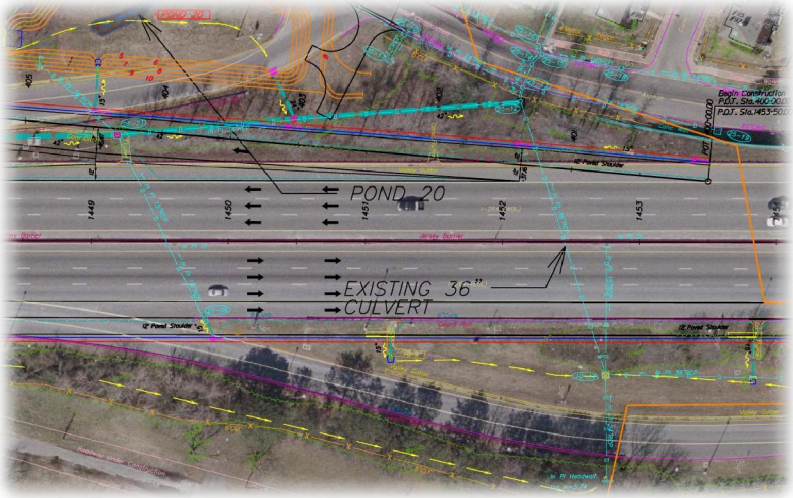


Figure 4 - Existing 36" Culvert under I-264

4.4. Proposed Box Culverts – Turnpike Road Project

VDOT’s proposed Turnpike Road Improvement Project may be constructed concurrently with the MLK Expressway. As part of the VDOT project’s design a proposed double six-foot by five-foot box culvert will be placed along Turnpike Road, and connected to the existing double box culvert to the east in Constitution Avenue. The outfall of Pond 24 will be connected to this box culvert and eventually to the outfall located north of London Boulevard at Chesapeake Avenue.

Delineations for each drainage basin of the Project are presented in Appendix C – Drainage Area Maps.

5. STORMWATER MANAGEMENT FACILITIES

Stormwater Management Facilities proposed on the Project include detention and retention ponds. These ponds are located along the MLK Expressway and in the vicinity of the MLK Expressway/Interstate 264 Interchange and are identified on the MLK Roadway Plans. There are seven (7) large stormwater management facilities in this Project; Ponds 14 and 30 are designed as Type III Retention Ponds (wet), Ponds 19, 24, and 25 are designed as Type I Retention Pond (wet), and Ponds 8 and 20 are designed as Extended Detention Ponds (dry). Also, there are four (4) smaller stormwater management facilities in this Project designed as detention basins to aid in lowering stormwater discharges into existing storm sewer systems. Ground water elevations were determined through geotechnical testing, test wells and field observations. *Table 3* provides a summary of the ground water elevations used in the design of each SWMF.

SWMF	Ground Water Elevations (ft)
Basin 5	8.0
Pond 7	8.5
Ramp C Basin	9.0
Ramp EN Basin	8.0
Pond 8	10.0
Pond 14	9.0
Pond 19	8.5
Pond 20	6.5
Pond 24	8.5
Pond 25	5.0
Pond 30	5.0

Table 3 – Ground Water Elevations

All stormwater management facilities comply with the Virginia Stormwater Management Handbook, Volumes 1 and 2, First Edition 1999. Earthen embankments on ponds are designed to Minimum Standard 3.01, sediment forebays are designed to Minimum Standard 3.04, retention ponds are designed to Minimum Standard 3.06 and detention ponds are designed to Minimum Standard 3.07.

Pond 8, presented in *Figure 5*, is a proposed extended detention pond in the southeast quadrant of the Frederick Boulevard and Interstate 264 Interchange. The pond has a total contributing drainage area of 4.96 acres from eastbound lanes of Interstate 264 and proposed Ramp EN. This pond accepts Project flows as well as offsite flows, which contribute to the total water quality requirements of the Project. Stormwater discharge is conveyed from the pond into the existing thirty inch storm sewer system located in westbound Frederick Boulevard.

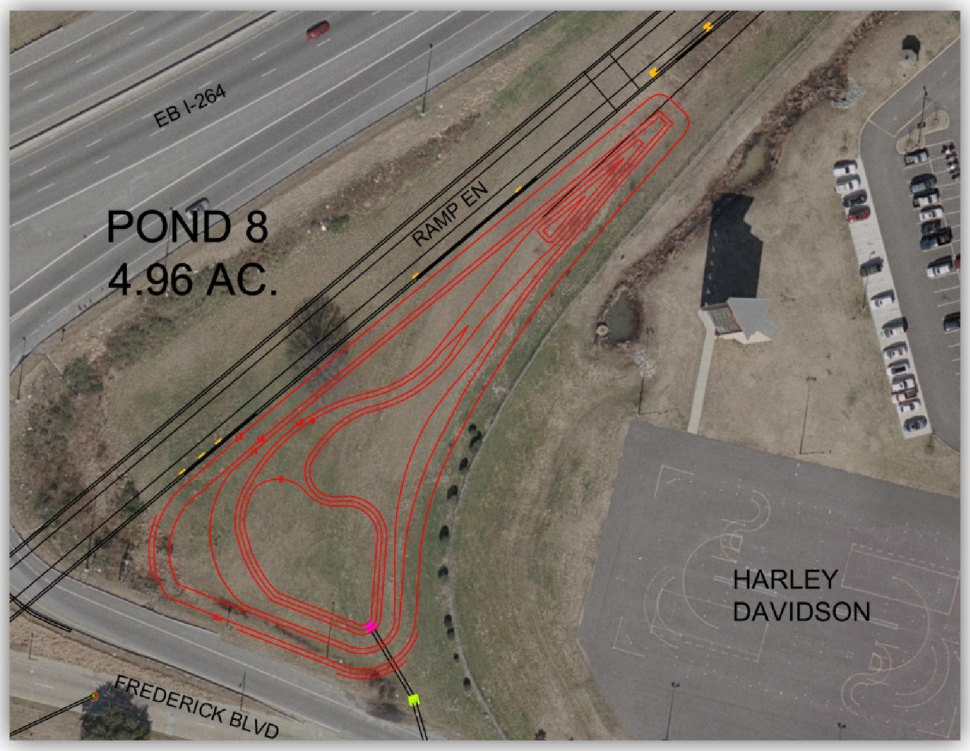


Figure 5 – Proposed Extended Detention Pond 8

Pond 14, presented in *Figure 6*, is located inside Ramp SE and collects 11.28 acres from the eastbound lanes of Interstate 264 and the interchange ramps. This pond accepts Project flows as well as offsite flows, which contribute to the total water quality requirements of the Project. Pond 14 is sized to mitigate increased flows from the additional impervious area as well as mitigate the existing runoff thus reducing the existing peak flow to the undersized downstream storm sewer system. Stormwater is conveyed from the pond, into a ditch on the south side of Interstate 264, under Interstate 264 through a double thirty inch culvert and into Pond 20.

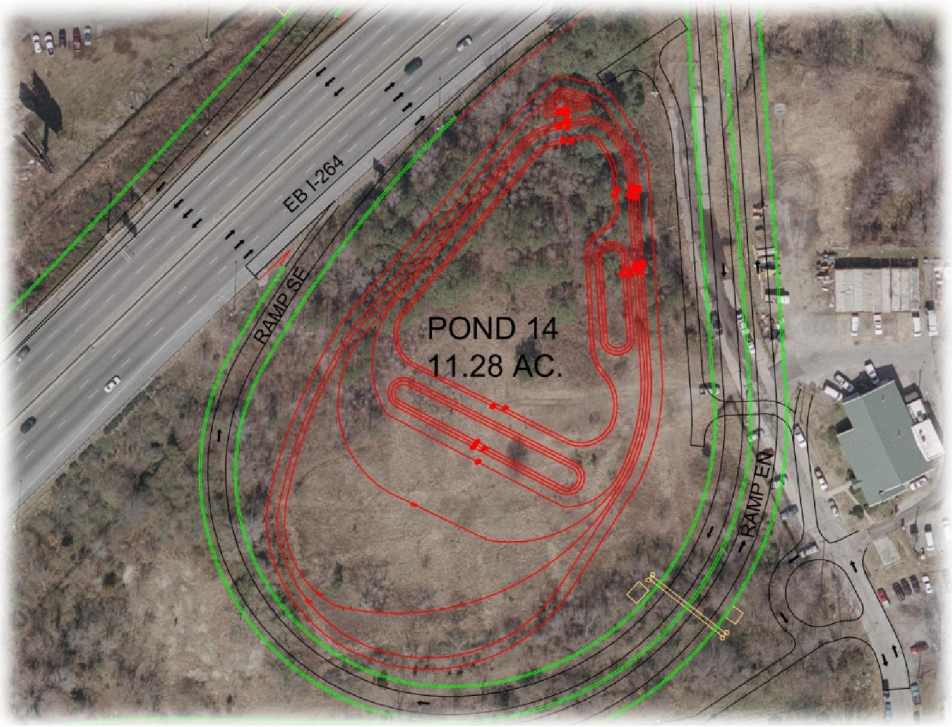


Figure 6 – Proposed Type III Retention Pond 14

Pond 19 is to be located to the east of the MLK Expressway and to the north of Interstate 264. Pond 19 collects 21.90 acres of existing westbound Interstate 264, proposed Ramp NW, and industrial area along Columbus Avenue. This pond is type II retention basin and is presented in *Figure 7*. This pond accepts Project flows as well as offsite flows, which contribute to the total water quality requirements of the Project and outfalls into Pond 20. The HERC property was evaluated for the potential contaminated groundwater mitigation to Pond 19. The results of this investigation were documented in the HERC & Murro Chemical Properties Phase 1 ESA (dated September 17, 2012) and HERC/BCSC Property Phase 1 ESA – Addendum 1 (dated March 18, 2013)

Pond 20, presented in *Figure 7*, is a proposed extended detention basin which outfalls to an existing drainage system to the north. It collects 24.87 acres of residential and industrial area from the south side of Interstate 264 as well as 13.67 acres of industrial, proposed Ramp north of Interstate 264 for a total contributing area of 38.54 acres. This pond accepts Project flows as well as offsite flows, which contribute to the total water quality requirements of the Project. The pond eventually outfalls into an existing 5'x3' box culvert that traverses northward towards CSXT property. The issues surrounding this existing culvert are discussed in Section 9.

Figure 7 - Proposed Type II Retention Pond 19 and Extended Detention Pond 20

Pond 24 is a detention pond located on the south side of Turnpike Road and Pond 25 is a detention pond located on the north side of Turnpike Road, both presented in Figure 8. Pond 24 has a contributing drainage area of 7.70 acres and pond 25 has a contributing drainage area of 6.00 acres. The outfall of pond 25 will connect into the rerouted 42" storm sewer system that eventually runs under King Street. The outfall of pond 24 will connect to the proposed box culverts in Turnpike Road (as part of a separate VDOT Project). Construction schedule and sequencing will need to be coordinated with the VDOT Turnpike Road project to complete construction of this proposed pond outfall. This is discussed in more detail in Section 7.4.

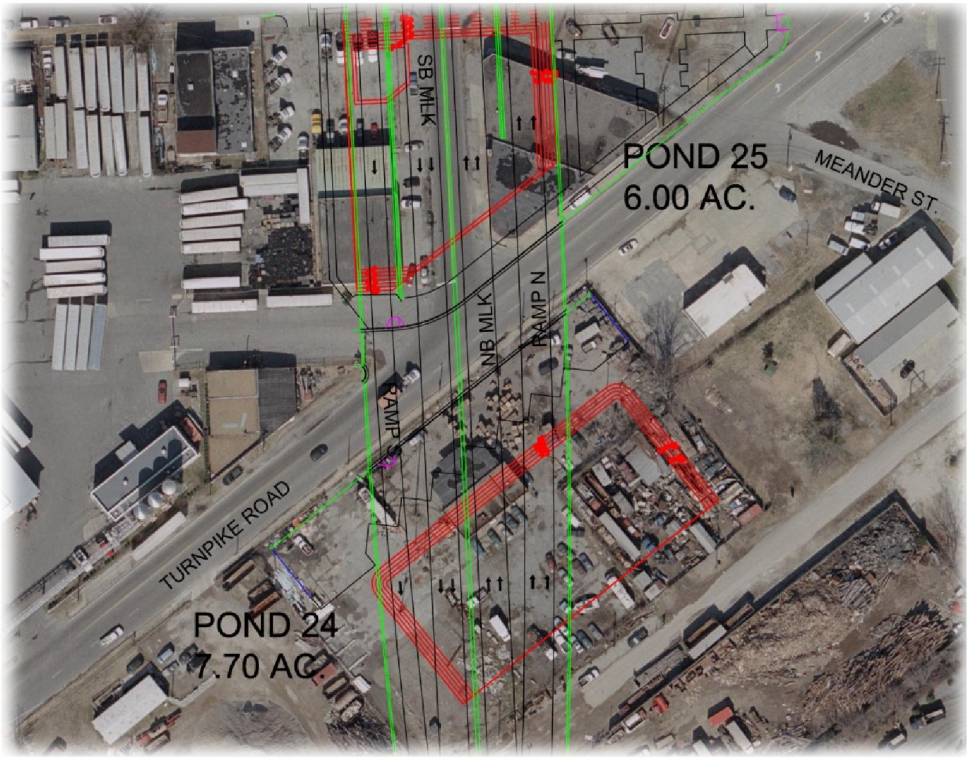


Figure 8 - Proposed Detention Ponds 24 and 25

Pond 30, located in the infield of the existing London Boulevard ramp, collects 12.60 acres of existing roadway, industrial area, residential area and proposed MLK roadway. It is designed as a type III retention pond and outfalls to an existing box culvert. Stormwater is then conveyed to an existing jurisdictional wetland just the north of the London Boulevard Interchange and ultimately to the Elizabeth River. This pond accepts Project flows as well as offsite flows, which contribute to the total water quality requirements of the Project. Pond 30 is shown in *Figure 9*.

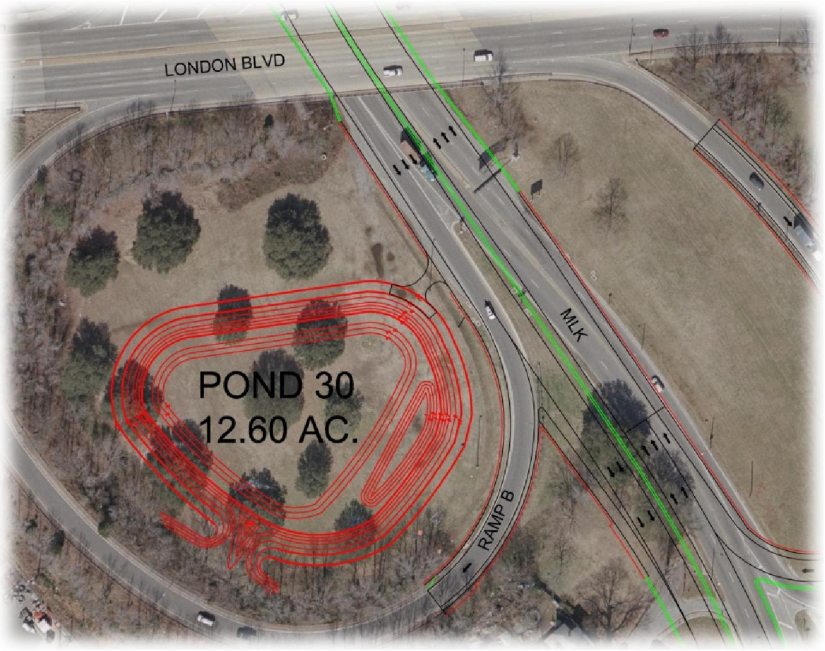


Figure 9 - Proposed Type III Retention Pond 30

Stormwater management ponds contributing areas are outlined in Appendix C – Drainage Area Maps while time of concentration calculations and pond routing is located in Appendix D – Stormwater Management Calculations.

6. STORMWATER QUALITY MITIGATION

Maintaining water quality during operation of the facilities is an important element of the design criteria for the Project. Runoff from the project area conveys into the Elizabeth River and its tributaries and ultimately into the Lower Chesapeake Bay. In order to provide water quality mitigation, the Project is being evaluated as a whole. This includes the Midtown Tunnel and its approaches, the MLK Expressway, the MLK Expressway/Interstate 264 Interchange and the widening of Interstate 264 adjacent to the Interchange.

Due to the lack of available right-of-way in the vicinity of the Midtown Tunnel portals, no water quality mitigation is proposed in these areas. Instead, overtreatment will be provided on the MLK portion of the project. This treatment is provided by the detention and retention ponds detailed in Section 5. The following is a summary of the water quality analysis results:

- The total net impervious area being added due to the Project is 11.5 Acres.
- The total additional phosphorus loading from the Project is 58.02 lbs/yr (including the 10% additional removal requirement).
- The total phosphorus removed by the proposed stormwater management facilities is 68.90 lbs/yr.

All water quality calculations are provided in Appendix D – Stormwater Management Calculations.

7. TIDAL FLOOD MITIGATION

One existing stormwater problem identified is the repetitive tidal flooding of the existing Midtown Tunnel through the Norfolk portal. This is thought to be caused during tidal events, where the tide will surcharge the existing storm sewer systems around the Norfolk portal and contribute to significant flows entering the tunnel. The largest example of this occurred in September 2003, when the tunnel was closed for over a month when the floodgate could not be closed properly and the tunnel flooded during Hurricane Isabel.

Our analysis determined that the existing outfall to the south of the crash house and its subsequent drainage system were allowing the tide to flow “up” through existing inlets and into the approach lanes to the tunnel. Furthermore, another drainage system to the east of the crash house, which drains the infield area next to Brambleton Avenue, allows higher stage tidal events to encroach on the approach lanes from this direction.

Improvements are proposed to decrease the frequency and severity of tidal flooding of the Norfolk portal. They are summarized below:

- Constructing a ten foot wide berm behind the crash house at elevation 8.25 NAVD 88 to prevent overland flow encroaching onto the roadway.
- Removing and re-directing the existing drainage system adjacent to the Norfolk crash house.
- Upgrading the existing pump station (to the south of the portal) to address additional flow from re-directed storm drain system.
- Protecting Ramp B with a flood wall and berm on the seaward side of the ramp.
- Modifying the vertical grade of eastbound Hampton Boulevard just east of the existing Brambleton Boulevard overpass bridge to function as a “berm”.
- Constructing Access Road N and Driveway N1 to an elevation that allows them to function as part of the berm system.
- Constructing a ten foot wide berm behind the crash house to prevent overland flow from the south.

The Tidal Flood Protection – Midtown Tunnel Norfolk Approach Area Memorandum located in Appendix E – Tidal Flood Protection thoroughly discusses the methodology for providing flood protection at the Norfolk approach.

8. CSX CULVERT ANALYSIS

The downstream pipe from Pond 20 is an existing five-foot by three-foot box culvert which conveys stormwater under the CSX Property to the north through adjacent thirty inch and forty-two inch culverts. It became apparent that the thirty inch and forty-two inch culverts were undersized for the existing

conditions; hence a Stormwater Management Model was developed in the Preliminary Hydrologic and Hydraulic Design Report dated April 2011 to analyze the systems conveying runoff to these pipes. This model was used to verify the sufficiency of the proposed ponds 14, 16 (now 19) and 20 in relation to the outfall pipes under the CSX Property. The model shows that by over sizing the ponds such as proposed, the culverts under CSX are adequate to handle the runoff in the proposed condition. Each pond in the system is shown to safely pass the 100 year storm event, with at least one foot of freeboard above the peak stage, per VDOT criteria. In short, no additional facilities are required to convey stormwater under the CSX Property.

A summary of the proposed land use areas and analysis of Pond 20's outfall to the existing CSX 5'x3' box culvert are located in Appendix I – Existing CSX Outfall Analysis. The proposed design has significantly decreased the discharge from the project. The Pond 20 summary in Appendix D – Stormwater Management Calculations and Table 2 show the dramatic decrease in discharge to the CSX 5'x3' box culvert.

9. APPENDICES

9.1. APPENDIX A – Drainage Design Criteria

MIDTOWN TUNNEL

Engineer: Robert Cade, PE
Consultant: Parsons Brinckerhoff

Drainage Design Criteria Summary

References: VDOT Drainage Manual, Virginia Stormwater Management Handbook, Virginia Erosion and Sediment Control Handbook

Roadway	Classification	Design Speed	Travelway Inundation Exceedence Probability	Culverts		Open Channels				Storm Sewer Pipes		Storm Sewer Drop Inlets******							
						Roadside Ditches		Drainage Channels				Design Intensity (in/hr)				Maximum Spread Width (ft)			
				Design Storm (yr)		Design Storm (yr)		Design Storm (yr)		Design Storm (yr)		With Shoulder		Without Shoulder		With Shoulder		Without Shoulder	
				Capacity	Scour	Capacity	Lining	Capacity	Lining	Shoulder	No Shlder	On Grade	Sag	On Grade	Sag	On Grade	Sag	On Grade	Sag
Route 58	Principal Arterial	40	2%	25	25	10	2	10	2	25	10	7.67	7.67	4 (6.5 check)	9.55	Shoulder Width +3	Shoulder Width +3	1/2 drive lane + gutter	1/2 drive lane + gutter
Interstate 264	Interstate	55	2%	50	50	10	2	10	2	25	25	7.67	7.67	7.67	9.55	Shoulder Width	Shoulder Width +3	1/2 drive lane + gutter	1/2 drive lane + gutter
MLK Freeway	Principal Arterial	50	2%	25	25	10	2	10	2	25	10	7.67	7.67	4 (6.5 check)	9.55	Shoulder Width	Shoulder Width +3	1/2 drive lane + gutter	1/2 drive lane + gutter
Tunnel***	Principal Arterial	40	2%	25	25	10	2	10	2	25	10	7.67	9.55	4 (6.5 check)	7.67	Shoulder Width +3	Shoulder Width +3	1/2 drive lane + gutter	1/2 drive lane + gutter
Interchange Ramps	Ramps	Varies	2%	50	50	10	2	10	2	25	10	7.67	7.67	4 (6.5 check)	4 (6.5 check)	Shoulder Width +3	Shoulder Width +3	1/2 drive lane + gutter	1/2 drive lane + gutter
Local Streets	Collector, Local	20	10%	10	10	10	2	10	2	10	10	4 (6.5 check)	4 (6.5 check)	4 (6.5 check)	4 (6.5 check)	Shoulder Width +3	Shoulder Width +3	1/2 drive lane + gutter	1/2 drive lane + gutter

Outlet Protection

Velocity Range (fps)	Outlet Protection
0-6	EC-3 Type B
6-8	EC-1 Class AI
8-14	EC-1 Class I
14-19	EC-1 Class II
<19	Special Design

Ditch Linings

Velocity Range (fps)	Manning's 'n'	Type of Lining
0-3	0.03	Bare Earth
3-4	0.05	EC-2
4-7	0.05	EC-3 Type A
7-10	0.05	EC-3 Type B
>10	0.04-0.045	Riprap
>10	0.015	Concrete

24-hr Rainfall

Project***	
Year	Depth (in)
1	2.97
2	3.61
5	4.66
10	5.56
25	6.88
50	8.01
100	9.27

Rainfall Distribution

Modified
Rational Method

Tidal Elevations

(Adding 2' for Global Warming)*****

10 - Year	EL 7.50*	(NAVD 88)
50 - Year	EL 8.90*	(NAVD 88)
100 - Year	EL 9.60*	(NAVD 88)
500 - Year	EL 10.90*	(NAVD 88)
Ultimate Storm	EL 14.10**	(NAVD 88)

Pump Station Capacities

When designing for stormwater conveying to a pump station, total volumes should be taken into account with respect to the design storm.

Tailwater Elevations

(VDOT DM APPENDIX 6I-1)
(Adding 2' for Global Warming)*****

TW = EL 2.70 (NAVD 88)

* Flood Insurance Study, City of Norfolk, Virginia; Federal Emergency Management Agency (September 2009)
** Flood Plain Information, Coastal Flooding, Portsmouth, Virginia; US Army Corps of Engineers (February 1973)
*** The tunnel is defined as the tunnel itself as well as the portions of the roadway that drain in the direction of the tunnel portals.
**** NOAA Atlas 14, Project Co-ordinates: 36.825 N, 76.336 W
***** NOAA Sewells Point station long term trend 1927 to 2006 = 1.46'/century, rounded up to 2'
****** Inlets located in sags require double slot lengths and where inlet and storm drain is the only means of water escaping the roadway shall be analyzed using the 50-year storm.

MIDTOWN TUNNEL

Engineer: Robert Cade, PE
Consultant: Parsons Brinckerhoff

Drainage Design Criteria Summary

References: VDOT Drainage Manual, Virginia Stormwater Management Handbook, Virginia Erosion and Sediment Control Handbook

City of Norfolk Rainfall Intensities (in/hr)

	Time of Concentration (minutes)								
Design Storm (yr)	5	10	15	20	25	30	40	50	60
2	5.85	4.67	3.91	3.38	2.98	2.67	2.23	1.92	1.69
5	6.80	5.50	4.65	4.05	3.60	3.25	2.73	2.37	2.10
10	7.67	6.17	5.23	4.57	4.08	3.70	3.14	2.75	2.46
25	8.71	7.05	6.01	5.29	4.75	4.33	3.71	3.28	2.95
50	9.55	7.65	6.52	5.75	5.18	4.74	4.10	3.65	3.32
100	10.08	8.07	6.88	6.08	5.50	5.05	4.39	3.92	3.57

Rational Method 'C' Values

Paved and Roofed Areas	0.9
Industrial/ Commercial	0.80-0.90
Apartments and Townhomes	0.65-0.75
Schools	0.50-0.60
Residential - lots up to 10000 SF	0.40-0.50
Residential - lots up to 12000 SF	0.40-0.45
Residential - lots up to 17000 SF	0.35-0.45
Residential - lots 1/2 acre or more	0.30-0.40
Parks, Cemeteries & Unimproved Areas	0.20-0.35
Cultivated Areas	0.50-0.70
Pasture	0.35-0.45
Lawns	0.25-0.35
Forest	0.20-0.30
Side Slopes	0.40-0.70
Unpaved Shoulder/Ditch Areas	0.35-0.50

Permanent Drainage Criteria shall be used in evaluation of temporary drainage situations

Intensity Variables

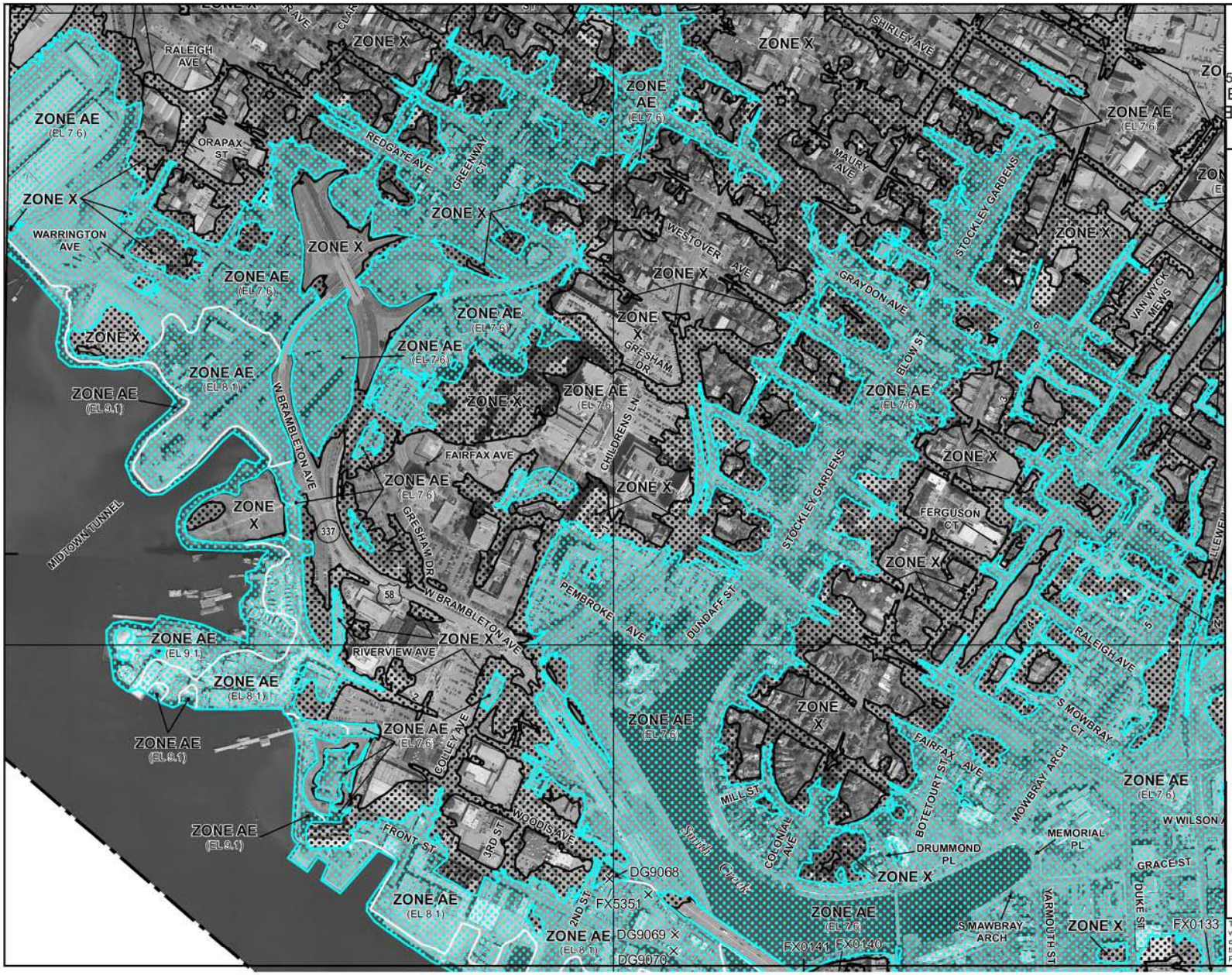
Norfolk			
i=b/((Tc+d)^e)			
Year	b	d	e
2	60.83	11.25	0.84
5	64.03	11.50	0.80
10	51.92	9.25	0.72
25	47.96	8.25	0.66
50	39.29	6.00	0.59
100	37.10	5.25	0.56

Corr. Factors

Storm	C_{f*}
25 - Year	1.10
50 - Year	1.20
100 - Year	1.25

* Cf x c must be less or equal to 1

9.2. **APPENDIX B – FEMA Flood Maps**



MAP SCALE 1" = 500'

50 0 500 1,000 FEET

METERS

NFIP

NATIONAL FLOOD INSURANCE PROGRAM

PANEL 0130 F

FIRM

FLOOD INSURANCE RATE MAP

CITY OF
NORFOLK, VIRGINIA
INDEPENDENT CITY

PANEL 130 OF 185

(SEE MAP INDEX FOR FIRM PANEL LAYOUT)

CONTAINS:

COMMUNITY	NUMBER	PANEL	SUFFIX
NORFOLK, CITY OF	510104	0130	F

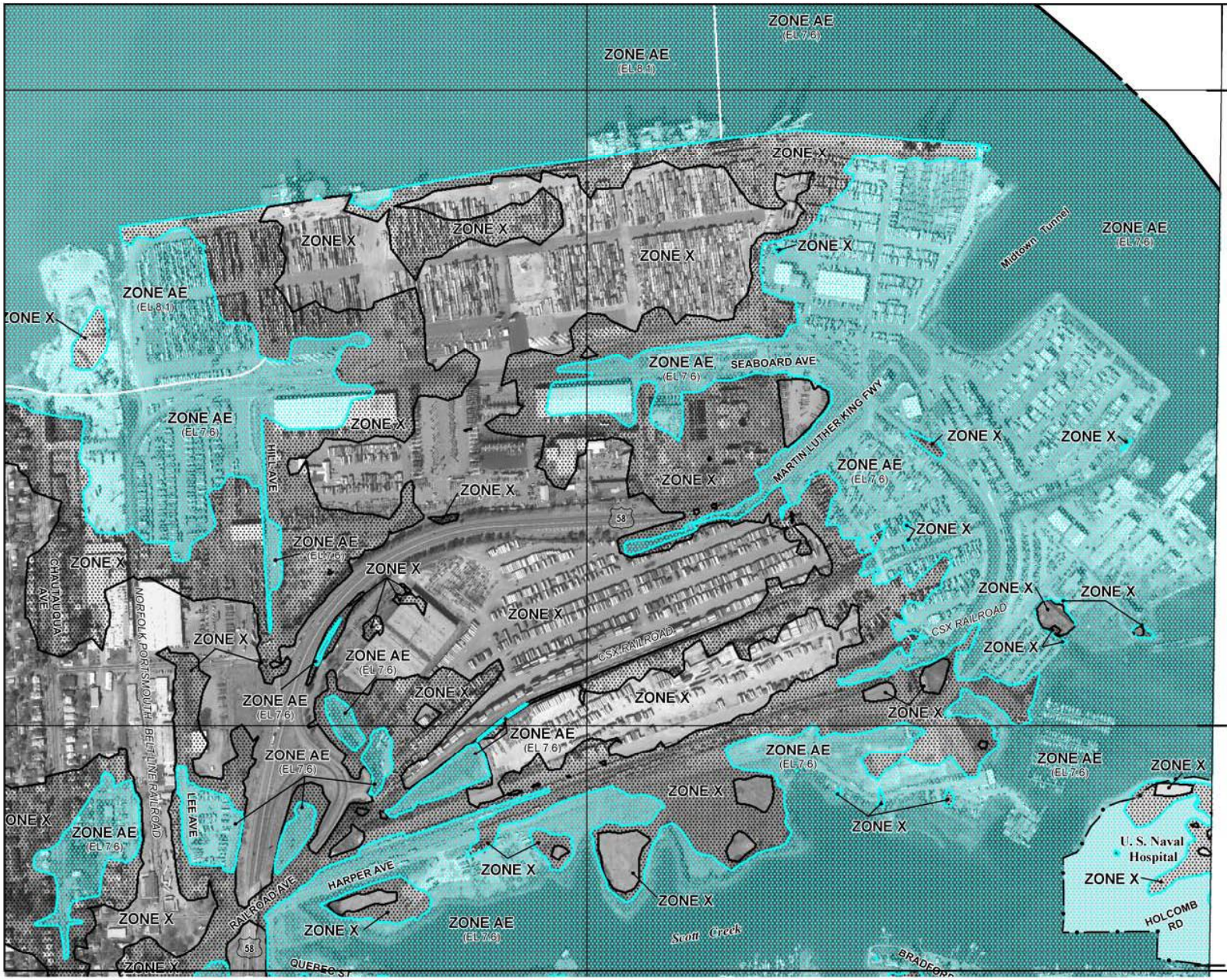
Notice to User: The **Map Number** shown below should be used when placing map orders; the **Community Number** shown above should be used on insurance applications for the subject community.

MAP NUMBER
5101040130F

MAP REVISED
SEPTEMBER 2, 2009

Federal Emergency Management Agency

This is an official copy of a portion of the above referenced flood map. It was extracted using F-MIT On-Line. This map does not reflect changes or amendments which may have been made subsequent to the date on the title block. For the latest product information about National Flood Insurance Program flood maps check the FEMA Flood Map Store at www.msc.fema.gov



MAP SCALE 1" = 500'

50 0 500 1000 FEET

METERS

NFIP

NATIONAL FLOOD INSURANCE PROGRAM

PANEL 0077C

FIRM

FLOOD INSURANCE RATE MAP

CITY OF
PORTSMOUTH, VIRGINIA
(INDEPENDENT CITY)

PANEL 77 OF 94

(SEE MAP INDEX FOR FIRM PANEL LAYOUT)

CONTAINS:

COMMUNITY	NUMBER	PANEL	SUFFIX
PORTSMOUTH, CITY OF	515529	0077	C

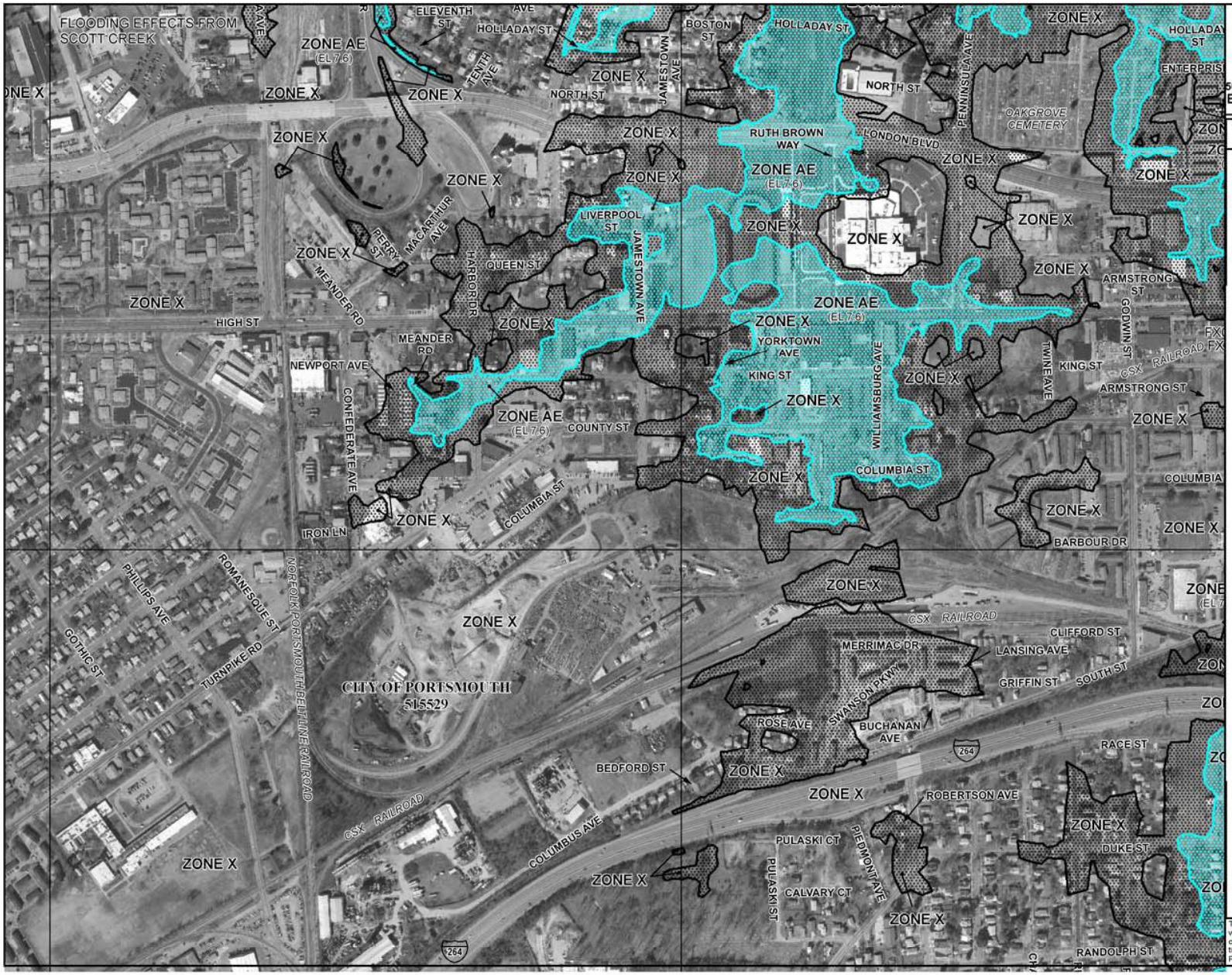
Notice to User: The **Map Number** shown below should be used when placing map orders; the **Community Number** shown above should be used on insurance applications for the subject community.

MAP NUMBER
5155290077C

MAP REVISED
SEPTEMBER 25, 2009

Federal Emergency Management Agency

This is an official copy of a portion of the above referenced flood map. It was extracted using F-MIT On-Line. This map does not reflect changes or amendments which may have been made subsequent to the date on the title block. For the latest product information about National Flood Insurance Program flood maps check the FEMA Flood Map Store at www.msc.fema.gov



MAP SCALE 1" = 500'

50 0 500 1000 FEET

METERS

NFIP

NATIONAL FLOOD INSURANCE PROGRAM

PANEL 0079C

FIRM

FLOOD INSURANCE RATE MAP

CITY OF
PORTSMOUTH, VIRGINIA
(INDEPENDENT CITY)

PANEL 79 OF 94

(SEE MAP INDEX FOR FIRM PANEL LAYOUT)

CONTAINS:

COMMUNITY	NUMBER	PANEL	SUFFIX
PORTSMOUTH, CITY OF	515529	0079	C

Notice to User: The **Map Number** shown below should be used when placing map orders; the **Community Number** shown above should be used on insurance applications for the subject community.

MAP NUMBER
5155290079C

MAP REVISED
SEPTEMBER 25, 2009

Federal Emergency Management Agency

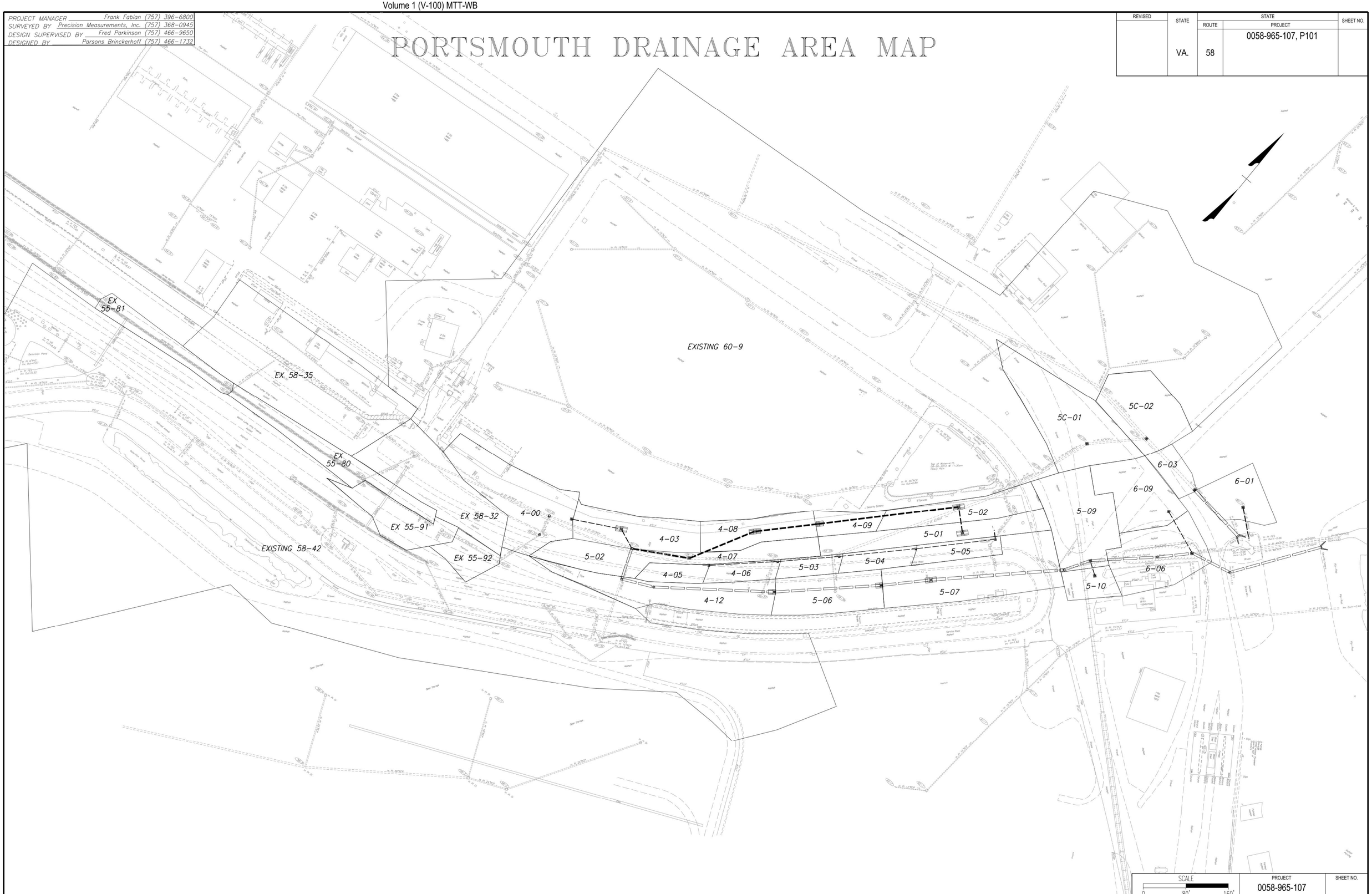
This is an official copy of a portion of the above referenced flood map. It was extracted using F-MIT On-Line. This map does not reflect changes or amendments which may have been made subsequent to the date on the title block. For the latest product information about National Flood Insurance Program flood maps check the FEMA Flood Map Store at www.msc.fema.gov

9.3. APPENDIX C – Drainage Area Maps

PROJECT MANAGER Frank Fabian (757) 396-6800
SURVEYED BY Precision Measurements, Inc. (757) 368-0945
DESIGN SUPERVISED BY Fred Parkinson (757) 466-9650
DESIGNED BY Parsons Brinckerhoff (757) 466-1732

PORTSMOUTH DRAINAGE AREA MAP

REVISED	STATE	STATE ROUTE	STATE PROJECT	SHEET NO.
	VA.	58	0058-965-107, P101	

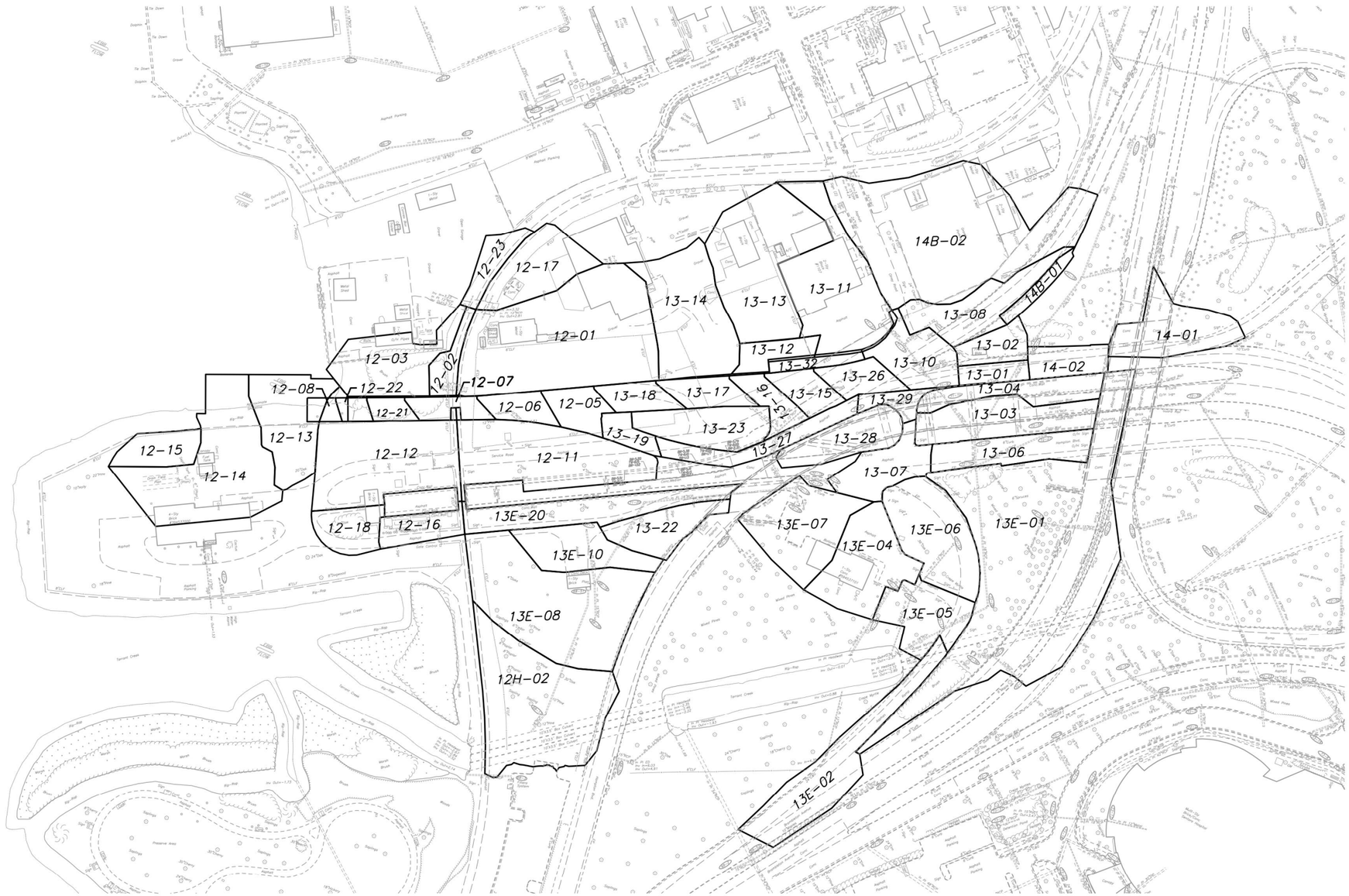


SCALE	PROJECT	SHEET NO.
0 80' 160'	0058-965-107	

PROJECT MANAGER Frank Fabian (757) 396-6800
SURVEYED BY Precision Measurements, Inc. (757) 368-0945
DESIGN SUPERVISED BY Fred Parkinson (757) 466-9650
DESIGNED BY Parsons Brinckerhoff (757) 466-1732

NORFOLK DRAINAGE AREA MAP

REVISED	STATE	STATE ROUTE	STATE PROJECT	SHEET NO.
	VA.	58	0058-965-107, P101	

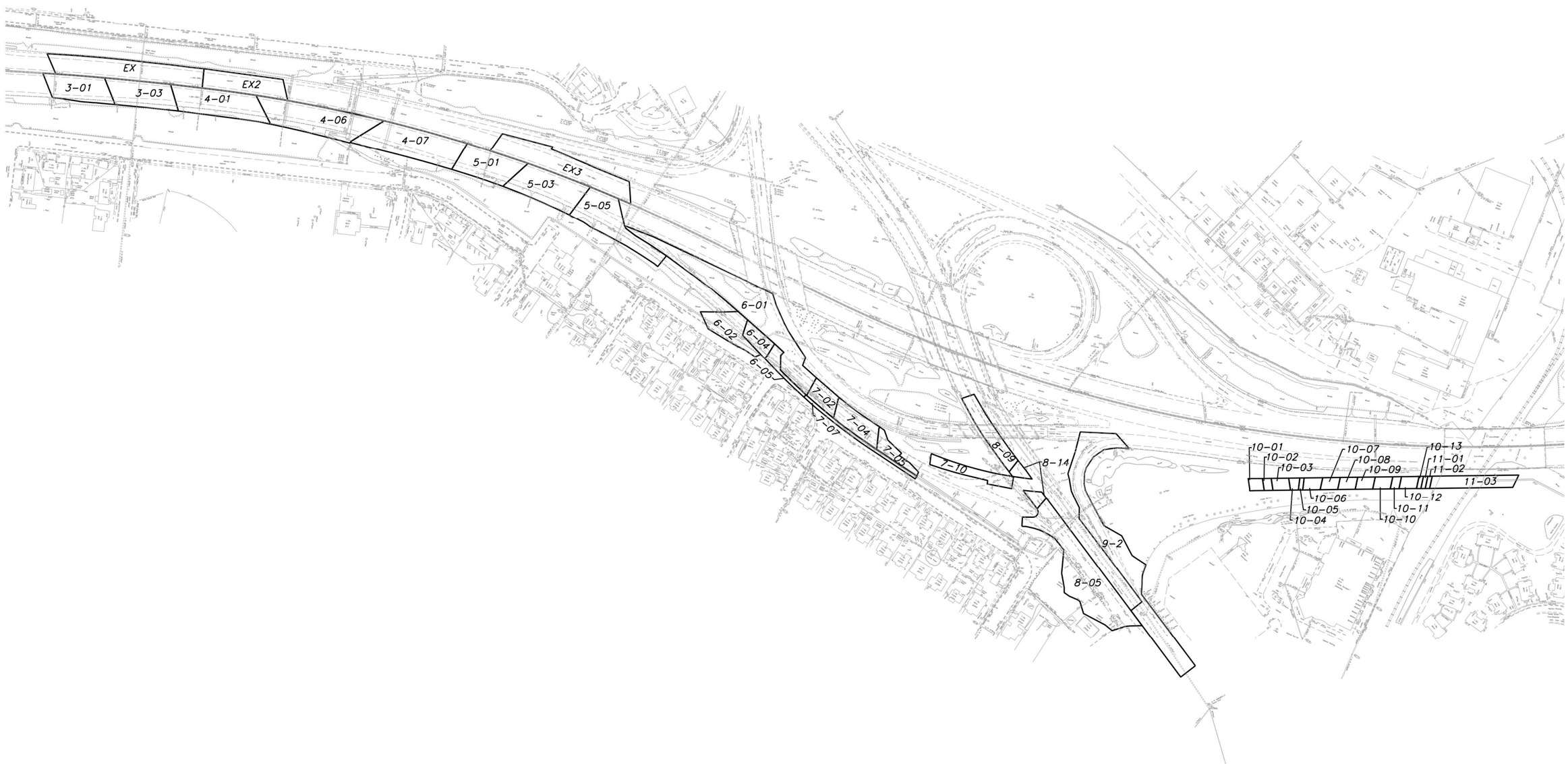


SCALE	PROJECT	SHEET NO.
0 80' 160'	0058-965-107	

PROJECT MANAGER Frank Fabian (757) 396-6800
SURVEYED BY Precision Measurements, Inc. (757) 368-0945
DESIGN SUPERVISED BY Fred Parkinson (757) 466-9650
DESIGNED BY Parsons Brinckerhoff (757) 466-1732

RAMP EN AND C DRAINAGE AREA MAP

REVISED	STATE	STATE ROUTE	STATE PROJECT	SHEET NO.
	VA.	US-58 SR-164	0058-965-107, P101	



SCALE	PROJECT	SHEET NO.
0 140' 280'	0058-965-107	

7:46:27 AM
5/23/2013
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1:58:55 PM

11/5/2012

c:\projectwise\pb\projectwiseintlanthony.evett\dms39078\Closed System Drainage Areas_Sheet 01.dgn

Closed System 1

Identification	Runoff C	Drainage Area	Time of	Time Used	Intensity	Discharge
30-04	0.897	0.098	5	5	8.714	0.845
30-01	0.4	0.59	5	5	8.714	2.262
30-03	0.9	0.183	5	5	8.714	1.575
30-02	0.9	0.051	5	5	8.714	0.442
28-05	0.525	0.699	5	5	8.714	3.522
28-07	0.9	0.033	5	5	8.714	0.282
28-09	0.899	0.464	5	5	8.714	4.003
28-01	0.514	1.305	11.26	11.261	6.75	4.98
28-02	0.897	0.023	5	5	8.714	0.198
28-04	0.889	0.029	5	5	8.714	0.25
28-06	0.754	0.113	5	5	8.714	0.815
28-08	0.9	0.421	5	5	8.714	3.632
27-05	0.434	0.408	5	5	8.714	1.7
28-03	0.9	0.03	5	5	8.714	0.261
27-04	0.559	1.304	7.14	7.137	7.895	6.331

Closed System 2

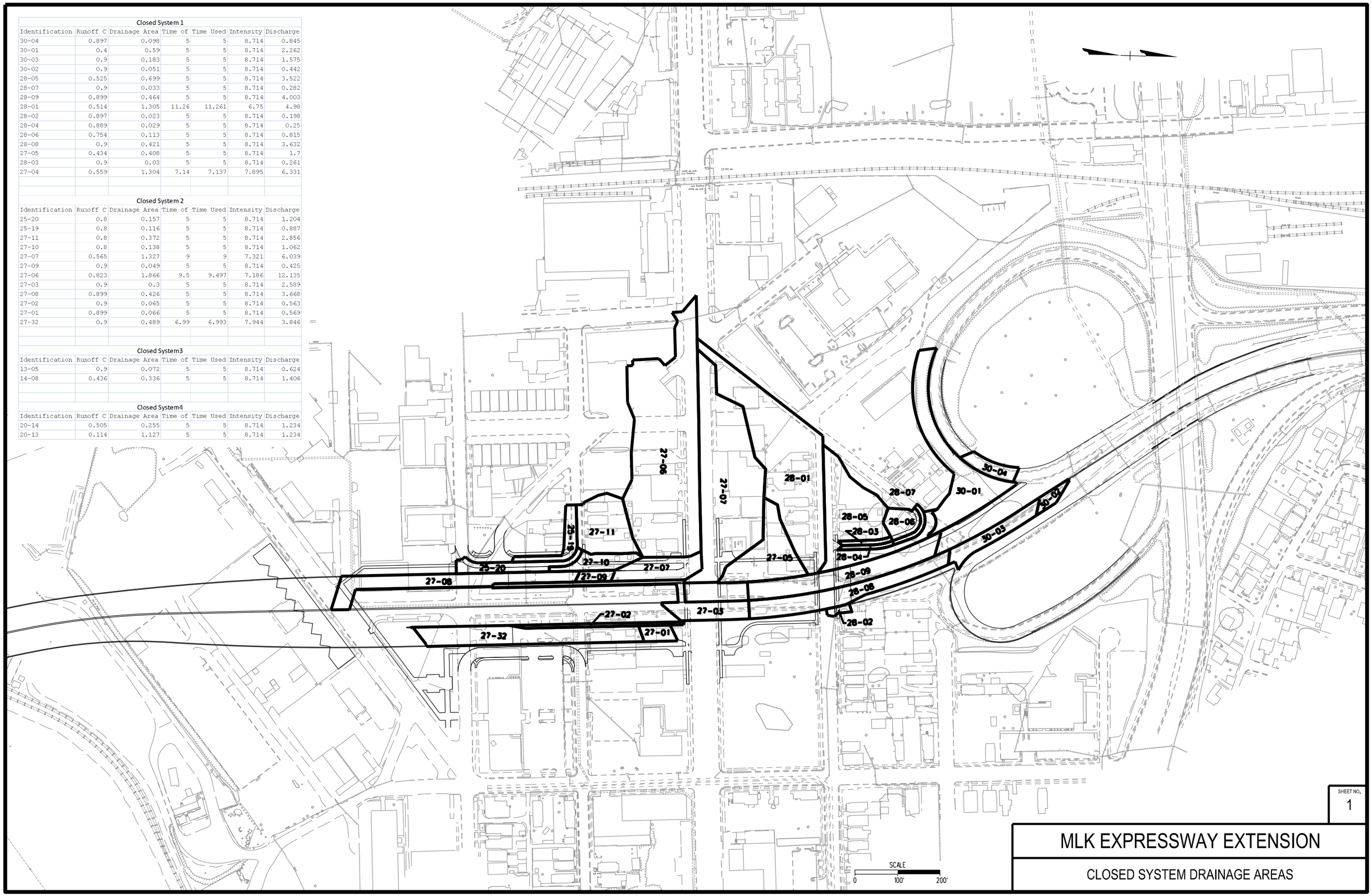
Identification	Runoff C	Drainage Area	Time of	Time Used	Intensity	Discharge
25-20	0.8	0.157	5	5	8.714	1.204
25-19	0.8	0.116	5	5	8.714	0.887
27-11	0.8	0.372	5	5	8.714	2.856
27-10	0.8	0.138	5	5	8.714	1.062
27-07	0.565	1.327	9	9	7.321	6.039
27-09	0.9	0.049	5	5	8.714	0.425
27-06	0.823	1.866	9.5	9.497	7.186	12.135
27-03	0.9	0.3	5	5	8.714	2.589
27-08	0.899	0.426	5	5	8.714	3.668
27-02	0.9	0.065	5	5	8.714	0.563
27-01	0.899	0.066	5	5	8.714	0.569
27-32	0.9	0.489	6.99	6.993	7.944	3.846

Closed System3

Identification	Runoff C	Drainage Area	Time of	Time Used	Intensity	Discharge
13-05	0.9	0.072	5	5	8.714	0.624
14-08	0.436	0.336	5	5	8.714	1.406

Closed System4

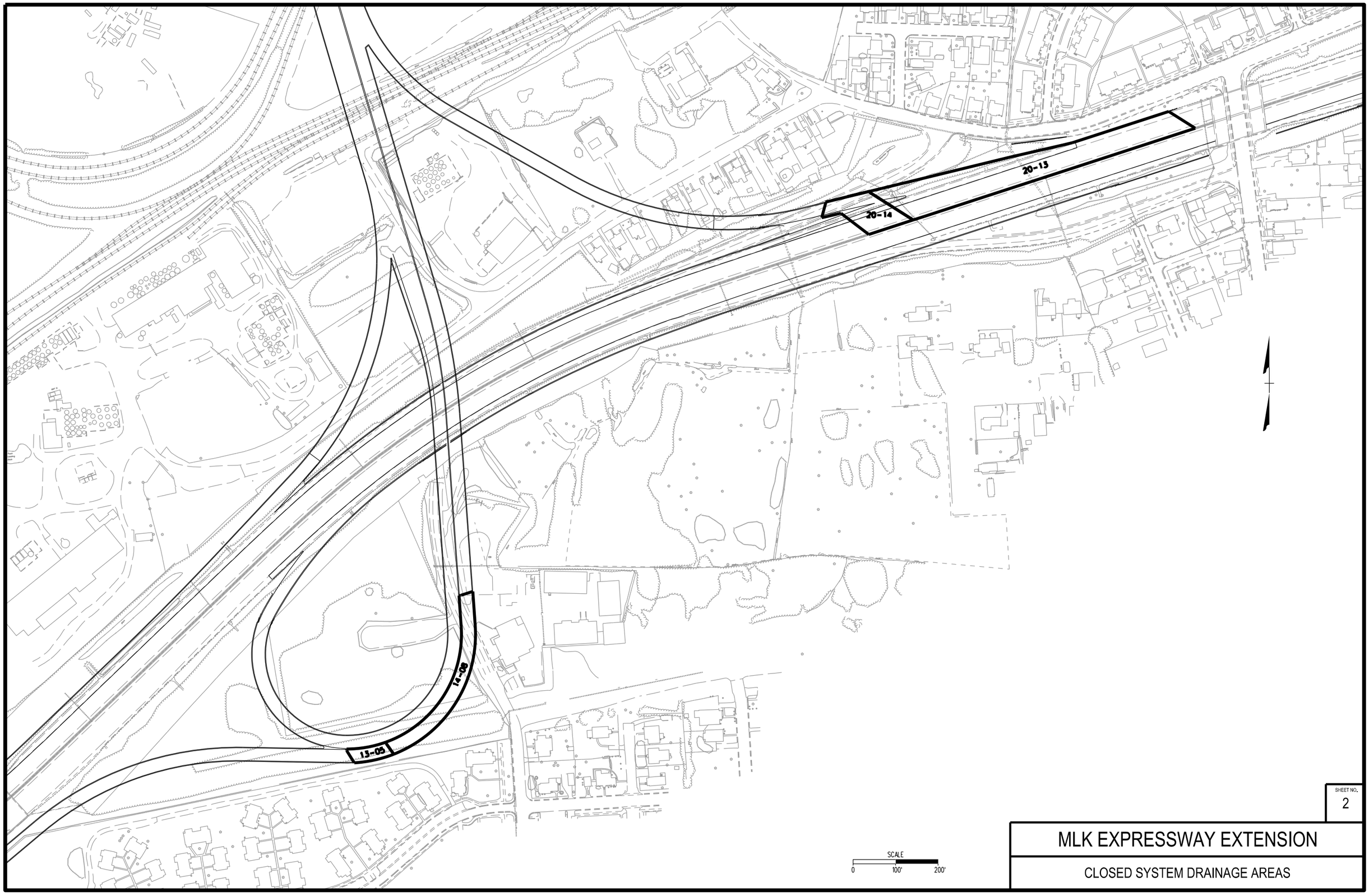
Identification	Runoff C	Drainage Area	Time of	Time Used	Intensity	Discharge
20-14	0.505	0.255	5	5	8.714	1.234
20-13	0.114	1.127	5	5	8.714	1.234



SHEET NO.
1

MLK EXPRESSWAY EXTENSION

CLOSED SYSTEM DRAINAGE AREAS



SHEET NO.
2

MLK EXPRESSWAY EXTENSION

CLOSED SYSTEM DRAINAGE AREAS

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11/5/2012
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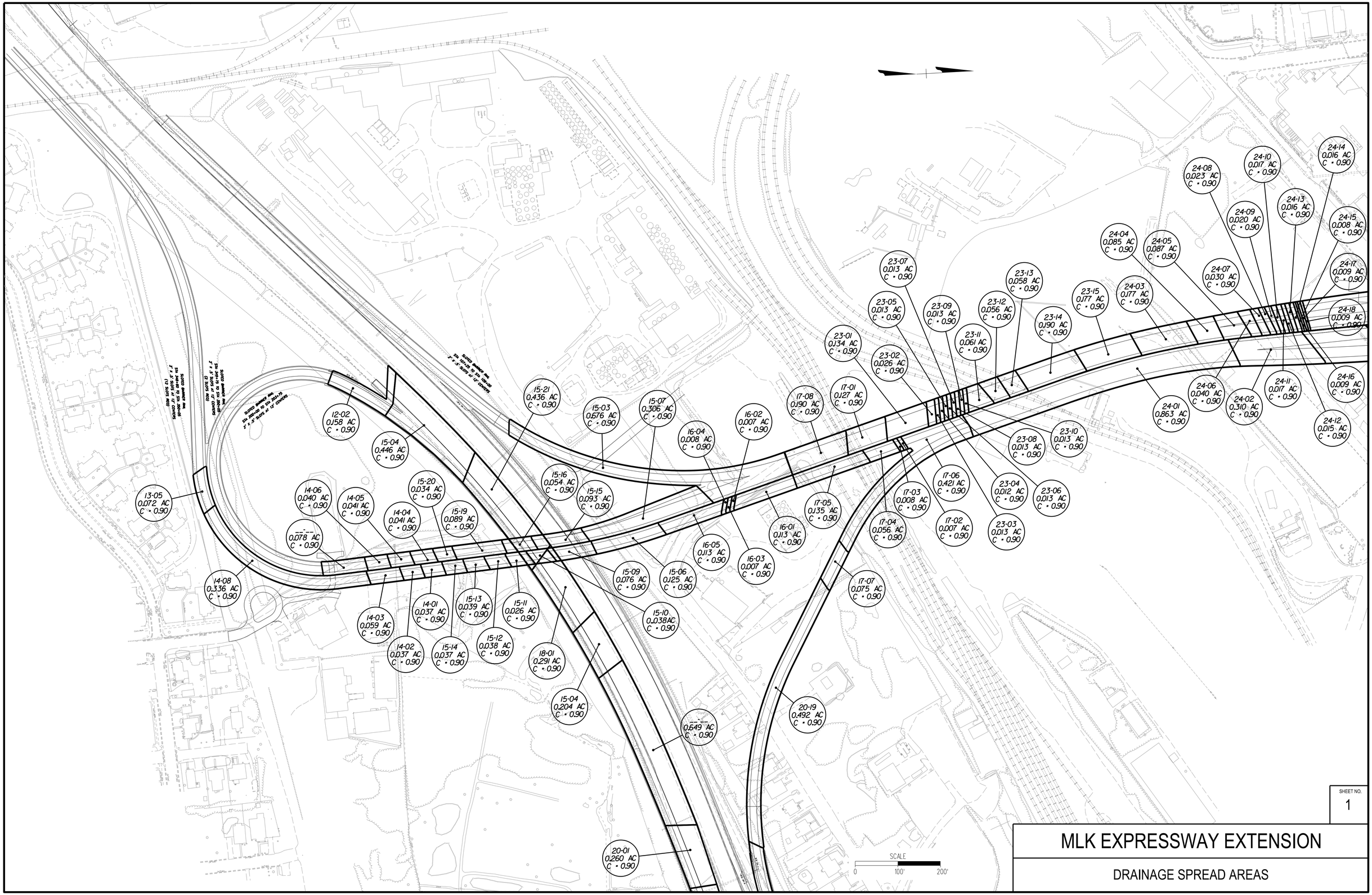

SHEET NO.
1

MLK EXPRESSWAY EXTENSION

DRAINAGE SPREAD AREAS

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11/5/2012

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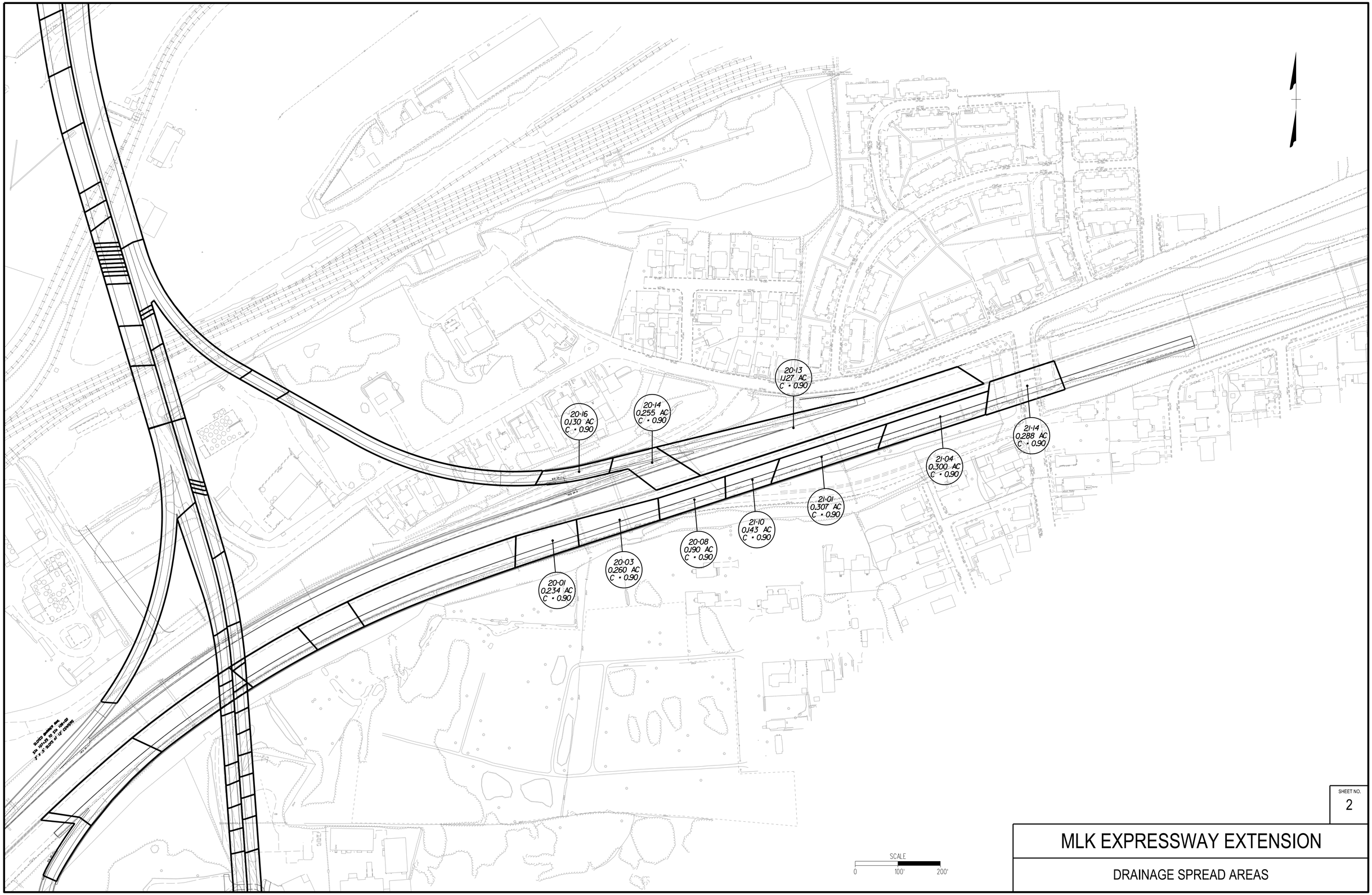

SHEET NO.
2

MLK EXPRESSWAY EXTENSION

DRAINAGE SPREAD AREAS

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11/5/2012

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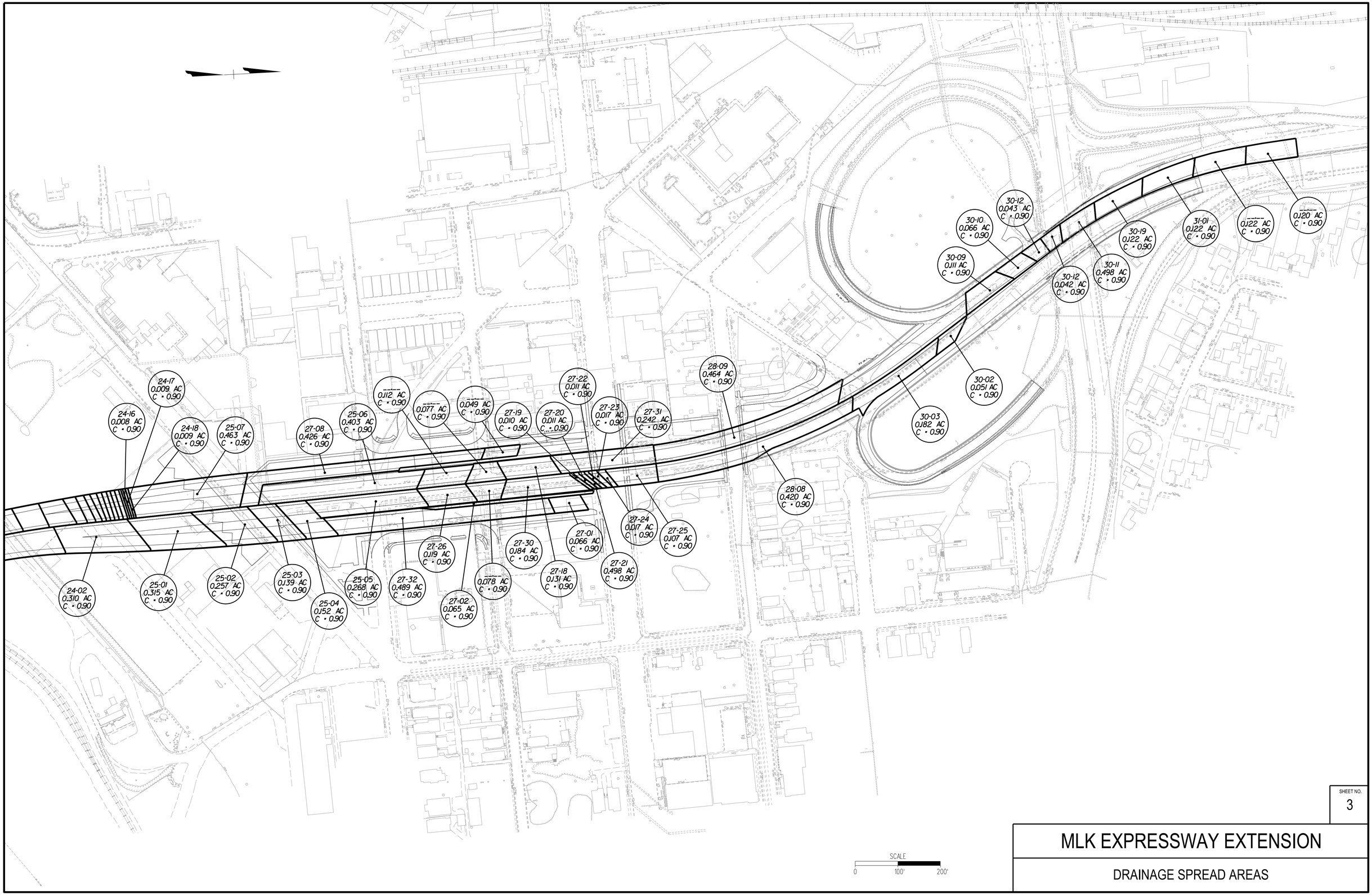

SHEET NO.
3

MLK EXPRESSWAY EXTENSION

DRAINAGE SPREAD AREAS

6:30:52 PM

11/5/2012

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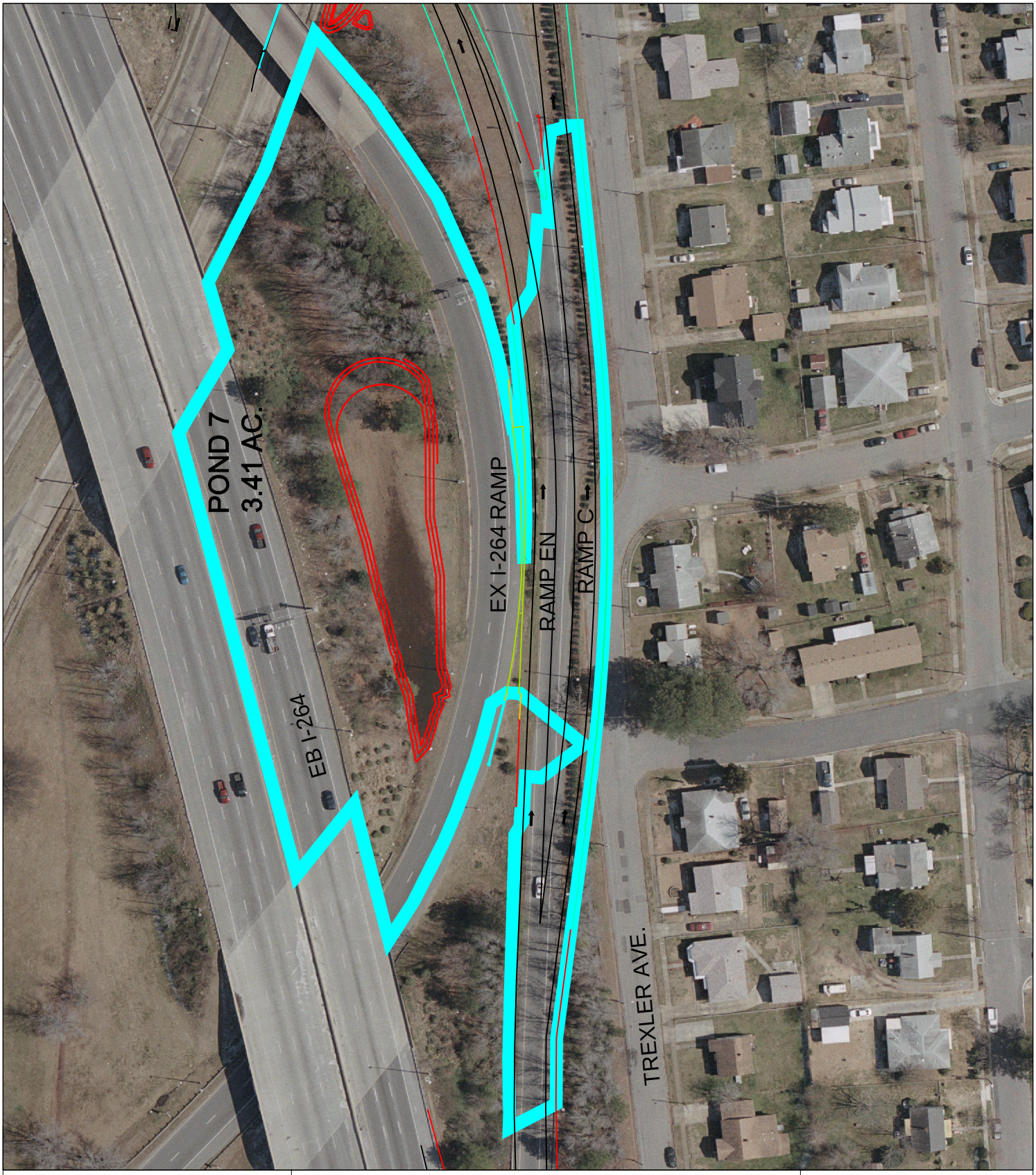
PARSONS BRINCKERHOFF

6161 KEMPSVILLE CIRCLE SUITE 110
NORFOLK, VA 23502

DOWNTOWN TUNNEL/MIDTOWN TUNNEL/
MLK EXPRESSWAY EXTENSION PROJECT

DRAINAGE AREA MAP

BASIN 5



PARSONS BRINCKERHOFF

6161 KEMPSVILLE CIRCLE SUITE 110
NORFOLK, VA 23502

ELIZABETH RIVER TUNNELS PROJECT

DRAINAGE AREA MAP

POND 7

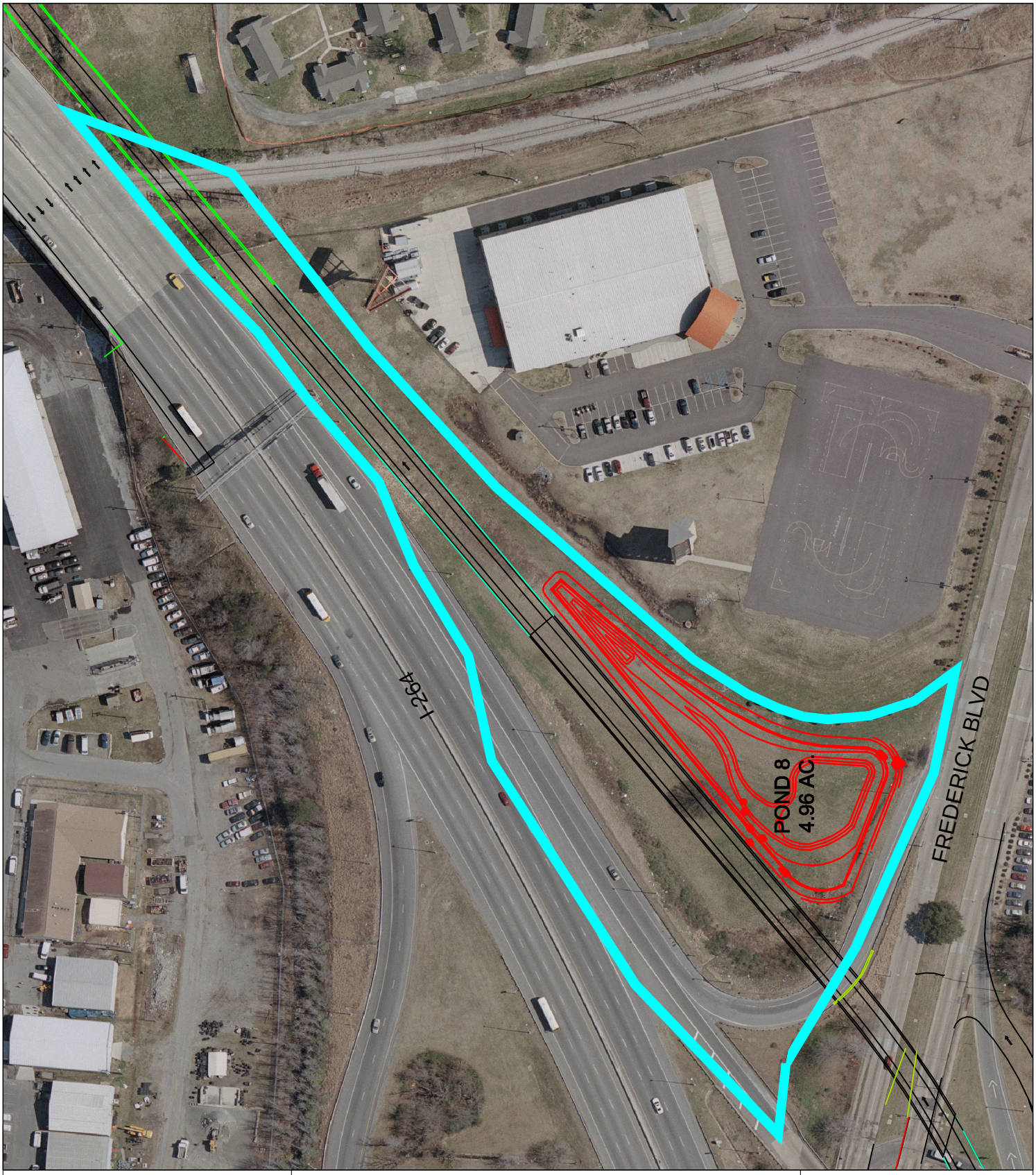
PARSONS BRINCKERHOFF

6161 KEMPSVILLE CIRCLE SUITE 110
NORFOLK, VA 23502

ELIZABETH RIVER TUNNELS PROJECT

DRAINAGE AREA MAP

RAMP EN&C BASINS



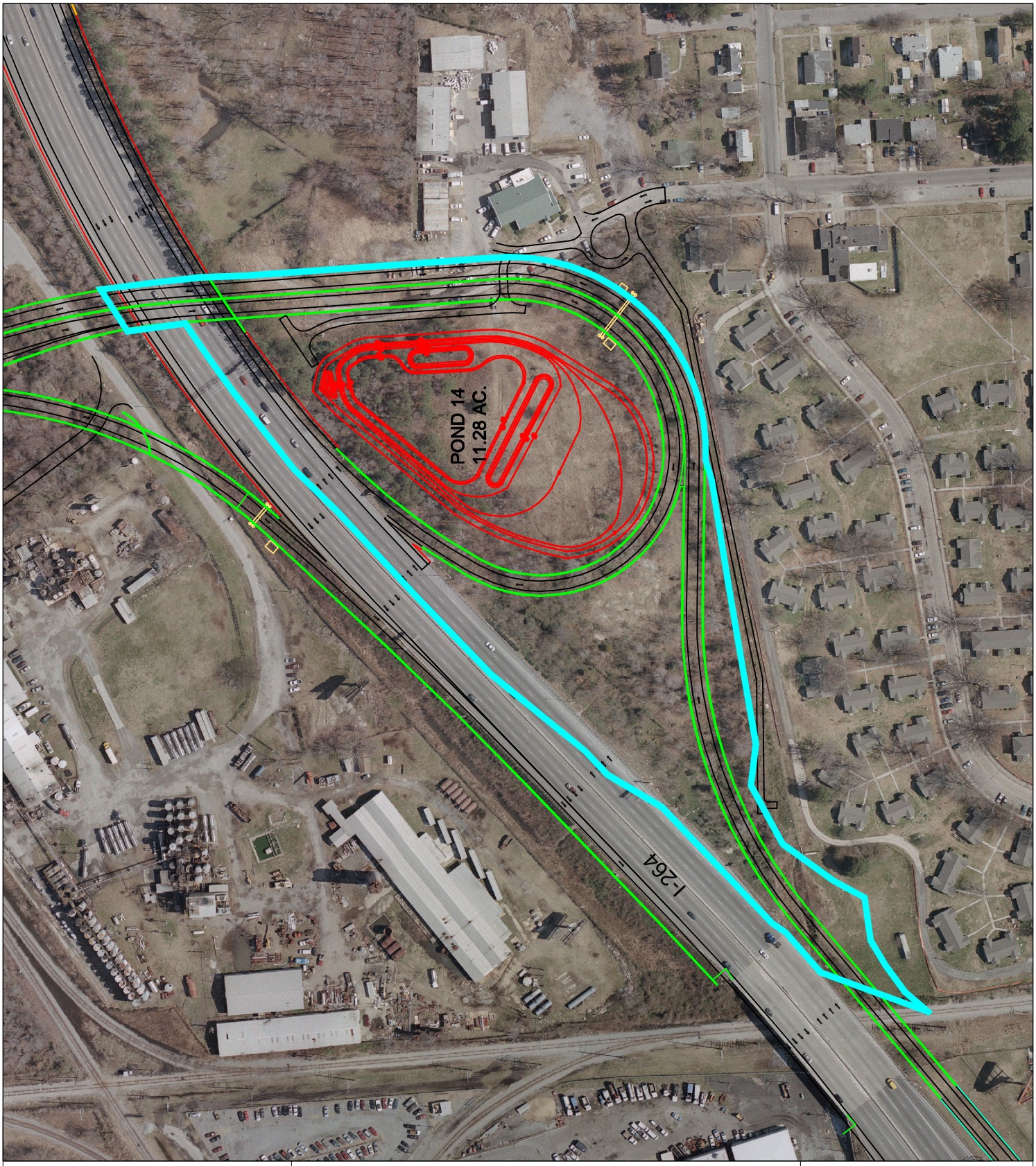
PARSONS BRINCKERHOFF

6161 KEMPSVILLE CIRCLE SUITE 110
NORFOLK, VA 23502

ELIZABETH RIVER TUNNELS PROJECT

DRAINAGE AREA MAP

POND 8



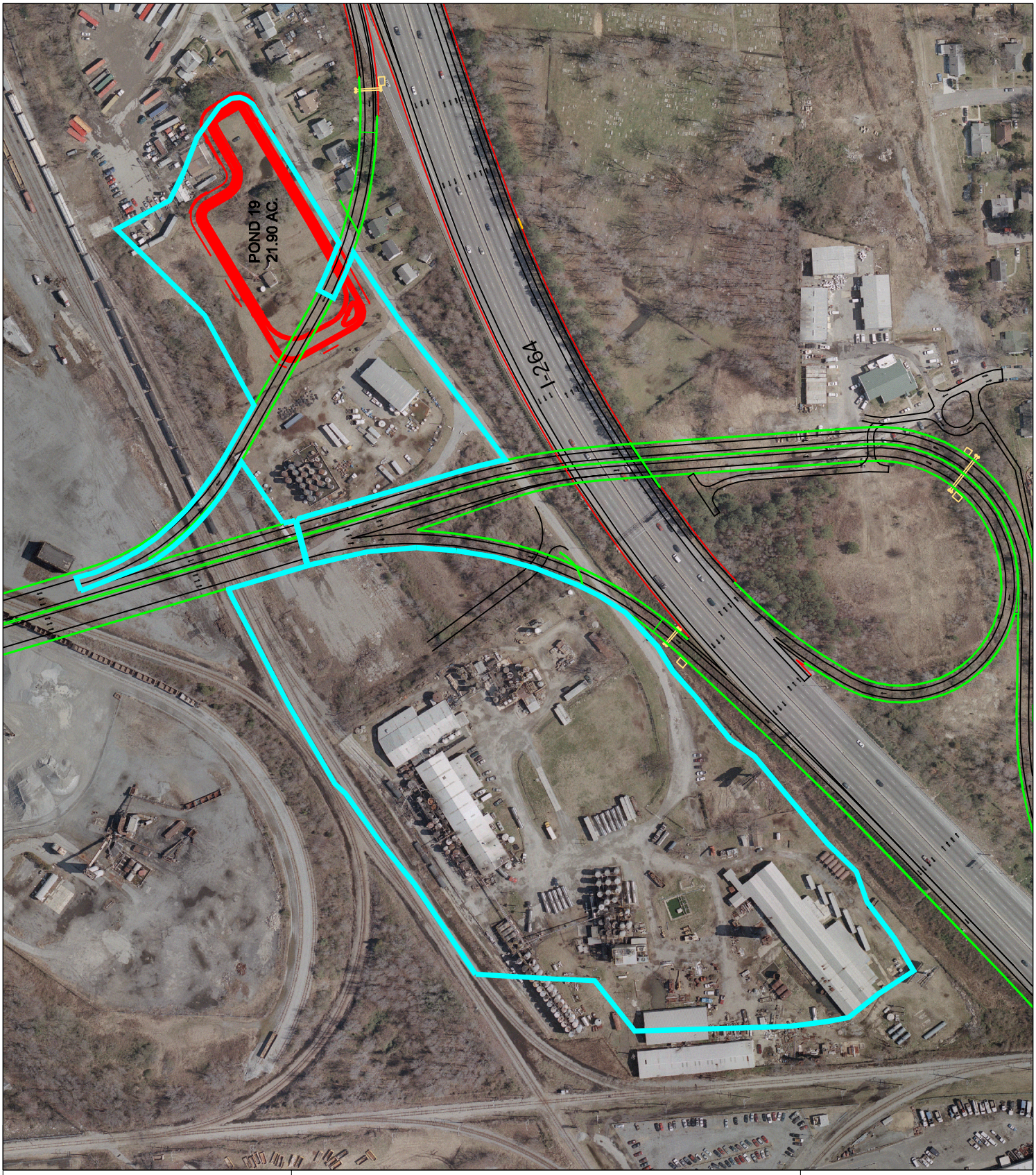
PARSONS BRINCKERHOFF

6161 KEMPSVILLE CIRCLE SUITE 110
NORFOLK, VA 23502

ELIZABETH RIVER TUNNELS PROJECT

DRAINAGE AREA MAP

POND 14



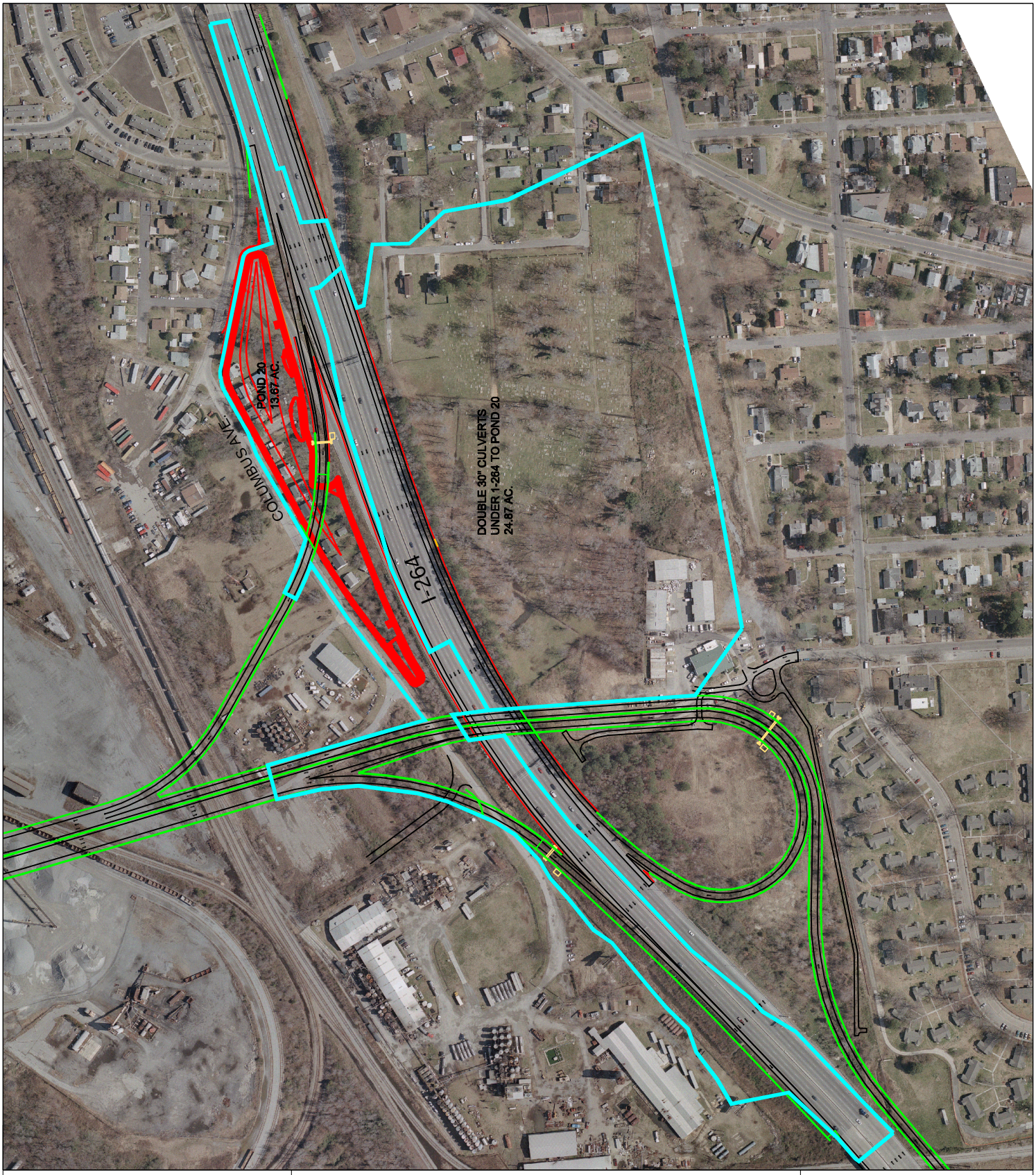
PARSONS BRINCKERHOFF

6161 KEMPSVILLE CIRCLE SUITE 110
NORFOLK, VA 23502

ELIZABETH RIVER TUNNELS PROJECT

DRAINAGE AREA MAP

POND 19



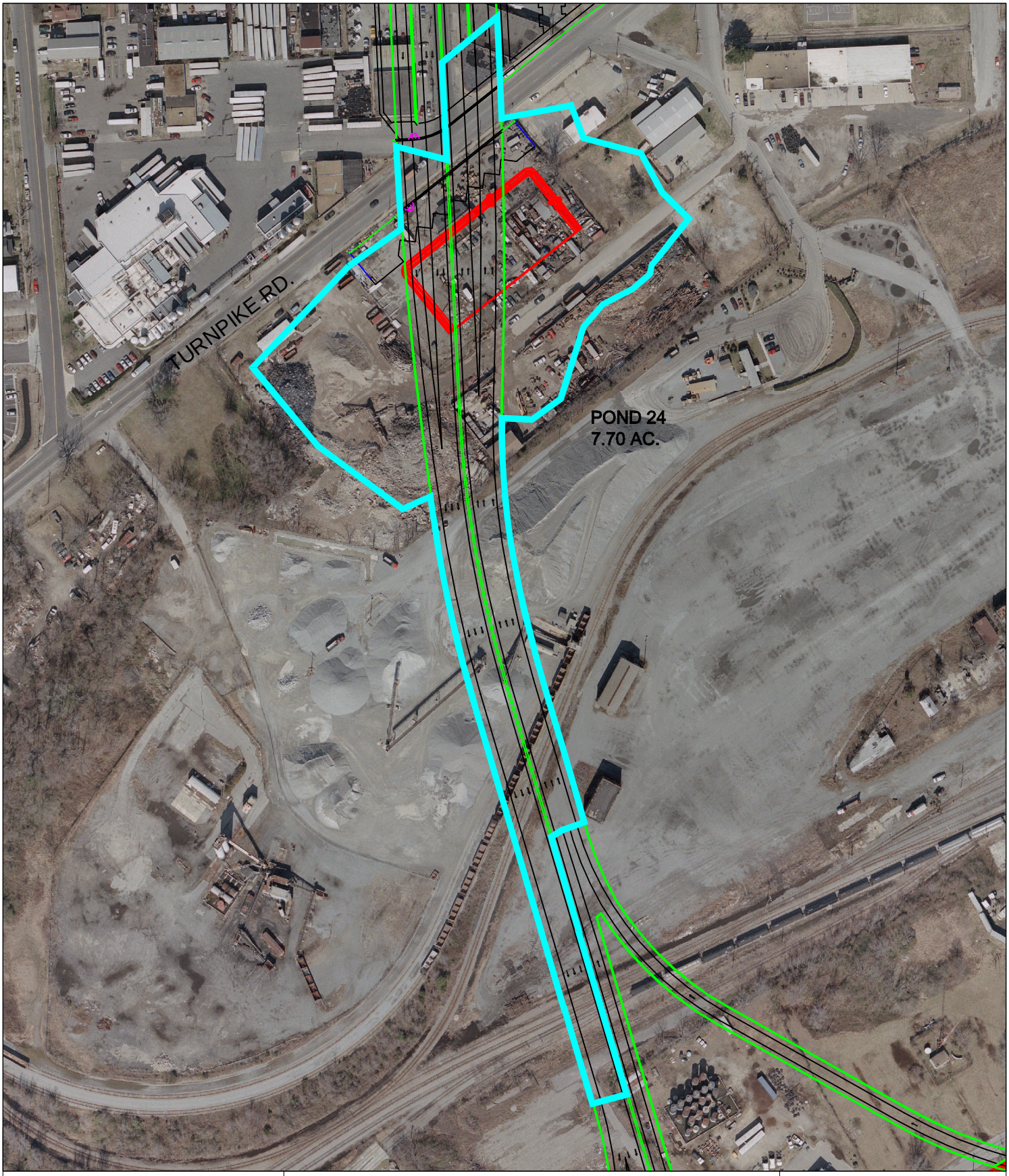
PARSONS BRINCKERHOFF

6161 KEMPSVILLE CIRCLE SUITE 110
NORFOLK, VA 23502

ELIZABETH RIVER TUNNELS PROJECT

DRAINAGE AREA MAP

POND 20



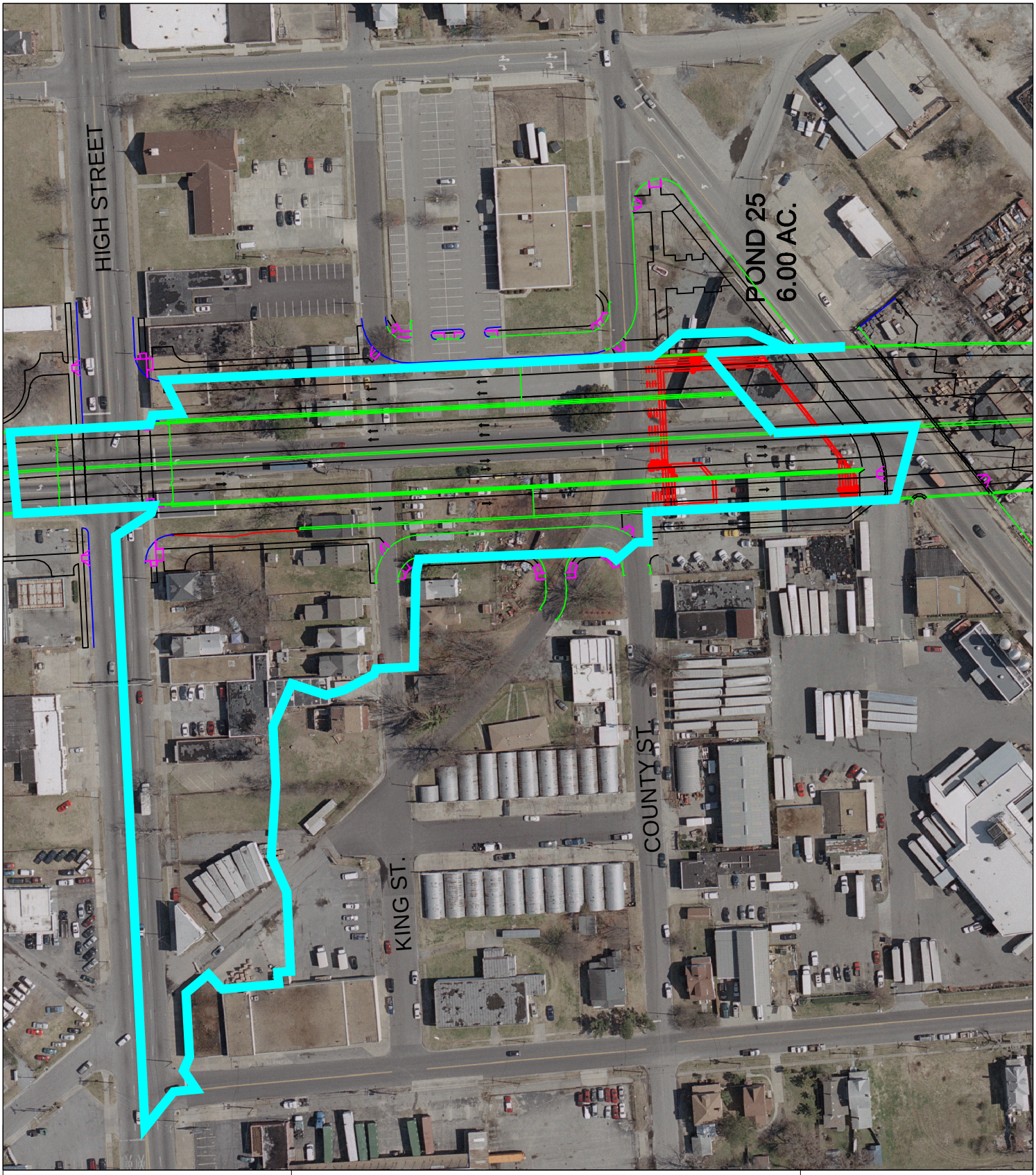
PARSONS BRINCKERHOFF

6161 KEMPSVILLE CIRCLE SUITE 110
NORFOLK, VA 23502

ELIZABETH RIVER TUNNELS PROJECT

DRAINAGE AREA MAP

POND 24



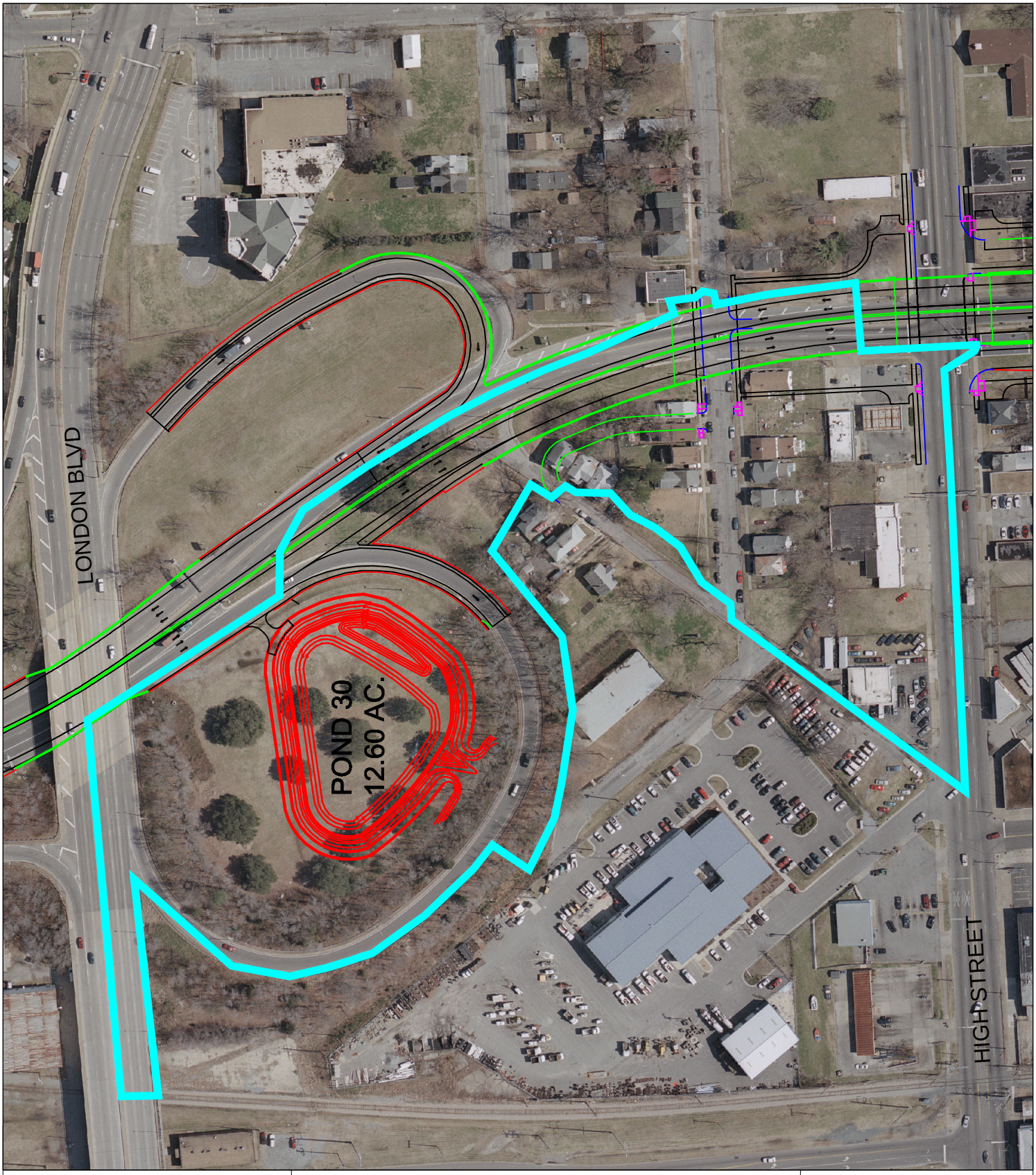
PARSONS BRINCKERHOFF

6161 KEMPSVILLE CIRCLE SUITE 110
NORFOLK, VA 23502

ELIZABETH RIVER TUNNELS PROJECT

DRAINAGE AREA MAP

POND 25



PARSONS BRINCKERHOFF

6161 KEMPSVILLE CIRCLE SUITE 110
NORFOLK, VA 23502

ELIZABETH RIVER TUNNELS PROJECT

DRAINAGE AREA MAP

POND 30

9.4. APPENDIX D – Stormwater Quality and Quantity Calculations

TOTAL PROJECT STORMWATER QUALITY REMOVAL REQUIREMENTS

Total Project Area (Including Offsite Area Draining towards Ponds)				145.48 Acres											
c pre-development				0.62											
c post-development				0.69											
I site(pre) =	142.86	x(	CR	-	0.2	)=									
I site(pre) =	142.86	x(	**0.620**	-	0.2	)=	**60**								
L site(pre) =	P	x	Pj	x [	0.05	+ (	0.009	x	I site(pre)	)] x	C	x	A	x	(2.72 / 12)
L site(pre) =	45	x	0.9	x [	0.05	+ (	0.009	x	60.00	)] x	0.26	x	145.48	x	0.23
L site(pre) =	**204.9**		lbs/yr												
I site(post) =	142.86	x(	CR	-	0.2	)=									
I site(post) =	142.86	x(	**0.691**	-	0.2	)=	**71**								
L site(post) =	P	x	Pj	x [	0.05	+ (	0.009	x	I site(post)	)] x	C	x	A	x	(2.72 / 12)
L site(post) =	45	x	0.9	x [	0.05	+ (	0.009	x	71	)] x	0.26	x	145.48	x	0.23
L site(post) =	**239.3**		lbs/yr												
Removal Requirement =				L site(post)	-	0.9 * L site(pre)			=	**RR**					
				239.3	-	184.39			=	54.86	lbs/yr				
Phosphorus Total Removal Requirment										**54.86**		lbs/yr			
Total Phosphorus Removed by Proposed BMPs										**62.61**		lbs/yr			

STORMWATER MANAGEMENT POND SUMMARY SHEET
STORMWATER MANAGEMENT BASIN 5

I. DRAINAGE AREAS PRE/POST

PRE-DEVELOPMENT

Area	Soil Type	Type	Area (acres)	CN	CR	CRA	Isite
EB 264	D	Pavement	2.28	98	0.9	2.05	
		Forest	1.71	77	0.2	0.34	
		Grass	1.56	80	0.3	0.47	
			5.55	**86**	**CR**	**0.52**	**45**

Weighted "C" (existing) 0.52
% impervious (existing) 45

Time of Concentration (Tc) = 10 minutes (See TOC calculation sheet)

POST-DEVELOPMENT

Area	Soil Type	Type	Area (acres)	CN	CR	CRA	Isite
EB 264	D	Pavement	3.44	98	0.9	3.10	
		Forest	1.01	77	0.2	0.20	
		Grass	0.98	80	0.3	0.29	
		Water	0.12	100	1	0.12	
			5.55	**91**	**CR**	**0.67**	**67**

Weighted "C" (proposed) 0.67
% impervious (proposed) 67

Time of Concentration (Tc) = 10 minutes (See TOC calculation sheet)

II. PROPOSED BMP **Detention**

Groundwater Elev per Boring

Boring #	GW Elev
12BH-010	8.00
12BH-012	8.00

Set Normal Pond Elevation at 8.00'

Pond Bottom material **SP-SM Cohesionless**

III. POND DIMENSIONS/STORAGE PROVIDED

Elevation	Area SF	Avg. Area SF	delta Volume CF	Sum Volume CF
8.00	4,021			
9.00	5,129	4,575	4,575	4,575
10.00	6,365	5,747	5,747	10,322
11.00	7,729	7,047	7,047	17,369
12.00	9,221	8,475	8,475	25,844

IV PHOSPHORUS REMOVAL

None - Quantity BMP only

V. POND OUTLET STRUCTURE SUMMARY

Type	Size	Elevation	
Culvert	18"	In = 9.00'	Out = 8.85'

VI. POND RESULTS SUMMARY

2-Year			25-Year			100-Year		
$Q_{max\ (pre)}$ =	**14.63**	cfs	$Q_{max\ (pre)}$ =	**22.50**	cfs	$Q_{max\ (pre)}$ =	**32.20**	cfs
$Q_{max\ (post)}$ =	**14.63**	cfs	$Q_{max\ (post)}$ =	**22.50**	cfs	$Q_{max\ (post)}$ =	**32.20**	cfs
			Reservoir Routing Results					
Outflow Q_{max} =	**3.82**	cfs	Outflow Q_{max} =	**8.06**	cfs	Outflow Q_{max} =	**11.88**	cfs
Max. Pond Water Surface Elevation =	**10.09**	feet	Max. Pond Water Surface Elevation =	**10.73**	feet	Max. Pond Water Surface Elevation =	**11.43**	feet

PARSONS BRINCKERHOFF COMPUTATION SHEET

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Made by Melissa Pritchard

Checked by Lewis White

PB PROJECT NO. 173513A

Subject **Elixabeth River Tunnels Project**

Norfolk/Portsmouth, VA

Post Development Tc Calculations

TIME OF CONCENTRATION (Tc) OR TRAVEL TIME (Tt)

Drainage Basin: Basin 5

SHEET FLOW

1	Surface Description			Pavement
2	Mannings Roughness Coefficient, n			0.02
3	Flow Length, L (total L , 300')		ft	20
4	Two-year, 24hr. Rainfall, P_2		in	3.61
5	Land Slope, s		ft/ft	0.012
6	$Tt = 0.007(nL)^{0.8}/P_2^{0.5}s^{0.4})$	Compute Tt	hr	0.01

SHALLOW CONCENTRATED FLOW

7	Surface Description (paved or unpaved)			unpaved
8	Flow Length, L		ft	0
9	Watercourse Slope, s		ft/ft	0.004
10	Average Velocity, V		ft/s	1.15
11	Tt=L/(3600*V)	Compute Tt	hr	0.000

CHANNEL FLOW

			Ditch	Pipes
12	Cross Sectional Area	ft^2	10.00	5.1
13	Wetted Permiter, Pw	ft	13.30	7.85
14	Hydraulic Radius, R_h=a/Pw	ft	0.75	0.65
15	Channel Slope, s	ft/ft	0.001	0.002
16	Mannings Open Channel Flow Coefficient, n		0.060	0.060
17	$V=(1.486/n)*R_h^{2/3}*s^{1/2}$	ft/s	0.50	0.74
18	Flow Length, L	ft	280	0
19	Tt=L/(3600*V)	hr	0.16	0.00
20	**Watershed or subarea Tc or Tt (add Tt in steps 6, 11, and 19)**	hr	0.16	
		min	9.80	

Use 10 Minutes

STORMWATER MANAGEMENT POND SUMMARY SHEET
STORMWATER MANAGEMENT POND 7

I. DRAINAGE AREAS PRE/POST

PRE-DEVELOPMENT

Area	Soil Type	Type	Area (acres)	CN	CR	CRA	Isite
Ramp EN	D	Pavement	1.09	98	0.9	0.98	
		Forest	0.64	77	0.2	0.13	
		Grass	1.68	80	0.3	0.50	
			3.41	**85**	**CR**	**0.47**	**39**

Weighted "C" (existing) 0.47
% impervious (existing) 39

Time of Concentration (Tc) = 10 minutes (See TOC calculation sheet)

POST-DEVELOPMENT

Area	Soil Type	Type	Area (acres)	CN	CR	CRA	Isite
Ramp EN	D	Pavement	1.89	98	0.9	1.70	
		Forest	0.64	77	0.2	0.13	
		Grass	0.56	80	0.3	0.17	
		Water	0.32	100	1	0.32	
			3.41	**91**	**CR**	**0.68**	**68**

Weighted "C" (proposed) 0.68
% impervious (proposed) 68

Time of Concentration (Tc) = 10 minutes (See TOC calculation sheet)

II. PROPOSED BMP **Dry Detention**

Groundwater Elev per Boring

Boring #	GW Elev
10BH-017	7.30
12BH-019	8.50

Set Normal Pond Elevation at 8.51'

III. POND DIMENSIONS/STORAGE PROVIDED

Elevation	Area SF	Avg. Area SF	delta Volume CF	Sum Volume CF
8.50	0			
8.51	200	100	1	1
9.00	10,687	5,444	2,667	2,668
10.00	12,579	11,633	11,633	14,301
11.00	14,547	13,563	13,563	27,864

IV PHOSPHORUS REMOVAL

Retrofitted existing dry detention basin.

V. POND OUTLET STRUCTURE SUMMARY

Type	Size	Elevation
Culvert	24"	8.51

VI. POND RESULTS SUMMARY

2-Year			25-Year			100-Year		
$Q_{max\ (pre)}$ =	**7.49**	cfs	$Q_{max\ (pre)}$ =	**12.73**	cfs	$Q_{max\ (pre)}$ =	**19.57**	cfs
$Q_{max\ (post)}$ =	**7.49**	cfs	$Q_{max\ (post)}$ =	**12.73**	cfs	$Q_{max\ (post)}$ =	**19.57**	cfs
			Reservoir Routing Results					
Outflow Q_{max} =	**3.23**	cfs	Outflow Q_{max} =	**5.11**	cfs	Outflow Q_{max} =	**7.08**	cfs
Max. Pond Water Surface Elevation =	**9.38**	feet	Max. Pond Water Surface Elevation =	**9.65**	feet	Max. Pond Water Surface Elevation =	**9.88**	feet

PARSONS BRINCKERHOFF COMPUTATION SHEET

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Made by Melissa Pritchard
Date
Checked by Lewis White
PB PROJECT NO. 173513A

Subject Elixabeth River Tunnels Project
Norfolk/Portsmouth, VA
Post Development Tc Calculations

TIME OF CONCENTRATION (Tc) OR TRAVEL TIME (Tt)

Drainage Basin: Pond 7

SHEET FLOW

1	Surface Description			Pavement
2	Mannings Roughness Coefficient, n			0.02
3	Flow Length, L (total L , 300')		ft	50
4	Two-year, 24hr. Rainfall, P_2		in	3.61
5	Land Slope, s		ft/ft	0.012
6	$Tt = 0.007(nL)^{0.8}/P_2^{0.5}s^{0.4})$	Compute Tt	hr	0.02

SHALLOW CONCENTRATED FLOW

7	Surface Description (paved or unpaved)			unpaved
8	Flow Length, L		ft	0
9	Watercourse Slope, s		ft/ft	0.004
10	Average Velocity, V		ft/s	1.15
11	Tt=L/(3600*V)	Compute Tt	hr	0.000

CHANNEL FLOW

			Ditch	Pipes
12	Cross Sectional Area	ft^2	10.00	5.1
13	Wetted Permiter, Pw	ft	13.30	7.85
14	Hydraulic Radius, R_h=a/Pw	ft	0.75	0.65
15	Channel Slope, s	ft/ft	0.001	0.002
16	Mannings Open Channel Flow Coefficient, n		0.060	0.060
17	$V=(1.486/n)*R_h^{2/3}*s^{1/2}$	ft/s	0.50	0.74
18	Flow Length, L	ft	0	370
19	Tt=L/(3600*V)	hr	0.00	0.14
20	**Watershed or subarea Tc or Tt (add Tt in steps 6, 11, and 19)**	hr	0.16	
		min	9.33	

Use 10 Minutes

STORMWATER MANAGEMENT POND SUMMARY SHEET
STORMWATER MANAGEMENT RAMP C BASIN

I. DRAINAGE AREAS PRE/POST

PRE-DEVELOPMENT

Area	Soil Type	Type	Area (acres)	CN	CR	CRA	Isite
Ramp EN&C	D	Pavement	0.36	98	0.9	0.32	
		Shoulder	0.35	85	0.5	0.18	
			0.71	**92**	**CR**	**0.70**	**72**

Weighted "C" (existing) 0.70
% impervious (existing) 72

Time of Concentration (Tc) = 5 minutes (See TOC calculation sheet)

POST-DEVELOPMENT

Area	Soil Type	Type	Area (acres)	CN	CR	CRA	Isite
Ramp EN&C	D	Pavement	0.48	98	0.9	0.43	
		Shoulder	0.14	85	0.5	0.07	
		Water	0.09	100	1	0.09	
			0.71	**96**	**CR**	**0.83**	**91**

Weighted "C" (proposed) 0.83
% impervious (proposed) 91

Time of Concentration (Tc) = 5 minutes (See TOC calculation sheet)

II. PROPOSED BMP **Detention**

Groundwater Elev per Boring

Boring #	GW Elev
12BH-030	8.00
12BH-031	10.00
12BH-032	8.00

Set Normal Pond Elevation at 9.00'

Pond Bottom material **SP-SM Cohesionless**

III. POND DIMENSIONS/STORAGE PROVIDED

Elevation	Area SF	Avg. Area SF	delta Volume CF	Sum Volume CF
8.00	2,920			
9.00	3,697	3,309	3,309	3,309
10.00	4,532	4,115	4,115	7,423
11.00	5,794	5,163	5,163	12,586

IV PHOSPHORUS REMOVAL

None - Quantity BMP only

V. POND OUTLET STRUCTURE SUMMARY

Type	Size	Elevation
Culvert	15"	7.00
Riser	4'	9.50
Orifice	3"	8.00

VI. POND RESULTS SUMMARY

2-Year			25-Year			100-Year		
$Q_{max\ (pre)}$ =	**2.79**	cfs	$Q_{max\ (pre)}$ =	**3.81**	cfs	$Q_{max\ (pre)}$ =	**6.02**	cfs
$Q_{max\ (post)}$ =	**2.79**	cfs	$Q_{max\ (post)}$ =	**3.81**	cfs	$Q_{max\ (post)}$ =	**6.02**	cfs
			Reservoir Routing Results					
Outflow Q_{max} =	**0.22**	cfs	Outflow Q_{max} =	**1.52**	cfs	Outflow Q_{max} =	**2.55**	cfs
Max. Pond Water Surface Elevation =	**9.37**	feet	Max. Pond Water Surface Elevation =	**9.59**	feet	Max. Pond Water Surface Elevation =	**9.66**	feet

PARSONS BRINCKERHOFF COMPUTATION SHEET

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Made by Melissa Pritchard

Checked by Lewis White

PB PROJECT NO. 173513A

Subject Elixabeth River Tunnels Project

Norfolk/Portsmouth, VA

Post Development Tc Calculations

TIME OF CONCENTRATION (Tc) OR TRAVEL TIME (Tt)

Drainage Basin: Ramp C Basin

SHEET FLOW

1	Surface Description			Pavement
2	Mannings Roughness Coefficient, n			0.02
3	Flow Length, L (total L , 300')		ft	50
4	Two-year, 24hr. Rainfall, P_2		in	3.61
5	Land Slope, s		ft/ft	0.012
6	$Tt = 0.007(nL)^{0.8}/P_2^{0.5}s^{0.4})$	Compute Tt	hr	0.02

SHALLOW CONCENTRATED FLOW

7	Surface Description (paved or unpaved)			unpaved
8	Flow Length, L		ft	0
9	Watercourse Slope, s		ft/ft	0.004
10	Average Velocity, V		ft/s	1.15
11	Tt=L/(3600*V)	Compute Tt	hr	0.000

CHANNEL FLOW

			Ditch	Pipes
12	Cross Sectional Area	ft^2	10.00	5.1
13	Wetted Permiter, Pw	ft	13.30	7.85
14	Hydraulic Radius, R_h=a/Pw	ft	0.75	0.65
15	Channel Slope, s	ft/ft	0.001	0.002
16	Mannings Open Channel Flow Coefficient, n		0.060	0.060
17	$V=(1.486/n)*R_h^{2/3}*s^{1/2}$	ft/s	0.50	0.74
18	Flow Length, L	ft	100	0
19	Tt=L/(3600*V)	hr	0.06	0.00
20	**Watershed or subarea Tc or Tt (add Tt in steps 6, 11, and 19)**	hr	0.07	
		min	4.35	

Use 5 Minutes

STORMWATER MANAGEMENT POND SUMMARY SHEET
STORMWATER MANAGEMENT RAMP EN BASIN

I. DRAINAGE AREAS PRE/POST

PRE-DEVELOPMENT

Area	Soil Type	Type	Area (acres)	CN	CR	CRA	Isite
Ramp EN	D	Pavement	0.05	98	0.9	0.05	
		Shoulder	0.82	85	0.5	0.41	
			0.87	**86**	**CR**	**0.52**	**46**

Weighted "C" (existing) 0.52
% impervious (existing) 46

Time of Concentration (Tc) = 5 minutes (See TOC calculation sheet)

POST-DEVELOPMENT

Area	Soil Type	Type	Area (acres)	CN	CR	CRA	Isite
Ramp EN	D	Pavement	0.44	98	0.9	0.40	
		Shoulder	0.40	85	0.5	0.20	
		Water	0.03	100	1	0.03	
			0.87	**92**	**CR**	**0.72**	**74**

Weighted "C" (proposed) 0.72
% impervious (proposed) 74

Time of Concentration (Tc) = 5 minutes (See TOC calculation sheet)

II. PROPOSED BMP **Detention**

Groundwater Elev per Boring

Boring #	GW Elev
10BH-020	7.20
12BH-123	7.00

Set Normal Pond Elevation at 8.00'

Pond Bottom material **SP-SM Cohesionless**

III. POND DIMENSIONS/STORAGE PROVIDED

Elevation	Area SF	Avg. Area SF	delta Volume CF	Sum Volume CF
7.90	43			
8.00	511	277	28	28
9.00	1,004	524	576	576
10.00	1,570	1,041	2,081	2,109
11.00	2,193	1,882	1,882	3,990

IV PHOSPHORUS REMOVAL

None - Quantity BMP only

V. POND OUTLET STRUCTURE SUMMARY

Type	Size	Elevation
Culvert	15"	7.30'
Riser	4'	10.0'
Orifice	3"	7.90'

VI. POND RESULTS SUMMARY

2-Year			25-Year			100-Year		
$Q_{max\ (pre)}$ =	**2.95**	cfs	$Q_{max\ (pre)}$ =	**4.45**	cfs	$Q_{max\ (pre)}$ =	**6.36**	cfs
$Q_{max\ (post)}$ =	**2.95**	cfs	$Q_{max\ (post)}$ =	**4.45**	cfs	$Q_{max\ (post)}$ =	**6.36**	cfs
			Reservoir Routing Results					
Outflow Q_{max} =	**0.26**	cfs	Outflow Q_{max} =	**3.29**	cfs	Outflow Q_{max} =	**4.67**	cfs
Max. Pond Water Surface Elevation =	**9.69**	feet	Max. Pond Water Surface Elevation =	**9.90**	feet	Max. Pond Water Surface Elevation =	**10.02**	feet

PARSONS BRINCKERHOFF COMPUTATION SHEET

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Made by Melissa Pritchard

Checked by Lewis White

PB PROJECT NO. 173513A

Subject **Elixabeth River Tunnels Project**

Norfolk/Portsmouth, VA

Post Development Tc Calculations

TIME OF CONCENTRATION (Tc) OR TRAVEL TIME (Tt)

Drainage Basin: Ramp EN Basin

SHEET FLOW

1	Surface Description			Pavement
2	Mannings Roughness Coefficient, n			0.02
3	Flow Length, L (total L , 300')		ft	40
4	Two-year, 24hr. Rainfall, P_2		in	3.61
5	Land Slope, s		ft/ft	0.012
6	$Tt = 0.007(nL)^{0.8}/P_2^{0.5}s^{0.4})$	Compute Tt	hr	0.01

SHALLOW CONCENTRATED FLOW

7	Surface Description (paved or unpaved)			unpaved
8	Flow Length, L		ft	0
9	Watercourse Slope, s		ft/ft	0.004
10	Average Velocity, V		ft/s	1.15
11	Tt=L/(3600*V)	Compute Tt	hr	0.000

CHANNEL FLOW

			Ditch	Pipes
12	Cross Sectional Area	ft^2	10.00	5.1
13	Wetted Permiter, Pw	ft	13.30	7.85
14	Hydraulic Radius, R_h=a/Pw	ft	0.75	0.65
15	Channel Slope, s	ft/ft	0.001	0.002
16	Mannings Open Channel Flow Coefficient, n		0.060	0.060
17	$V=(1.486/n)*R_h^{2/3}*s^{1/2}$	ft/s	0.50	0.74
18	Flow Length, L	ft	120	0
19	Tt=L/(3600*V)	hr	0.07	0.00
20	**Watershed or subarea Tc or Tt (add Tt in steps 6, 11, and 19)**	hr	0.08	
		min	4.85	

Use 5 Minutes

II. PROPOSED BMP **Extended-Detention Pond**
Phosphorous Removal EFF = 35%
Permanent Storage req'd = 2WQV

IV PHOSPHORUS REMOVAL

I site(post) =	142.86	x(	CR	-	0.2	)=									
I site(post) =	142.86	x(	**0.61**	-	0.2	)=	**58**								
L site(post) =	P	x	Pj	x [	0.05	+ (	0.009	x	I site(post)	)] x	C	x	A	x	(2.72 / 12)
L site(post) =	45	x	0.9	x [	0.05	+ (	0.009	x	88	)] x	0.26	x	4.96	x	0.23
L site(post) =	**10.0**		lbs/yr												
Removal Efficiency	35%														
Phosphorus Removed	**3.49**		lbs/yr												

STORMWATER MANAGEMENT POND SUMMARY SHEET
STORMWATER MANAGEMENT POND #8

I. DRAINAGE AREAS PRE/POST

PRE-DEVELOPMENT

Area	Soil Type	Type	Area (acres)	CN	CR	CRA	Isite
POND 8	D	Pavement	0.90	98	0.9	0.81	
		Shoulder	2.03	85	0.5	1.02	
		Grass	2.03	80	0.3	0.61	
			4.96	**85**	**CR**	**0.49**	**41**

Weighted "C" (existing) 0.49
% impervious (existing) 41

Time of Concentration (Tc) = 26 minutes (See TOC calculation sheet)

POST-DEVELOPMENT

Area	Soil Type	Type	Area (acres)	CN	CR	CRA	Isite
POND 8	D	Pavement	1.67	98	0.9	1.50	
		Shoulder	2.20	85	0.5	1.10	
		Grass	0.96	80	0.3	0.29	
		Water	0.13	100	1	0.13	
			4.96	**89**	**CR**	**0.61**	**58**

Weighted "C" (proposed) 0.61
% impervious (proposed) 58

Time of Concentration (Tc) = 26 minutes (See TOC calculation sheet)

II. PROPOSED BMP **Extended Dry Detention**
Phosphorous Removal EFF = 35%
Permanent Storage req'd = 2WQV

Groundwater Elev per Boring

Boring #	GW Elev
10BH-023	9.40
12BH-033	10.50
12BH-128	9.50
12BH-132	10.50

Set Normal Pond Elevation at 10.00

Pond Bottom material **SP-SM Cohesionless**

WQV = 4.96 Acres x 58% impervious x .5 inches
WQV = 5218 Cu Ft
2WQV = 10436 Cu Ft

Required storage below permanent pool = **10,436** Cu Ft

Provided storage below permanent pool = **17,832** Cu Ft

III. POND DIMENSIONS/STORAGE PROVIDED

Elevation	Area SF	Avg. Area SF	delta Volume CF	Sum Volume CF			
7.50	10						
8.00	5,457	2,734	1,367	1,367			
9.00	7,864	6,661	6,661	8,027			
10.00	11,745	9,805	9,805	**17,832**	**Cu Ft**	**2WQV**	**Perm. Pool = 10.00**
11.00	25,479	18,612	18,612	36,444			
12.00	28,409	26,944	26,944	63,388			

IV PHOSPHORUS REMOVAL

See Water Quality Calculation Sheets

V. POND OUTLET STRUCTURE SUMMARY

Type	Size	Elevation
Culvert	24"	7.00
Riser	4'x4'	11.00
Orifice	3"	7.50
Orifice	1-6"	10.00

VI. POND RESULTS SUMMARY

2-Year			25-Year			100-Year		
$Q_{max\ (pre)}$ =	**8.27**	cfs	$Q_{max\ (pre)}$ =	**13.39**	cfs	$Q_{max\ (pre)}$ =	**19.52**	cfs
$Q_{max\ (post)}$ =	**8.27**	cfs	$Q_{max\ (post)}$ =	**13.39**	cfs	$Q_{max\ (post)}$ =	**19.52**	cfs
			Reservoir Routing Results					
Outflow Q_{max} =	**1.07**	cfs	Outflow Q_{max} =	**3.71**	cfs	Outflow Q_{max} =	**8.92**	cfs
Max. Pond Water Surface Elevation =	**10.76**	feet	Max. Pond Water Surface Elevation =	**11.10**	feet	Max. Pond Water Surface Elevation =	**11.30**	feet

PARSONS BRINCKERHOFF COMPUTATION SHEET

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PB PROJECT NO. 173513A

Subject Elixabeth River Tunnels Project

Norfolk/Portsmouth, VA

Post Development Tc Calculations

TIME OF CONCENTRATION (Tc) OR TRAVEL TIME (Tt)

Drainage Basin: POND 8

SHEET FLOW

1	Surface Description			Paved
2	Mannings Roughness Coefficient, n			0.02
3	Flow Length, L (total L , 300')		ft	267
4	Two-year, 24hr. Rainfall, P_2		in	3.61
5	Land Slope, s		ft/ft	0.007
6	$Tt = 0.007(nL)^{0.8}/P_2^{0.5}s^{0.4}$)	Compute Tt	hr	0.08

SHALLOW CONCENTRATED FLOW

7	Surface Description (paved or unpaved)			paved
8	Flow Length, L		ft	100
9	Watercourse Slope, s		ft/ft	0.002
10	Average Velocity, V		ft/s	2.45
11	Tt=L/(3600*V)	Compute Tt	hr	0.011

CHANNEL FLOW

			Ditch	Pipes
12	Cross Sectional Area	ft^2	10.00	5.1
13	Wetted Permiter, Pw	ft	13.30	7.85
14	Hydraulic Radius, R_h=a/Pw	ft	0.75	0.65
15	Channel Slope, s	ft/ft	0.001	0.002
16	Mannings Open Channel Flow Coefficient, n		0.060	0.060
17	$V=(1.486/n)*R_h^{2/3}*s^{1/2}$	ft/s	0.50	0.74
18	Flow Length, L	ft	587	0
19	Tt=L/(3600*V)	hr	0.33	0.00
20	**Watershed or subarea Tc or Tt (add Tt in steps 6, 11, and 19)**	hr	0.42	
		min	25.07	

Use 26 Minutes

II. PROPOSED BMP **Retention Basin III**
Phosphorous Removal EFF = 65%
Permanent Storage req'd = 4WQV

IV PHOSPHORUS REMOVAL

I site(post) =	142.86	x(	CR	-	0.2	)=									
I site(post) =	142.86	x(	**0.63**	-	0.2	)=	**61**								
L site(post) =	P	x	Pj	x [	0.05	+ (	0.009	x	I site(post)	)] x	C	x	A	x	(2.72 / 12)
L site(post) =	45	x	0.9	x [	0.05	+ (	0.009	x	61	)] x	0.26	x	11.28	x	0.23
L site(post) =	**16.1**		lbs/yr												
Removal Efficiency	65%														
Phosphorus Removed	**10.48**		lbs/yr												

STORMWATER MANAGEMENT POND SUMMARY SHEET
STORMWATER MANAGEMENT POND #14

I. DRAINAGE AREAS PRE/POST

PRE-DEVELOPMENT

Area	Soil Type	Type	Area (acres)	CN	CR	CRA	Isite
POND 14	D	Pavement	1.69	98	0.9	1.52	
		Industrial	0.73	93	0.85	0.62	
		Grass	8.86	80	0.3	2.66	
			11.28	**84**	**CR**	**0.43**	**32**

Weighted "C" (existing) 0.43
% impervious (existing) 32

Time of Concentration (Tc) = 26 minutes (See TOC calculation sheet)

POST-DEVELOPMENT

Area	Soil Type	Type	Area (acres)	CN	CR	CRA	Isite
POND 14	D	Pavement	3.89	98	0.9	3.50	
		Industrial	0.73	93	0.85	0.62	
		Grass	5.29	80	0.3	1.59	
		Water	1.37	100	1	1.37	
			11.28	**89**	**CR**	**0.63**	**61**

Weighted "C" (proposed) 0.63
% impervious (proposed) 61

Time of Concentration (Tc) = 26 minutes (See TOC calculation sheet)

II. PROPOSED BMP **Retention Basin III**
Phosphorous Removal EFF = 65%
Permanent Storage req'd = 4WQV

Groundwater Elev per Boring

Boring #	GW Elev
12BH-039	10.00
10BH-073	8.00
10BH-075	6.50
10BH-077	9.10

Set Normal Pond Elevation at 9.0

Pond Bottom material **SP-SM Cohesionless**

WQV = 11.28 Acres x 61% impervious x .5 inches
WQV = 12488 Cu Ft
4WQV = 49950 Cu Ft

Required storage below permanent pool = **49,950** Cu Ft

Provided storage below permanent pool = **81,963** Cu Ft

III. POND DIMENSIONS/STORAGE PROVIDED

Elevation	Area SF	Avg. Area SF	delta Volume CF	Sum Volume CF			
6.20	0.01						
7.00	30,179	15,090	12,072	12,072			
8.00	32,395	31,287	31,287	43,359			
9.00	44,813	38,604	38,604	**81,963**	**Cu Ft**	**4WQV**	**Perm. Pool = 9.00**
10.00	81,997	63,405	63,405	145,368			
11.00	100,904	91,451	91,451	236,818			
12.00	117,638	109,271	109,271	346,089			

IV PHOSPHORUS REMOVAL

See Water Quality Calculation Sheets

V. POND OUTLET STRUCTURE SUMMARY

Type	Size	Elevation
Culvert	18"	9.00
Riser	4'x4'	11.27
Orifice	3"	9.00

VI. POND RESULTS SUMMARY

2-Year			25-Year			100-Year		
$Q_{max\ (pre)}$ =	**14.08**	cfs	$Q_{max\ (pre)}$ =	**26.09**	cfs	$Q_{max\ (pre)}$ =	**33.35**	cfs
$Q_{max\ (post)}$ =	**14.06**	cfs	$Q_{max\ (post)}$ =	**26.06**	cfs	$Q_{max\ (post)}$ =	**33.30**	cfs
			Reservoir Routing Results					
Outflow Q_{max} =	**0.15**	cfs	Outflow Q_{max} =	**0.23**	cfs	Outflow Q_{max} =	**0.26**	cfs
Max. Pond Water Surface Elevation =	**9.55**	feet	Max. Pond Water Surface Elevation =	**10.05**	feet	Max. Pond Water Surface Elevation =	**10.39**	feet

PARSONS BRINCKERHOFF COMPUTATION SHEET

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Made by Melissa Pritchard

Checked by Lewis White

Subject Elixabeth River Tunnels Project

Norfolk/Portsmouth, VA

Post Development Tc Calculations

PB PROJECT NO. 173513A

TIME OF CONCENTRATION (Tc) OR TRAVEL TIME (Tt)

Drainage Basin: POND 14

SHEET FLOW

1	Surface Description			Grass
2	Mannings Roughness Coefficient, n			0.06
3	Flow Length, L (total L , 300')		ft	300
4	Two-year, 24hr. Rainfall, P_2		in	3.61
5	Land Slope, s		ft/ft	0.006
6	$Tt = 0.007(nL)^{0.8}/P_2^{0.5}s^{0.4})$	Compute Tt	hr	0.29

SHALLOW CONCENTRATED FLOW

7	Surface Description (paved or unpaved)			unpaved
8	Flow Length, L		ft	0
9	Watercourse Slope, s		ft/ft	0.004
10	Average Velocity, V		ft/s	1.15
11	Tt=L/(3600*V)	Compute Tt	hr	0.000

CHANNEL FLOW

			Ditch	Pipes
12	Cross Sectional Area	ft^2	10.00	5.1
13	Wetted Permiter, Pw	ft	13.30	7.85
14	Hydraulic Radius, R_h=a/Pw	ft	0.75	0.65
15	Channel Slope, s	ft/ft	0.008	0.002
16	Mannings Open Channel Flow Coefficient, n		0.060	0.060
17	$V=(1.486/n)*R_h^{2/3}*s^{1/2}$	ft/s	1.83	0.74
18	Flow Length, L	ft	693	50
19	Tt=L/(3600*V)	hr	0.11	0.02
20	**Watershed or subarea Tc or Tt (add Tt in steps 6, 11, and 19)**	hr	0.42	
		min	25.06	

Use 26 Minutes

II. PROPOSED BMP **Retention Basin II**
Phosphorous Removal EFF = 50%
Permanent Storage Req'd = 4WQV

IV PHOSPHORUS REMOVAL

I site(post) =	142.86	x(	CR	-	0.2	)=									
I site(post) =	142.86	x(	**0.78**	-	0.2	)=	**83**								
L site(post) =	P	x	Pj	x [	0.05	+ (	0.009	x	I site(post)	)] x	C	x	A	x	(2.72 / 12)
L site(post) =	45	x	0.9	x [	0.05	+ (	0.009	x	85	)] x	0.26	x	21.90	x	0.23
L site(post) =	**42.6**		lbs/yr												
Removal Efficiency	50%														
Phosphorus Removed	**21.30**		lbs/yr												

STORMWATER MANAGEMENT POND SUMMARY SHEET
STORMWATER MANAGEMENT POND #19

I. DRAINAGE AREAS PRE/POST

PRE-DEVELOPMENT

Area	Soil Type	Type	Area (acres)	CN	CR	CRA	Isite
POND 19	D	Pavement	2.29	98	0.9	2.06	
		Industrial	15.31	93	0.85	13.01	
		Grass	4.30	80	0.3	1.29	
			21.90	**91**	**CR**	**0.75**	**78**

Weighted "C" (existing) 0.75
% impervious (existing) 78

Time of Concentration (Tc) = 74 minutes (See TOC calculation sheet)

POST-DEVELOPMENT

Area	Soil Type	Type	Area (acres)	CN	CR	CRA	Isite
POND 19	D	Pavement	2.84	98	0.9	2.56	
		Industrial	14.25	93	0.85	12.11	
		Grass	3.30	80	0.3	0.99	
		Water	1.51	100	1	1.51	
			21.90	**92**	**CR**	**0.78**	**83**

Weighted "C" (proposed) 0.78
% impervious (proposed) 83

Time of Concentration (Tc) = 74 minutes (See TOC calculation sheet)

II. PROPOSED BMP **Retention Basin II**
Phosphorous Removal EFF = 50%
Permanent Storage req'd = 4WQV

Groundwater Elev per Boring

Boring #	GW Elev
10BH-118	8.50
10BH-133	7.00

Set Normal Pond Elevation at 8.5

Pond Bottom material **SP-SM Cohesionless**

WQV = 21.9 Acres x 83% impervious x .5 inches
WQV = 32991 Cu Ft
4WQV = 131965 Cu Ft

Required storage below permanent pool = **131,965** Cu Ft

Provided storage below permanent pool = **159,561** Cu Ft

III. POND DIMENSIONS/STORAGE PROVIDED

Elevation	Area SF	Avg. Area SF	delta Volume CF	Sum Volume CF			
5.50	0						
6.00	54,165	27,083	13,541	13,541			
7.00	57,534	55,850	55,850	69,391			
8.00	60,959	59,247	59,247	128,637			
8.50	62,693	60,114	90,170	**159,561**	**Cu Ft**	**4WQV**	**Perm. Pool = 8.50**
9.00	69,031	65,862	32,931	192,492			
10.00	72,770	67,732	101,597	261,158			
11.00	76,566	38,283	421,113	421,113			
12.00	80,419	40,210	482,514	482,514			

IV PHOSPHORUS REMOVAL

See Water Quality Calculation Sheets

V. POND OUTLET STRUCTURE SUMMARY

Type	Size	Elevation	
Culvert	4-23"x14"	8.50	6.50

VI. POND RESULTS SUMMARY

2-Year			25-Year			100-Year		
$Q_{max\ (pre)}$ =	**18.77**	cfs	$Q_{max\ (pre)}$ =	**36.15**	cfs	$Q_{max\ (pre)}$ =	**73.99**	cfs
$Q_{max\ (post)}$ =	**18.77**	cfs	$Q_{max\ (post)}$ =	**36.15**	cfs	$Q_{max\ (post)}$ =	**72.95**	cfs
			Reservoir Routing Results					
Outflow Q_{max} =	**12.20**	cfs	Outflow Q_{max} =	**26.92**	cfs	Outflow Q_{max} =	**35.83**	cfs
Max. Pond Water Surface Elevation =	**9.54**	feet	Max. Pond Water Surface Elevation =	**10.18**	feet	Max. Pond Water Surface Elevation =	**10.65**	feet

PARSONS BRINCKERHOFF COMPUTATION SHEET

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Made by Melissa Pritchard

Checked by Lewis White

PB PROJECT NO. 173513A

Subject **Elixabeth River Tunnels Project**

Norfolk/Portsmouth, VA

Post Development Tc Calculations

TIME OF CONCENTRATION (Tc) OR TRAVEL TIME (Tt)

Drainage Basin: POND 19

SHEET FLOW

1	Surface Description			Grass
2	Mannings Roughness Coefficient, n			0.02
3	Flow Length, L (total L , 300')		ft	300
4	Two-year, 24hr. Rainfall, P_2		in	3.61
5	Land Slope, s		ft/ft	0.002
6	$Tt = 0.007(nL)^{0.8}/P_2^{0.5}s^{0.4})$	Compute Tt	hr	0.15

SHALLOW CONCENTRATED FLOW

7	Surface Description (paved or unpaved)			unpaved
8	Flow Length, L		ft	1000
9	Watercourse Slope, s		ft/ft	0.003
10	Average Velocity, V		ft/s	1.05
11	Tt=L/(3600*V)	Compute Tt	hr	0.265

CHANNEL FLOW

			Ditch	Pipes
12	Cross Sectional Area	ft^2	10.00	5.1
13	Wetted Permiter, Pw	ft	13.30	7.85
14	Hydraulic Radius, R_h=a/Pw	ft	0.75	0.65
15	Channel Slope, s	ft/ft	0.002	0.002
16	Mannings Open Channel Flow Coefficient, n		0.070	0.060
17	$V=(1.486/n)*R_h^{2/3}*s^{1/2}$	ft/s	0.78	0.74
18	Flow Length, L	ft	2250	42
19	Tt=L/(3600*V)	hr	0.80	0.02
20	**Watershed or subarea Tc or Tt (add Tt in steps 6, 11, and 19)**	hr	1.22	
		min	73.43	

Use 74 Minutes

II. PROPOSED BMP **Extended Detention Pond**
Phosphorous Removal EFF = 35%
Permanent Storage Req'd = 2WQV

IV PHOSPHORUS REMOVAL

I site(post) =	142.86	x(	CR	-	0.2	)=									
I site(post) =	142.86	x(	**0.54**	-	0.2	)=	**49**								
L site(post) =	P	x	Pj	x [	0.05	+ (	0.009	x	I site(post)	)] x	C	x	A	x	(2.72 / 12)
L site(post) =	45	x	0.9	x [	0.05	+ (	0.009	x	49	)] x	0.26	x	38.54	x	0.23
L site(post) =	**45.2**		lbs/yr												
Removal Efficiency	35%														
Phosphorus Removed	**15.81**		lbs/yr												

STORMWATER MANAGEMENT POND SUMMARY SHEET
STORMWATER MANAGEMENT POND #20

I. DRAINAGE AREAS PRE/POST

PRE-DEVELOPMENT

Area	Soil Type	Type	Area (acres)	CN	CR	CRA	Isite
POND 20	D	Pavement	8.85	98	0.9	7.97	
		Industrial	2.10	93	0.85	1.79	
		Grass	21.87	80	0.3	6.56	
		Residential	5.72	92	0.45	2.57	
			38.54	**87**	**CR**	**0.49**	**41**

Weighted "C" (existing) 0.49
% impervious (existing) 41

Time of Concentration (Tc) = 69 minutes

POST-DEVELOPMENT

Area	Soil Type	Type	Area (acres)	CN	CR	CRA	Isite
POND 20	D	Pavement	9.93	98	0.9	8.94	
		Industrial	2.10	93	0.85	1.79	
		Grass	21.71	80	0.3	6.51	
		Residential	2.64	92	0.45	1.19	
		Water	2.16	100	1	2.16	
			38.54	**87**	**CR**	**0.53**	**48**

Weighted "C" (proposed) 0.53
% impervious (proposed) 48

Time of Concentration (Tc) = 78 minutes (See TOC calculation sheet)

II. PROPOSED BMP **Extended Detention Pond**
Phosphorous Removal EFF = 35%
Permanent Storage req'd = 2WQV

Groundwater Elev per Boring

Boring #	GW Elev
12BH-064	6.50
12BH-065	6.00

Set Normal Pond Elevation at 6.50

Pond Bottom material **SP-SM Cohesionless**

WQV = 38.54 Acres x 48% impervious x .5 inches
WQV = 33576 Cu Ft
2WQV = 67152 Cu Ft

Required storage below permanent pool = **67,152** Cu Ft

Provided storage below permanent pool = **102,832** Cu Ft

III. POND DIMENSIONS/STORAGE PROVIDED

Elevation	Area SF	Avg. Area SF	delta Volume CF	Sum Volume CF			
4.60	3,294						
5.00	10,425	6,860	2,744	2,744			
6.00	33,036	21,731	21,731	24,474			
6.50	101,183	52,239	78,358	**102,832**	**Cu Ft**	**2WQV**	**Permanent Pool = 6.5**
7.00	104,892	103,038	51,519	154,351			
8.00	112,362	108,627	108,627	262,978			
9.00	119,906	116,134	116,134	379,112			
10.00	127,546	123,726	123,726	502,838			
11.00	132,450	129,998	129,998	632,836			

IV PHOSPHORUS REMOVAL

See Water Quality Calculation Sheets

V. POND OUTLET STRUCTURE SUMMARY

Type	Size	Elevation
Culvert	45"x29"	4.50
Riser	4'x4'	8.50
Orifice	2-6"	6.50
Orifice	3"	4.60

VI. POND RESULTS SUMMARY

2-Year			25-Year			100-Year		
$Q_{max\ (pre)}$ =	**31.10**	cfs	$Q_{max\ (pre)}$ =	**56.48**	cfs	$Q_{max\ (pre)}$ =	**80.91**	cfs
$Q_{max\ (post)}$ =	**34.56**	cfs	$Q_{max\ (post)}$ =	**66.58**	cfs	$Q_{max\ (post)}$ =	**104.90**	cfs
			Reservoir Routing Results					
Outflow Q_{max} =	**2.82**	cfs	Outflow Q_{max} =	**24.03**	cfs	Outflow Q_{max} =	**47.66**	cfs
Max. Pond Water Surface Elevation =	**8.38**	feet	Max. Pond Water Surface Elevation =	**9.18**	feet	Max. Pond Water Surface Elevation =	**9.87**	feet

PARSONS BRINCKERHOFF COMPUTATION SHEET

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Made by Melissa Pritchard

Checked by Lewis White

Subject Elixabeth River Tunnels Project

Norfolk/Portsmouth, VA

Post Development Tc Calculations

PB PROJECT NO. 173513A

TIME OF CONCENTRATION (Tc) OR TRAVEL TIME (Tt)

Drainage Basin: Pond 20

SHEET FLOW

1	Surface Description			Grass
2	Mannings Roughness Coefficient, n			0.06
3	Flow Length, L (total L , 300')		ft	0
4	Two-year, 24hr. Rainfall, P_2		in	3.61
5	Land Slope, s		ft/ft	0.001
6	$Tt = 0.007(nL)^{0.8}/P_2^{0.5}s^{0.4})$	Compute Tt	hr	0.00

SHALLOW CONCENTRATED FLOW

7	Surface Description (paved or unpaved)			Grass
8	Flow Length, L		ft	0
9	Watercourse Slope, s		ft/ft	0.001
10	Average Velocity, V		ft/s	0.00
11	Tt=L/(3600*V)	Compute Tt	hr	0.000

CHANNEL FLOW

				Ditch	Pipes
12	Cross Sectional Area		ft^2	10.00	5.1
13	Wetted Permiter, Pw		ft	13.30	7.85
14	Hydraulic Radius, R_h=a/Pw		ft	0.75	0.65
15	Channel Slope, s		ft/ft	0.003	0.001
16	Mannings Open Channel Flow Coefficient, n			0.060	0.060
17	$V=(1.486/n)*R_h^{2/3}*s^{1/2}$		ft/s	1.06	0.59
18	Flow Length, L		ft	151	33
19	Tt=L/(3600*V)		hr	0.04	0.02
20	**Watershed or subarea Tc or Tt (add Tt in steps 6, 11, and 19)**		hr	0.06	
			min	3.30	

	4	Minutes
POND 19	74	Minutes
TOTAL	78	Minutes

STORMWATER MANAGEMENT POND SUMMARY SHEET
STORMWATER MANAGEMENT POND #24

I. DRAINAGE AREAS PRE/POST

PRE-DEVELOPMENT

Area	Soil Type	Type	Area (acres)	CN	CR	CRA	Isite
POND 24	D	Pavement	0.50	98	0.9	0.45	
		Industrial	7.20	93	0.85	6.12	
			7.70	**93**	**CR**	**0.85**	**93**

Weighted "C" (existing) 0.85
% impervious (existing) 93

Time of Concentration (Tc) = 8 minutes (See TOC calculation sheet)

POST-DEVELOPMENT

Area	Soil Type	Type	Area (acres)	CN	CR	CRA	Isite
POND 24	D	Pavement	4.50	98	0.9	4.05	
		Industrial	2.80	93	0.85	2.38	
		Water	0.40	100	1	0.40	
			7.70	**96**	**CR**	**0.89**	**98**

Weighted "C" (proposed) 0.89
% impervious (proposed) 98

Time of Concentration (Tc) = 8 minutes (See TOC calculation sheet)

II. PROPOSED BMP **Retention Basin**

Groundwater Elev per Boring

Boring #	GW Elev
10BH-179	7.40
10BH-182	8.20

Set Normal Pond Elevation at 8.5

Pond Bottom material **SP-SM Cohesionless**

III. POND STAGE/STORAGE TABLE

Elevation	Area SF	Avg. Area SF	delta Volume CF	Sum Volume CF
7.00	25,496			
8.00	27,609	26,553	26,553	26,553
9.00	29,787	28,698	28,698	55,251
10.00	32,029	30,908	30,908	86,159
11.00	34,335	33,182	33,182	119,341

IV. POND OUTLET STRUCTURE SUMMARY

Type	Size	Elevation
Riser	4'x4'	9.67
Orifice	3"	8.50
Culvert	15"	6.90

V. POND RESULTS SUMMARY

2-Year			25-Year			100-Year		
$Q_{max\ (pre)}$ =	**38.30**	cfs	$Q_{max\ (pre)}$ =	**57.20**	cfs	$Q_{max\ (pre)}$ =	**82.35**	cfs
$Q_{max\ (post)}$ =	**38.30**	cfs	$Q_{max\ (post)}$ =	**57.20**	cfs	$Q_{max\ (post)}$ =	**82.35**	cfs
			Reservoir Routing Results					
Outflow Q_{max} =	**0.14**	cfs	Outflow Q_{max} =	**0.17**	cfs	Outflow Q_{max} =	**0.22**	cfs
Max. Pond Water Surface Elevation =	**8.97**	feet	Max. Pond Water Surface Elevation =	**9.19**	feet	Max. Pond Water Surface Elevation =	**9.49**	feet

PARSONS BRINCKERHOFF COMPUTATION SHEET

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PB PROJECT NO. 173513A

Subject Elixabeth River Tunnels Project

Norfolk/Portsmouth, VA

Post Development Tc Calculations

TIME OF CONCENTRATION (Tc) OR TRAVEL TIME (Tt)

Drainage Basin: POND 24

SHEET FLOW

1	Surface Description			Pavement
2	Mannings Roughness Coefficient, n			0.02
3	Flow Length, L (total L , 300')		ft	100
4	Two-year, 24hr. Rainfall, P_2		in	3.61
5	Land Slope, s		ft/ft	0.003
6	$Tt = 0.007(nL)^{0.8}/P_2^{0.5}s^{0.4})$	Compute Tt	hr	0.05

SHALLOW CONCENTRATED FLOW

7	Surface Description (paved or unpaved)			Paved
8	Flow Length, L		ft	0
9	Watercourse Slope, s		ft/ft	0.004
10	Average Velocity, V		ft/s	1.15
11	Tt=L/(3600*V)	Compute Tt	hr	0.000

CHANNEL FLOW

			Ditch	Pipes
12	Cross Sectional Area	ft^2	10.00	0.79
13	Wetted Permiter, Pw	ft	13.30	3.14
14	Hydraulic Radius, R_h=a/Pw	ft	0.75	0.25
15	Channel Slope, s	ft/ft	0.001	0.005
16	Mannings Open Channel Flow Coefficient, n		0.060	0.060
17	$V=(1.486/n)*R_h^{2/3}*s^{1/2}$	ft/s	0.50	0.70
18	Flow Length, L	ft	0	200
19	Tt=L/(3600*V)	hr	0.00	0.08
20	**Watershed or subarea Tc or Tt (add Tt in steps 6, 11, and 19)**	hr	0.13	
		min	7.90	

Use 8 Minutes

STORMWATER MANAGEMENT POND SUMMARY SHEET
STORMWATER MANAGEMENT POND #25

I. DRAINAGE AREAS PRE/POST

PRE-DEVELOPMENT

Area	Soil Type	Type	Area (acres)	CN	CR	CRA	Isite
POND 25	D	Pavement	1.00	98	0.9	0.90	
		Industrial	2.55	93	0.85	2.17	
		Residential	2.45	92	0.45	1.10	
			6.00	**93**	**CR**	**0.70**	**71**

Weighted "C" (existing) 0.70
% impervious (existing) 71

Time of Concentration (Tc) = 14 minutes (See TOC calculation sheet)

POST-DEVELOPMENT

Area	Soil Type	Type	Area (acres)	CN	CR	CRA	Isite
POND 25	D	Pavement	1.20	98	0.9	1.08	
		Industrial	2.15	93	0.85	1.83	
		Grass	0.08	80	0.3	0.02	
		Residential	2.30	92	0.45	1.04	
		Water	0.27	100	1	0.27	
			6.00	**94**	**CR**	**0.71**	**72**

Weighted "C" (proposed) 0.71
% impervious (proposed) 72

Time of Concentration (Tc) = 14 minutes (See TOC calculation sheet)

II. PROPOSED BMP **Detention**

Groundwater Elev per Boring

Boring #	GW Elev
10BH-190	5.10
10BH-191	4.90

Set Normal Pond Elevation at 5.00
.
Pond Bottom material **SP-SM Cohesionless**

III. POND STAGE/STORAGE TABLE

Elevation	Area SF	Avg. Area SF	delta Volume CF	Sum Volume CF
4.00	24,309			
5.00	26,072	25,191	25,191	25,191
6.00	27,061	26,567	26,567	51,757
7.00	28,025	27,543	27,543	79,300
8.00	29,004	28,515	28,515	107,815
9.00	30,003	29,504	29,504	137,318
10.00	30,951	30,477	30,477	167,795

IV PHOSPHORUS REMOVAL

None - Quantity BMP only

V. POND OUTLET STRUCTURE SUMMARY

Type	Size	Elevation
Riser	4'x4'	7.35
Orifice	12"	5.00
Culvert	15"	4.90

VI. POND RESULTS SUMMARY

2-Year			25-Year			100-Year		
$Q_{max\ (pre)}$ =	**13.35**	cfs	$Q_{max\ (pre)}$ =	**19.16**	cfs	$Q_{max\ (pre)}$ =	**27.84**	cfs
$Q_{max\ (post)}$ =	**13.35**	cfs	$Q_{max\ (post)}$ =	**19.16**	cfs	$Q_{max\ (post)}$ =	**27.84**	cfs
			Reservoir Routing Results					
Outflow Q_{max} =	**1.05**	cfs	Outflow Q_{max} =	**2.18**	cfs	Outflow Q_{max} =	**3.03**	cfs
Max. Pond Water Surface Elevation =	**5.66**	feet	Max. Pond Water Surface Elevation =	**6.10**	feet	Max. Pond Water Surface Elevation =	**6.59**	feet

PARSONS BRINCKERHOFF COMPUTATION SHEET

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Checked by Lewis White

PB PROJECT NO. 173513A

Subject Elixabeth River Tunnels Project

Norfolk/Portsmouth, VA

Post Development Tc Calculations

TIME OF CONCENTRATION (Tc) OR TRAVEL TIME (Tt)

Drainage Basin: POND 25

SHEET FLOW

1	Surface Description			Unpaved
2	Mannings Roughness Coefficient, n			0.06
3	Flow Length, L (total L , 300')		ft	83
4	Two-year, 24hr. Rainfall, P_2		in	3.61
5	Land Slope, s		ft/ft	0.005
6	$Tt = 0.007(nL)^{0.8}/P_2^{0.5}s^{0.4})$	Compute Tt	hr	0.11

SHALLOW CONCENTRATED FLOW

7	Surface Description (paved or unpaved)			Paved
8	Flow Length, L		ft	30
9	Watercourse Slope, s		ft/ft	0.005
10	Average Velocity, V		ft/s	1.43
11	Tt=L/(3600*V)	Compute Tt	hr	0.006

CHANNEL FLOW

			Ditch	Pipes
12	Cross Sectional Area	ft^2	10.00	1.23
13	Wetted Permiter, Pw	ft	13.30	3.93
14	Hydraulic Radius, R_h=a/Pw	ft	0.75	0.31
15	Channel Slope, s	ft/ft	0.001	0.005
16	Mannings Open Channel Flow Coefficient, n		0.060	0.060
17	$V=(1.486/n)*R_h^{2/3}*s^{1/2}$	ft/s	0.50	0.84
18	Flow Length, L	ft	0	320
19	Tt=L/(3600*V)	hr	0.00	0.11
20	**Watershed or subarea Tc or Tt (add Tt in steps 6, 11, and 19)**	hr	0.22	
		min	13.35	

Use 14 Minutes

II. PROPOSED BMP **Retention Basin III**
Phosphorous Removal EFF = 65%
Permanent Storage req'd = 4WQV

IV PHOSPHORUS REMOVAL

I site(post) =	142.86	x(	CR	-	0.2	)=									
I site(post) =	142.86	x(	**0.62**	-	0.2	)=	**60**								
Simple Method General Pollutant Load															
L site(post) =	P	x	Pj	x [	0.05	+ (	0.009	x	I site(post)	)] x	C	x	A	x	(2.72 / 12)
L site(post) =	45	x	0.9	x [	0.05	+ (	0.009	x	60	)] x	0.26	x	12.60	x	0.23
L site(post) =	**17.7**		lbs/yr												
Removal Efficiency	65%														
Phosphorus Removed	**11.53**		lbs/yr												

STORMWATER MANAGEMENT POND SUMMARY SHEET
STORMWATER MANAGEMENT POND #30

I. DRAINAGE AREAS PRE/POST

PRE-DEVELOPMENT

Area	Soil Type	Type	Area (acres)	CN	CR	CRA	Isite
POND 30	D	Pavement	3.57	98	0.9	3.21	
		Industrial	0.58	93	0.85	0.49	
		Grass	6.73	80	0.3	2.02	
		Residential	1.10	92	0.45	0.50	
	C	Pavement	0.10	98	0.9	0.09	
		Industrial	0.11	93	0.85	0.09	
		Grass	0.21	80	0.3	0.06	
		Residential	0.20	92	0.45	0.09	
			12.60	**87**	**CR**	**0.52**	**46**

Weighted "C" (existing) 0.52
% impervious (existing) 46

Time of Concentration (Tc) = 10 minutes (See TOC calculation sheet)

POST-DEVELOPMENT

Area	Soil Type	Type	Area (acres)	CN	CR	CRA	Isite
POND 30	D	Pavement	4.80	98	0.9	4.32	
		Industrial	0.38	93	0.85	0.32	
		Grass	4.82	80	0.3	1.45	
		Residential	1.10	92	0.45	0.50	
		Water	0.88	100	1	0.88	
	C	Pavement	0.10	98	0.9	0.09	
		Industrial	0.11	93	0.85	0.09	
		Grass	0.21	80	0.3	0.06	
		Residential	0.20	92	0.45	0.09	
			12.60	**90**	**CR**	**0.62**	**60**

Weighted "C" (proposed) 0.62
% impervious (proposed) 60

Time of Concentration (Tc) = 12 minutes (See TOC calculation sheet)

II. PROPOSED BMP **Retention Basin III**
Phosphorous Removal EFF = 65%
Permanent Storage req'd = 4WQV

Groundwater Elev per Boring

Boring #	GW Elev
12BH-109	5.00
12BH-108	7.50
12BH-111	5.50

Set Normal Pond Elevation at 5.00

Pond Bottom material **SP-SM Cohesionless**

WQV = 12.6 Acres x 60% impervious x .5 inches
WQV = 13721 Cu Ft
4WQV = 54886 Cu Ft

Required storage below permanent pool = **54,886** Cu Ft

Provided storage below permanent pool = **98,340** Cu Ft

III. POND DIMENSIONS/STORAGE PROVIDED

Elevation	Area SF	Avg. Area SF	delta Volume CF	Sum Volume CF			
2.00	24,876						
3.00	28,040	26,458	26,458	26,458			
4.00	31,361	28,119	56,237	56,237			
5.00	43,842	35,941	71,882	**98,340**	**Cu Ft**	**4WQV**	**Perm. Pool = 5.0**
6.00	46,209	45,026	45,026	143,366			
7.00	48,634	47,422	47,422	190,787			
8.00	51,115	49,875	49,875	240,662			
9.00	64,227	57,671	57,671	298,333			

IV PHOSPHORUS REMOVAL

See Water Quality Calculation Sheets

V. POND OUTLET STRUCTURE SUMMARY

Type	Size	Elevation
Riser	4'x4'	6.50
Orifice	3"	5.00
Culvert	18"	2.50

VI. POND RESULTS SUMMARY

2-Year			25-Year			100-Year		
$Q_{max\ (pre)}$ =	**25.21**	cfs	$Q_{max\ (pre)}$ =	**47.29**	cfs	$Q_{max\ (pre)}$ =	**67.67**	cfs
$Q_{max\ (post)}$ =	**25.21**	cfs	$Q_{max\ (post)}$ =	**47.29**	cfs	$Q_{max\ (post)}$ =	**67.67**	cfs
			Reservoir Routing Results					
Outflow Q_{max} =	**0.18**	cfs	Outflow Q_{max} =	**0.21**	cfs	Outflow Q_{max} =	**0.26**	cfs
Max. Pond Water Surface Elevation =	**5.74**	feet	Max. Pond Water Surface Elevation =	**5.94**	feet	Max. Pond Water Surface Elevation =	**6.33**	feet

PARSONS BRINCKERHOFF COMPUTATION SHEET

Page 1 of 1

Made by Melissa Pritchard

Checked by Lewis White

PB PROJECT NO. 173513A

Subject **Elixabeth River Tunnels Project**

Norfolk/Portsmouth, VA

Post Development Tc Calculations

TIME OF CONCENTRATION (Tc) OR TRAVEL TIME (Tt)

Drainage Basin: POND 30

SHEET FLOW

1	Surface Description			Pavement
2	Mannings Roughness Coefficient, n			0.02
3	Flow Length, L (total L , 300')		ft	90
4	Two-year, 24hr. Rainfall, P_2		in	3.61
5	Land Slope, s		ft/ft	0.012
6	$Tt = 0.007(nL)^{0.8}/P_2^{0.5}s^{0.4})$	Compute Tt	hr	0.03

SHALLOW CONCENTRATED FLOW

7	Surface Description (paved or unpaved)			unpaved
8	Flow Length, L		ft	0
9	Watercourse Slope, s		ft/ft	0.004
10	Average Velocity, V		ft/s	1.15
11	Tt=L/(3600*V)	Compute Tt	hr	0.000

CHANNEL FLOW

			Ditch	Pipes
12	Cross Sectional Area	ft^2	10.00	5.1
13	Wetted Permiter, Pw	ft	13.30	7.85
14	Hydraulic Radius, R_h=a/Pw	ft	0.75	0.65
15	Channel Slope, s	ft/ft	0.001	0.002
16	Mannings Open Channel Flow Coefficient, n		0.060	0.060
17	$V=(1.486/n)*R_h^{2/3}*s^{1/2}$	ft/s	0.50	0.74
18	Flow Length, L	ft	50	370
19	Tt=L/(3600*V)	hr	0.03	0.14
20	**Watershed or subarea Tc or Tt (add Tt in steps 6, 11, and 19)**	hr	0.19	
		min	11.61	

Use 12 Minutes

Sediment Forebay Calculations for Water Quality Basins					
Pond	DA (acre)	% Impervious	Impervious area (acre)	0.1" Volume (CF)	Actual Volume (CF)
8	4.96	58%	2.88	1,044	1,160
14	11.28	61%	6.88	2,498	13,116
19*	18.83	83%	15.63	5,673	5,690
20	38.54	48%	18.50	6,715	7,135
30	12.6	60%	7.56	2,744	5,147

*Note: 18.83 acres is the contributing drainage area to the forebay. The additional 3.07 acres sheet flows through a wooded buffer area into the basin.

Forebay - Pond 8				
Elevation	Area (SF)	Avg. Area (SF)	delta Volume (CF)	Sum Volume (CF)
8.00	120			
9.00	510	315	315	315
10.00	1,040	580	1,160	1,160

Forebay 1 - Pond 14				
Elevation	Area (SF)	Avg. Area (SF)	delta Volume (CF)	Sum Volume (CF)
6.00	3,041			
7.00	4,222	3,632	3,632	3,632
8.00	5,460	4,251	8,501	8,501

Forebay 2 - Pond 14				
Elevation	Area (SF)	Avg. Area (SF)	delta Volume (CF)	Sum Volume (CF)
5.00	1,460			
6.00	2,280	1,870	1,870	1,870
7.00	3,155	2,308	4,615	4,615

Forebay - Pond 19				
Elevation	Area (SF)	Avg. Area (SF)	delta Volume (CF)	Sum Volume (CF)
5.00	190			
6.00	850	520	520	520
7.00	1,750	970	1,940	1,940
8.00	2,678	1,764	3,528	4,048
8.50	3,250	2,500	3,750	5,690

Forebay 1 - Pond 20				
Elevation	Area (SF)	Avg. Area (SF)	delta Volume (CF)	Sum Volume (CF)
4.50	1,361			
5.00	1,739	1,550	775	775
6.00	2,545	1,953	2,930	2,930

Forebay 2 - Pond 20				
Elevation	Area (SF)	Avg. Area (SF)	delta Volume (CF)	Sum Volume (CF)
4.50	1,610			
5.00	1,955	1,783	891	891
6.00	2,692	2,151	3,227	3,227

Forebay 3 - Pond 20				
Elevation	Area (SF)	Avg. Area (SF)	delta Volume (CF)	Sum Volume (CF)
4.50	325			
5.00	528	427	213	213
6.00	980	653	979	979

Forebay - Pond 30				
Elevation	Area (SF)	Avg. Area (SF)	delta Volume (CF)	Sum Volume (CF)
2.00	1,765			
3.00	2,545	2,155	2,155	2,155
4.00	3,382	2,574	5,147	5,147

9.5. APPENDIX E – Tidal Flood Protection

PARSONS BRINCKERHOFF

MEMORANDUM

TO: J. POHLE

FROM: D. PIPER / L. WHITE / F. PARKINSON

SUBJECT: Tidal Flood Protection – Midtown Tunnel Norfolk Approach Area

DATE: NOVEMBER 14, 2012

The purpose of this Memo is to present the design methodology for providing flood protection for the Norfolk approach to formally demonstrate compliance with the Technical Requirements.

Technical Requirements:

The Technical Requirements provide direction on the design of flood mitigation measures, as follows:

> *1.15.1. A – The Work shall maintain the existing flood protection provisions as a minimum. The Concessionaire shall coordinate the design, construction and operation of the Work in accordance with FHWA Technical Manual for the Design and Construction of Road Tunnels – Civil Elements (Publication No. FHWA-NHI-10-034, June 2010 Draft Version) and with the United States Army Corps of Engineers (USACE) and any other relevant authorities.*
>
> *1.15.1.F – Flood mitigation measures shall be determined by the Concessionaire, but at a minimum shall meet Extreme High Water Level (EHWL) requirements and all State and Federal Law and the Standard Documents. Flood mitigation measures shall be submitted as part of the Design Development and Detailed Design.*
>
> *1.15.1.G- The EWHL used in the design of flood protection measures shall be calculated by the Concessionaire and will be included in the design Development and Detailed Design. The EWHL shall be the water level with the probability of being exceeded no more than 0.002 times in one year (the 500 year flood level). The flood protection shall be designed for wave heights corresponding to the same return period.*
>
> *1.15.6.L – The calculations for the cut-and-cover tunnels, service buildings and approach ramps shall consider a case with a high groundwater level with a minimum factor of safety against uplift of 1.10, and a case with extreme high groundwater level with a minimum factor of safety against uplift of 1.03.*

The design of the flood protection system complies with TR Section 1.15.1.A as documented below. Similarly, flood mitigation measures to protect the new Midtown Tunnel from inundation as a result of the EWHL (500-year flood) are included as documented below.

Current FEMA Flood Elevations:

From the Norfolk Flood Insurance Study (Revised September 2009), the following is provided:

FEMA 10-Year Tidal Flood	5.5' NAVD 88
FEMA 50-Year Tidal Flood	6.9' NAVD 88

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FEMA 100-Year Tidal Flood 7.6' NAVD 88

FEMA does not define the 4% (25 yr) tide stage; however, this stage can be approximated by developing a tide frequency curve using the four events defined by FEMA, as presented in the graph below.

The approximate 4% tide level is Elevation 6.25-feet (NAVD 88 datum). Allowing for a 2 foot sea level rise as required per Drainage Design Criteria Table 3.1.5, the future 4% tide level would be 8.25-feet (NAVD88). [Note: this elevation generally coincides with the proposed elevation of graded berms as presented in the Pricing Plans during Phase 2 of project development.]

Design Criteria:

The Drainage Design Criteria (Exhibit C, Attachment 1D, Table 3.1.5) lists the tidal flood frequencies required for design. The table below lists the current FEMA tide frequencies and corresponding tide frequencies noted in the Design Criteria. The Criteria stages are 2-feet higher than the FEMA stages, to allow for sea level rise over the design life of the Project, per the notes associated with Table 3.1.5.

Tide Frequency	2009 FEMA Tide Stage	Design Criteria Tide Stage
10% (10 year)	5.5	7.5
2% (50 year)	6.9	8.9

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1% (100 year)	7.6	9.6
0.2% (500 year)	8.9	10.9

Elevations are in NAVD88 datum

Per the table above and Technical Requirements Section 1.15.1.G noted above, the Concessionaire shall provide for the protection of the tunnel to the 0.2% (500 year) tidal event or Elevation 10.9-feet (NAVD88). Most of the area surrounding the tunnel approach is within the current 1% flood plain (elev. 7.6-8.1) and the 0.2% flood plain (as shown on the attached FEMA mapping). Once the tide level reaches the level of the current 1% stage, flood water will inundate the tunnel approach roadways in all directions, including Hampton Boulevard, Brambleton Avenue (at the terminus with Ramp B) and the Claremont Avenue and Brambleton Boulevard intersection area. It is apparent from review of both the attached FEMA mapping and detailed topographic survey data of the area, that the tunnel approach cannot be protected to the future 0.2% storm surge without major changes in the character of the area, adjacent land areas, and/or significant impacts to the City of Norfolk drainage system that traverses the Norfolk approach interchange. Therefore, the only means of providing protection for the 0.2% storm is by means of the existing/proposed flood gates at the portals of the existing/proposed Midtown Tunnel.

The Drainage Design Criteria (Table 3.1.1) requires that the drainage system of the approach road be designed to a 4% (25 yr) event. The VDOT Drainage Design Manual, Chapter 6, presents the methodology required for a detailed hydrologic analysis. And, Appendix 6I-1 of the Drainage Manual addresses the Flood Frequency Analysis for joint probability of tidal and rainfall events coincidentally. The Appendix specifically addresses the Norfolk Harbor area stating that the *"combinations of events at the extremities of the tables will usually be critical and often the intermediate combinations may be ignored."* The tables list only the 10 year and 100 year events. Appendix 6I-1 suggests that either the rainfall event or the tidal event may be used to meet the design criteria. If the rainfall intensity governs, the tailwater would be mean high water (MHL). If the tide levels govern, no significant rainfall intensity is added.

Norfolk Approach Flood Mitigation Design Considerations:

The Norfolk approach area (outside of the boat section) of the Midtown Tunnel is draining through gravity storm sewers discharging to tidal waters. Tidal waters back up the approach drainage system during tidal storm surges and flood the existing tunnel approach via overland flow, which in turn floods the existing tunnel boat section. The current "low-point" in the existing drainage collection system is located along Ramp B, where an existing storm inlet connected to the adjacent City of Norfolk open culvert (carrying former Torrants Creek) has a top elevation of 2.96-feet (NAVD88). During tidal flooding events, flood waters reach this

elevation and create a ponding area adjacent to Ramp B, which eventually traverses overland to the existing Midtown Tunnel boat section.

Per Table 1 below, the recent Hurricane Sandy (October 2012) flood event involved storm surge to Elevation 5.17-feet (NAVD88), while Hurricane Isabel in September 2003 included storm surge to Elevation 6.24-feet NAVD88.

Table 1
Extreme Flood Events
(Most Recent 10 year period)

YEAR	STORM	Sewells Point (ft NAVD88)	Chesapeake Bay Bridge Tunnel (ft NAVD88)
2012	Hurricane Sandy	5.14	5.2
2011	Hurricane Irene	5.91	5.5
2009	Nor 'Ida	6.08/5.67	5.7
2006	Tropical Storm Ernesto	4.98	3.6
2003	Hurricane Isabel	6.24	5.7

Highest Value Flood Data, Sewells Point Station (NOAA Station ID 8638510)
Highest Value Flood Data, Chesapeake Bay Bridge Tunnel (NOAA Station ID 8638863)

The Hurricane Isabelle event approximated the 4% (25 year) tidal storm surge based on the tide frequency information provided in the FEMA Flood Insurance Study for Norfolk (revised September 2009). Per the flood data presented in Table 1, above, the existing 10-year flood elevation of 5.5-feet (NAVD88) has been exceeded four (4) times in the past ten years.

Flood Mitigation:

The existing access roadways to/from the tunnel approach constrain the operation of the tunnel during flood events. There are three approach roadways to the tunnel, presented in Figure Nos. 1 – 3 below:

MEMORANDUM

Figure 1 – Loop Ramp D

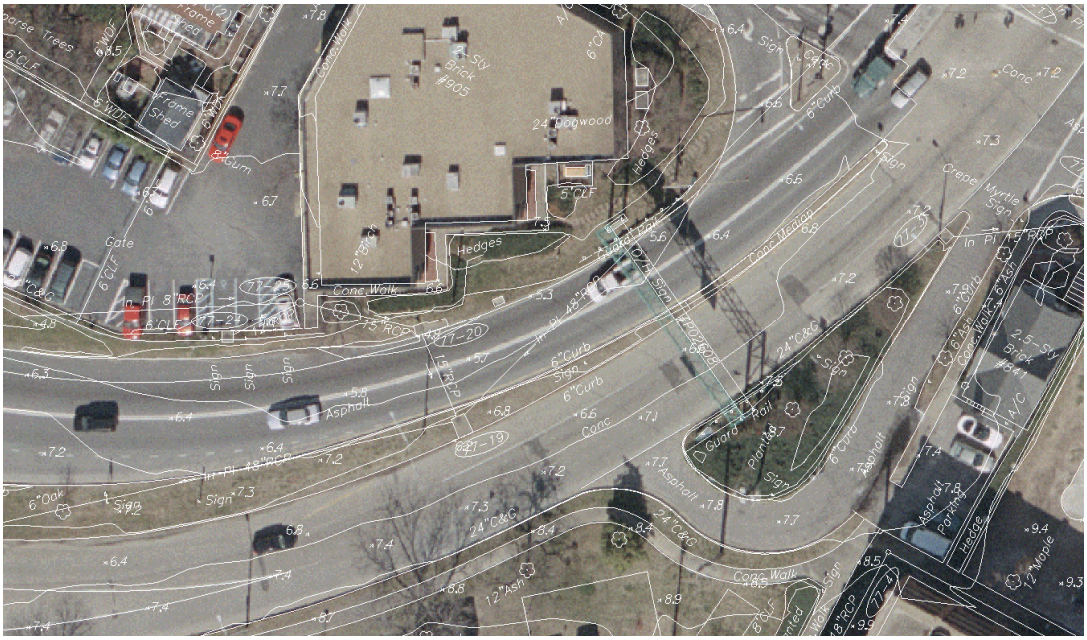

Figure 2 – Hampton Boulevard Westbound

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Figure 3 –Brambleton Avenue near Claremont Avenue

From the figures above, existing approach roadways will commence flooding at the existing roadway centerline/baseline elevations as follows:

- Loop Ramp D – Elevation 7.3-feet (NAVD88)
- Hampton Boulevard Westbound - Elevation 5.7-feet (NAVD88)
- Brambleton Avenue near Claremont Avenue – Elevation 6.5-feet (NAVD88)

And, there are two departure roadways from the existing tunnel, presented as Figures Nos. 4 – 5 below:

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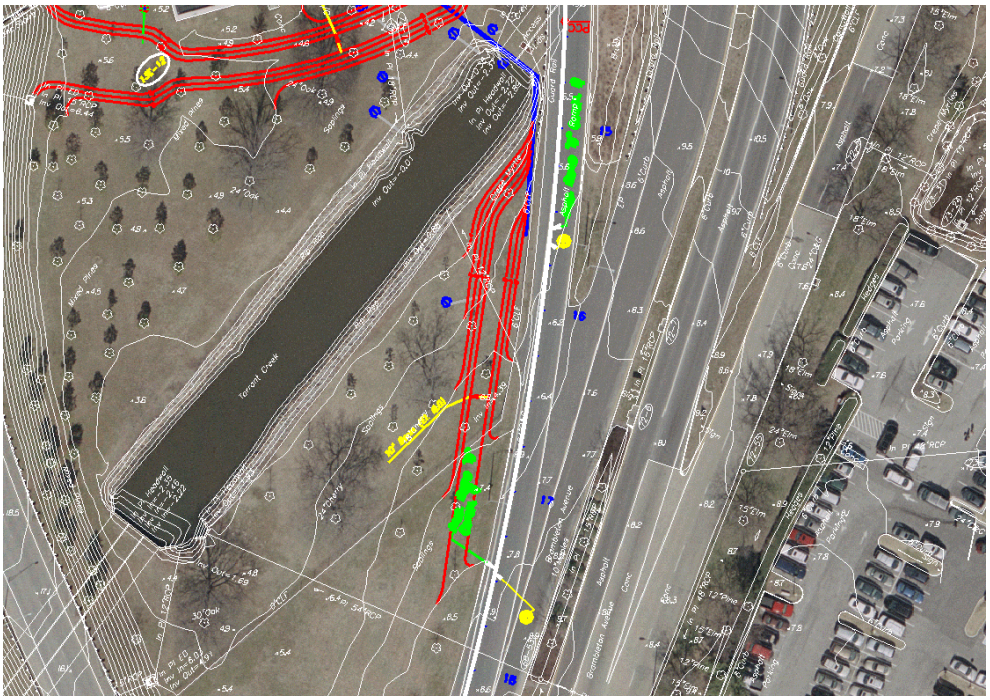

Figure 4 – Ramp B at Brambleton Avenue

Figure 5 – Hampton Boulevard Eastbound

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From the figures above, existing departure roadways will commence flooding at the existing roadway centerline/baseline elevations as follows:

- Ramp B at Brambleton Avenune – Elevation 6.4-feet (NAVD88)
- Hampton Boulevard Eastbound - Elevation 5.5-feet (NAVD88)

Providing "berming" to Elevation 8 (NAVD88) would involve substantial modification to adjacent areas and approach/departure roadways, but does make sense. Although all approach roadways become flooded above elevation 7.3-feet (NAVD88) and all departure roadways become flooded above Elevation 6.4-feet (NAVD88), providing such berming reduces the frequency that VDOT/ERC will need to operate the floodgates. When VDOT/ERC close the floodgates and the tunnel boat sections fill up with water, considerable time and effort is involved in pumping out the boat section, removing the accumulated debris, and washing the walls. This delays re-opening of the tunnel by several hours after flood waters recede. And, providing the proposed floodwall/berming adjacent to Ramp B will protect that departure roadway to Elevation 8 (NAVD).

From a pumping capacity perspective, the Norfolk approach pump station must be designed to accommodate a 50-year storm event for pump station area of influence, per the Technical Requirements. As such, the "berming" design has been developed to minimize the area of influence to improve operations of the pump station, pumping capacity, and wet-well storage capacity.

To address all of the various issues, PB proposes graded berms (or adjacent wall systems) be constructed to Elevation 8.25-feet (NAVD88) with 'berming' of approach roadways to Elevation 8.0-feet (NAVD88). As such, the tunnel approach would be protected from flooding to the 25-year <u>design</u> tidal event accounting for the required 2-feet of sea level rise, and very nearly the <u>existing</u> 100-year tidal event, thus meeting VDOT Drainage Manual requirements for designing approach roadways to address the 25-year flood event.

<u>Operational Considerations:</u>

Theoretically, if the approach roadways are protected from flooding to Elevation 8 (NAVD88), access 'to' the tunnel could be maintained to nearly this elevation via Loop Ramp D; while access 'from' the tunnel could be maintained via Ramp B (with proposed flood wall system to Elevation 8.25-feet). Realistically, ERC/VDOT will most likely close the flood gates when area flood levels exceed 6.0 – 6.5 feet (NAVD88). <u>PB is currently modeling various flood mitigation levels to determine pumping durations to remove water from the tunnel approach and boat sections after flooding events. Preliminary analyses revealed estimates of less than 12-hours.</u>

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Basis of Design:

Per the Technical Requirements (Exhibit C, Attachment 1B - Final Basis of Design Midtown Tunnel), Section 3.3, *"the Project will include a flood mitigation project to minimize potential for flooding from the existing open storm channel located within the interchange area…"* Such is being accomplished by isolating the drainage collection system that currently connects to the existing open channel located within the interchange area, and proposing a 'berming system' to isolate the tunnel approach drainage area contributing to the Norfolk approach pump station.

FHWA Technical Manual

The following is from Chapter 2 of the Manual, Section 2.1.1, Paragraph 5:

> The recommendations in this Manual are provided as a guide for the Engineer to exercise sound judgment in applying standards to the geometric design of tunnels; the recommendations generally are based on the Green Book (2004) and the 2008 edition of NFPA 502. The design standards used for a road tunnel project should equal or exceed the minimum standards given in this Manual to the maximum extent feasible, taking into account costs, traffic volumes, safety requirements, right-of-way, and socioeconomic and environmental impacts, without compromising safety considerations. The readers should always refer to the latest requirements in the references identified in this article.

Per the first sentence in the paragraph above, the recommendations in the Manual are a "guide" for the Engineer to exercise sound judgment.

The following is from Chapter 2 of the Manual, Section 2.2.4, Paragraph 3:

> In addition to structural requirements, inundation of the tunnel by floods, surges, tides and waves, or combinations thereof resulting from storms must be prevented. The height and shape of walls surrounding tunnel entrances, the elevation of access road surfaces and any entrances, accesses and holes must be designed such that entry of water is prevented. It is recommended that water level with the probability of being exceeded no more than 0.005 times in any one year (the 500-year flood level) be used as the design water level.

First, this section includes a 'recommendation' to use the 500-year flood elevation as the design water level. The flood mitigation system as currently proposed accommodates the 500-year flood, as the entire 'system' includes a flood gate, protecting the tunnel from flooding during a 500-year flood event. If indeed the tunnel approach roadways were designed to the 500-year flood elevation, such may obviate the need for including the flood gate.

And finally, from Chapter 2 of the Manual, Section 2.4.8, Paragraph 4:

> In determining portal locations and the points at which to end the approach structure and retaining walls, protection should be provided against flooding resulting from high water levels near bodies of water and tributary watercourses, or from storm runoff. The height of the portal end wall and the approach retaining walls should be set to a level at least 2 ft higher than the design flood level. Alternatively, a flood gate can be provided. Adequate provision should be made for immediate and effective removal of water from rainfall, drainage, groundwater seepage, or any other source. Portal cross drain and a sump pump should be provided.

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From our review, the section above is the only mention of use of a flood gate in the Manual. It appears that use of a flood gate would be an acceptable alternative to setting the portal end walls and approach retaining walls at least 2 feet higher than the design flood level. As such, by exercising sound judgment, it would be reasonable then that the flood gate would also be an acceptable means to protect the tunnel from flooding for the design flood level.

Tunnel Stability

Because the facility can be protected against flooding to Elev. 8-feet (NAVD88) without the use of the floodgate, this elevation will be the critical elevation for buoyancy and tunnel stability calculations for the open approach roadways. Although the Technical Requirements reference the EHWL that is greater than Elev. 8-feet (NAVD88), the preceding sections of this memorandum have demonstrated that the +8 elevation will govern the buoyancy calculations for the approach ramps. The proposed approach ramps have been designed with a factor of safety against buoyancy of 1.10 or greater in all sections; the structure weight and the soil backfill on top of the wall heels will be used to counter buoyancy.

When the approach roadways are graded and bermed to protect against floodwaters to Elev. 8-feet (NAVD88), the existing approach will experience flood waters greater than for which it was originally designed. Using the existing tunnel plans, PB has performed calculations of structural adequacy and buoyancy. No field investigations were performed to verify information presented on the existing plans, nor was any testing done to attempt to verify the size and spacing of the rebars, or strength of the concrete. Nominal values typical for the age of the structures were used. Based on these investigations, the safety factors against uplift for various portions of the boat section are presented in Table 2 below. The first column neglects any soil friction, and the second column includes soil friction along the side shear plane.

Table 1

Extreme Flood Events Section Unit	PGLs	PGLe	Max. slab thickness (ft)	Buoyancy Safety factor	
				No Soil Friction	Soil Friction
1 to 3	-17.35	-13.30	4'-10"	1.062	1.108
5 to 6	-13.30	-9.25	4'-10"	1.063	1.097
7 to 9	-9.25	-5.20	4'-5"	1.070	1.096
10 to 12	-5.20	-1.15	3'-11"	1.102	1.121
13 to 14	-1.15	1.37	3'-5"	0.864*	0.868*
15 to 16	1.37	3.39	2'-11"	0.902*	0.904*

* West wall removed

Where the existing structure ties into the proposed structure (Sta. 133+75 to Sta. 134+94 – Section Units 13 to 16), the factor of safety against buoyancy of the existing structure will be

compromised as a result of the removal of the existing wall. Therefore, tiedown anchors will be implemented in these areas to compensate for the removal of the walls and the subsequent lowered factor of safety against buoyancy. The proposed anchors provide a minimum factor of safety of 1.10. Figure 6 depicts the locations of the tie-down anchors in plan view.

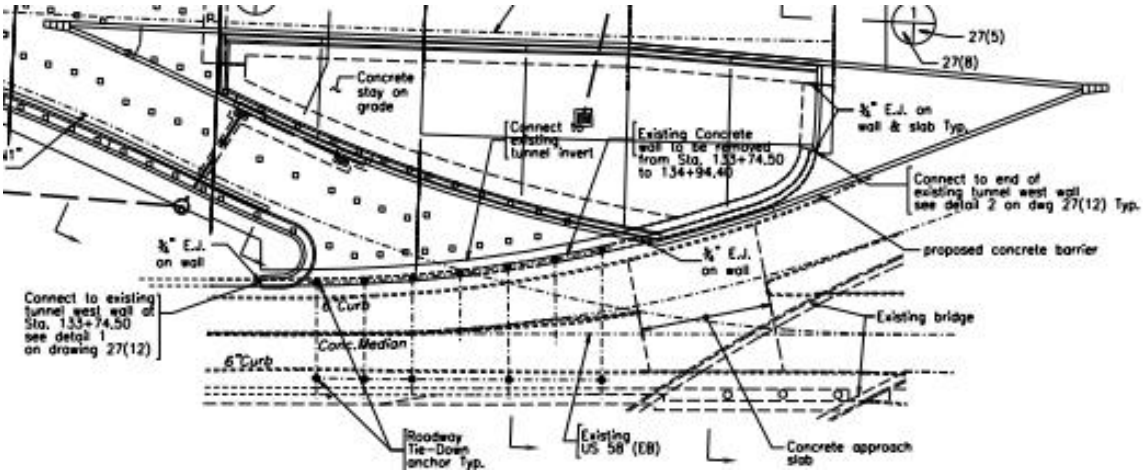

Figure 6 – Norfolk Tie-In Location

For the structural analysis of the existing structure, typical sections at stations 129+85 and 134+22 were analyzed for bending in the wall and slab, respectively. Sections are shown in Figure 7 and 8. Using 3000 psi concrete and grade 40 rebar, along with LRFD codes, it was determined that the sections investigated had a flexural capacity/demand ratio of 1.33 for the wall and 1.21 for the invert.

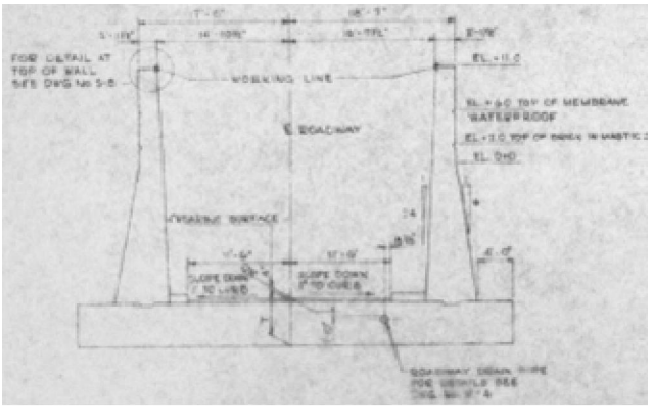

Figure 7 – Section at Sta. 129+85

MEMORANDUM

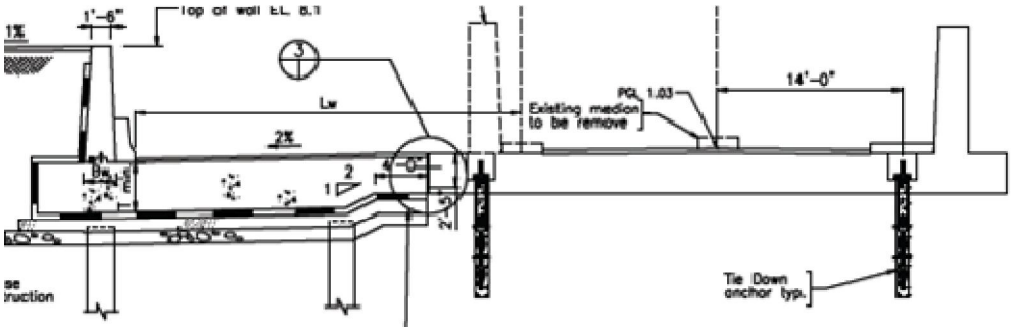

Figure 8 – Section at Sta. 134+22

Although open approaches would only need to be reasonably protected to a flood elevation of Elev. 8-feet(NAVD88), the cut-and-cover tunnel structures would need to account for significantly higher water levels in line with the EHWL specified in the Technical requirements. These proposed structures were designed accordingly, and exhibit a factor of safety against buoyancy of 1.10 or greater.

Summary:

In summary, PB has executed sound engineering judgment in designing a flood mitigation system for the Norfolk approach. Specifically, the flood mitigation system includes 'layered' levels of protection and mitigation for these extremely valuable transportation assets. The layered protection includes an initial flood level design for the Norfolk approach based on the 25-year design tidal event, the Norfolk approach pump station with pumping capacity for a 50-year event, the Norfolk portal pump station (new Midtown Tunnel only) with anticipated pumping capacity for a 100-year event, and ultimately, the Norfolk portal flood gates to protect the asset against a 500-year event (meeting both the Technical Requirements and FHWA's Technical Manual). Furthermore, the new structures have been designed accordingly for the design water levels, and the existing section modified where the structure was compromised due to the proposed construction.

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MEMORANDUM

Sewells Point, VA

Station ID: 8638610

Sewells Point, VA: Data Inventory

Page Help

Extremes

HighestValues

Station: 8638610 Begin Date: 20020101
Name: Sewells Point, VA End Date: 20121002
Product: High/Low Units: Feet
Datum: StnDatum Quality: Verified

Rank	Highest	Highest Date	Zone	NAVD88
1	12.27	20030918 21:00	GMT	6.24
2	12.11	20091112 23:18	GMT	6.08
3	11.94	20110828 00:18	GMT	5.91
4	11.70	20091113 11:12	GMT	5.67
5	11.11	20091112 11:00	GMT	5.05
6	11.01	20061122 15:06	GMT	4.98
7	10.90	20061007 13:42	GMT	4.87
8	10.70	20061007 01:42	GMT	4.67
9	10.57	20091113 23:18	GMT	
10	10.53	20091219 16:18	GMT	

10 year tidal flood elevation 5.5 NAVD 88 exceeded 4 times is the last 10 years

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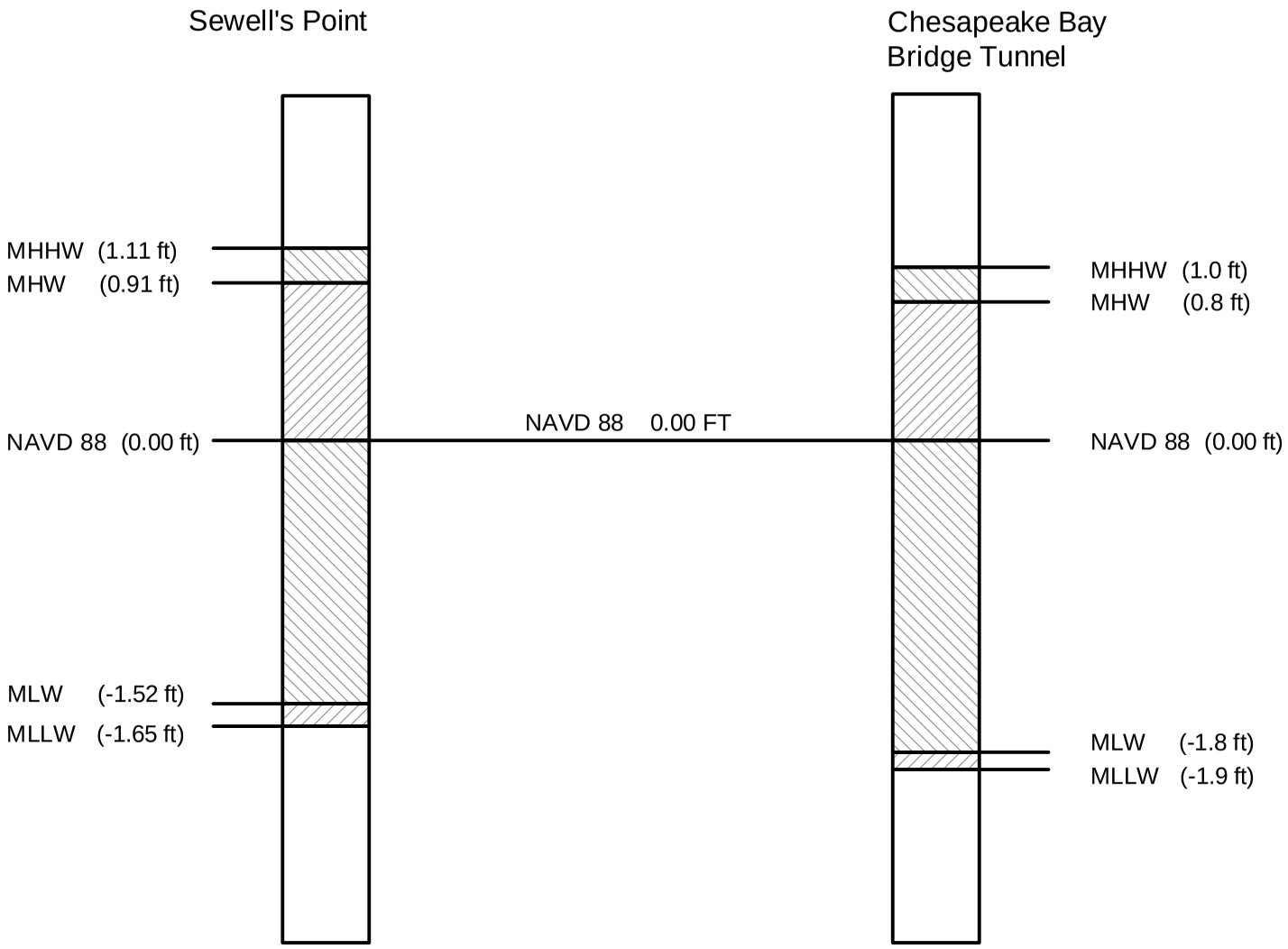
TIDE ELEVATIONS



9.6. APPENDIX F – MTT Drainage Calculations

ROUTE WB US 58, Port Road A, Port Road C **PROJECT** Elizabeth River Tunnels Project
Portsmouth Approach

DESIGNER: MJP **DATE** 5/23/2013
CHECKED: AMO **UNITS** ENGLISH

INLET																													Sag Inlets Only				
NUMBER	TYPE	LENGTH (FT; M)	STATION	DRAINAGE AREA (AC; HA)	C	CA	ΣCA	I (IN/HR; mm/HR)	Q INCR. (CFS; CMS)	Qc CARRYOVER (CFS; CMS)	QT GUTTER FLOW (CFS; CMS)	S GUTTER SLOPE (FT/FT; M/M)	Sx CROSS SLOPE (FT/FT; M/M)	T (SPREAD) (FT; M)	W (GUTTER WIDTH) (FT; M)	W/T	Sw (GUTTER SLOPE) (FT/FT; M/M)	Sw/Sx	Eo (App. 9C-8)	a	S'w	Se	COMPUTED LENGTH L_T (FT; M)	INLET / GRATE LENGTH (FT; M)	L/LT	E (App. 9C-18)	Q INTERCEPTED (CFS; CMS) or d/h	Qb CARRYOVER (CFS; CMS)	d (FT; M)	h (FT; M)	d/h	T SPREAD @ SAG (FT; M)	REMARKS
4-00	DI-7	3.000	79+40.88	0.240	0.90	0.216																											
				0.350	0.35	0.1225																											
							0.339	6.5	2.204	0	2.204	0.005			3.000									3.000		1.000	2.204	0.000	0.7558				BHt.=0.154'
4-03	DI-7B	3.000	80+42.40	0.130	0.90	0.117																											Back/Lt.
				0.050	0.35	0.0175																											Back/Lt.
							0.135	6.5	0.878	0																							Back/Lt.
				0.100	0.90	0.09																											Ahead/Rt.
				0.090	0.35	0.0315																											Ahead/Rt.
							0.122	6.5	0.793	0																							Ahead/Rt.
											1.671	0.0100			3.000									3			1.671						
4-07	DI-7	3.000	81+84.72	0.050	0.90	0.045																											Back/Lt.
				0.160	0.35	0.056																											Back/Lt.
							0.101	6.5	0.657	0																							Back/Lt.
				0.050	0.90	0.045																											Ahead/Rt.
				0.180	0.35	0.063																											Ahead/Rt.
							0.108	6.5	0.702	0																							Ahead/Rt.
											1.359	0.0100			3.000									3			1.359						
4-08	DI-7B	3.000	83+16.77	0.070	0.90	0.063																											Back/Lt.
				0.060	0.35	0.021																											Back/Lt.
							0.084	6.5	0.546	0																							Back/Lt.
				0.060	0.90	0.054																											Ahead/Rt.
				0.070	0.35	0.0245																											Ahead/Rt.
							0.079	6.5	0.514	0																							Ahead/Rt.
											1.060	0.001			3.000									3			1.060						
4-09	DI-7A	3.000	84+36.20	0.050	0.90	0.045																											
				0.070	0.35	0.0245																											
							0.07	6.5	0.455	0	0.455	0.008			3.000									3.000		1.000	0.455	0.000	0.383				BHt.=0.053'
4-12	DI-7A	3.000	83+42.69	0.450	0.35	0.1575																											
							0.158	6.5	1.027	0	1.027	0.005			3.000									3.000		1.000	1.027	0.000	0.5038				BHt.=0.092'
5-01	DI-7B	3.000	87+07.34	0.070	0.90	0.063																											Back/Lt.
				0.020	0.35	0.007																											Back/Lt.
							0.07	6.5	0.455	0																							Back/Lt.
				0.090	0.90	0.081																											Ahead/Rt.
				0.160	0.35	0.056																											Ahead/Rt.
							0.137	6.5	0.891	0																							Ahead/Rt.
											1.346	0.001			3.000									3			1.346						
5-02	DI-7B	3.000	86+80.60	0.050	0.90	0.045																											Back/Lt.
				0.130	0.35	0.0455																											Back/Lt.
							0.091	6.5	0.592	0																							Back/Lt.

ROUTE WB US 58, Port Road A, Port Road C **PROJECT** Elizabeth River Tunnels Project Portsmouth Approach **DESIGNER:** MJP **CHECKED:** AMO **DATE** 5/23/2013 **UNITS** ENGLISH

INLET NUMBER	INLET TYPE	INLET LENGTH (FT; M)	STATION	DRAINAGE AREA (AC; HA)	C	CA	ΣCA	I (IN/HR; mm/HR)	Q INCR. (CFS; CMS)	Qc CARRYOVER (CFS; CMS)	QT GUTTER FLOW (CFS; CMS)	S GUTTER SLOPE (FT/FT; M/M)	Sx CROSS SLOPE (FT/FT; M/M)	T (SPREAD) (FT; M)	W (GUTTER WIDTH) (FT; M)	W/T	Sw (GUTTER SLOPE) (FT/FT; M/M)	Sw/Sx	Eo (App. 9C-8)	a	S'w	Se	COMPUTED LENGTH L_T (FT; M)	INLET / GRATE LENGTH (FT; M)	L/LT	E (App. 9C-18)	Q INTERCEPTED (CFS; CMS) or d/h	Qb CARRYOVER (CFS; CMS)	Sag Inlets Only d (FT; M)	h (FT; M)	d/h	T SPREAD @ SAG (FT; M)	REMARKS
				0.060	0.90	0.054																											Ahead/Rt.
				0.060	0.35	0.021																											Ahead/Rt.
							0.075	6.5	0.488	0																							Ahead/Rt.
											1.079	0.001			3.000									3			1.079						
5-06	DI-7A	3.000	85+43.62	0.340	0.35	0.119																											
							0.119	6.5	0.774	0	0.774	0.005			3.000									3.000		1.000	0.774	0.000	0.4531				BHt.=0.076'
5-07	DI-7B	3.000	86+37.10	0.080	0.35	0.028																											Back/Lt.
							0.028	6.5	0.182	0																							Back/Lt.
				0.030	0.90	0.027																											Ahead/Rt.
				0.400	0.35	0.14																											Ahead/Rt.
							0.167	6.5	1.086	0																							Ahead/Rt.
											1.268	0.001			3.000									3			1.268						
5-09	DI-7	3.000	89+36.73	0.100	0.90	0.09																											Back/Lt.
				0.030	0.35	0.0105																											Back/Lt.
							0.101	6.5	0.657	0																							Back/Lt.
				0.100	0.90	0.09																											Ahead/Rt.
				0.030	0.35	0.0105																											Ahead/Rt.
							0.101	6.5	0.657	0																							Ahead/Rt.
											1.313	0.0100			3.500									3			1.313						
5-10	DI-7	3.000	89+53.82	0.030	0.90	0.027																											Back/Lt.
				0.030	0.35	0.0105																											Back/Lt.
							0.038	6.5	0.247	0																							Back/Lt.
				0.030	0.90	0.027																											Ahead/Rt.
				0.030	0.35	0.0105																											Ahead/Rt.
							0.038	6.5	0.247	0																							Ahead/Rt.
											0.494	0.0100			3.000									3			0.494						
5C-01	DI-7	3.000	11+13.73	0.210	0.90	0.189																											Back/Lt.
							0.189	6.5	1.229	0		0.001	0.0208	11.443	0.000	0.000	0.0208	1		2.00													Back/Lt.
				0.210	0.90	0.189																											Ahead/Rt.
							0.189	6.5	1.229	0																							Ahead/Rt.
											2.457	0.001			3.000									3			2.457		0.2539			12.208	T > 8.0 ft
5C-02	DI-7	3.000	11+15	0.200	0.90	0.18																											Back/Lt.
							0.18	6.5	1.17	0		0.001	0.0208	11.234	0.000	0.000	0.0208	1		2.00													Back/Lt.
				0.200	0.90	0.18																											Ahead/Rt.
							0.18	6.5	1.17	0																							Ahead/Rt.
											2.340	0.001			3.000									3			2.340		0.2458			11.817	T > 8.0 ft
6-01	DI-7	3.000	92+35.77	0.200	0.90	0.18																											Back/Lt.
							0.18	6.5	1.17	0																							Back/Lt.
				0.200	0.90	0.18																											Ahead/Rt.
							0.18	6.5	1.17	0																							Ahead/Rt.
											2.340	0.0100			3.000									3			2.340						

STORMWATER INLET COMPUTATIONS

ROUTE WB US 58, Port Road A, Port Road C **PROJECT** Elizabeth River Tunnels Project
Portsmouth Approach

DESIGNER: MJP **DATE** 5/23/2013
CHECKED: AMO **UNITS** ENGLISH

INLET																													Sag Inlets Only				
NUMBER	TYPE	LENGTH (FT; M)	STATION	DRAINAGE AREA (AC; HA)	C	CA	ΣCA	I (IN/HR; mm/HR)	Q INCR. (CFS; CMS)	Qc CARRYOVER (CFS; CMS)	QT GUTTER FLOW (CFS; CMS)	S GUTTER SLOPE (FT/FT; M/M)	Sx CROSS SLOPE (FT/FT; M/M)	T (SPREAD) (FT; M)	W (GUTTER WIDTH) (FT; M)	W/T	Sw (GUTTER SLOPE) (FT/FT; M/M)	Sw/Sx	Eo (App. 9C-8)	a	Sw	Se	COMPUTED LENGTH L_T (FT; M)	INLET / GRATE LENGTH (FT; M)	L/LT	E (App. 9C-18)	Q INTERCEPTED (CFS; CMS) or d/h	Qb CARRYOVER (CFS; CMS)	d (FT; M)	h (FT; M)	d/h	T SPREAD @ SAG (FT; M)	REMARKS
6-03	DI-7	3.000	91+52.70	0.110	0.90	0.099																											
							0.099	6.5	0.644	0	0.644	0.0100	0.0208	5.836	0.000	0.000	0.0208	1	0.854	2.00	0.0833	0.0920	6.516	3.000	0.460	0.909	0.585	0.059					
6-06	DI-7A	3.000	91+25	0.400	0.90	0.36																											Back/Lt.
							0.36	6.5	2.34	0																							Back/Lt.
				0.040	0.90	0.036																											Ahead/Rt.
							0.036	6.5	0.234	0																							Ahead/Rt.
											2.574	0.001			3.000									3			2.574						
6-09	DI-7	3.000	12+50	0.200	0.90	0.18																											Back/Lt.
							0.18	6.5	1.17	0																							Back/Lt.
				0.170	0.90	0.153																											Ahead/Rt.
							0.153	6.5	0.995	0																							Ahead/Rt.
											2.165	0.001			3.500									3			2.165						

LD-229
STORM SEWER DESIGN COMPUTATIONS

STORM FREQUENCY **25**

PROJECT: Elizabeth River Tunnels Project
LOCATION: Portsmouth Approach
COUNTY: Portsmouth (city)

Designed by: MJP
5/6/2013
Checked by: AMO

UNITS **ENGLISH**

PIPE NO.	FROM POINT REFERENCE (1)	FROM POINT STA.	TO POINT REFERENCE (2)	TO POINT STA.	DRAIN. AREA "A" Acre (3)	RUNOFF COEFF. "C" (4)	CA INCRE-MENT (5)	CA ACCUM-ULATED (6)	TOTAL INLET TIME Minutes (7)	RAIN FALL In/Hr (8)	RUNOFF Lateral CFS	RUNOFF Total Q CFS (9)	INVERT ELEVATIONS UPPER END (10)	INVERT ELEVATIONS LOWER END (11)	LENGTH of Pipe Ft. (12)	SLOPE Ft./Ft. (13)	SIZE (Dia. Or Span/Rise) In. (14)	SHAPE	Number of Pipes	Capacity CFS (15)	Friction Slope Ft./Ft.	NORMAL FLOW Depth of Flow, dn Ft.	NORMAL FLOW Area of Flow, An SqFt	NORMAL FLOW Hrn Ft.	NORMAL FLOW Vn Ft/Sec (16)	NORMAL FLOW En Ft.	FLOW TIME Sec. (17)	REMARKS (18)
5592/4-01	5592		4-01	78+86.91	0.14	0.90	0.13	0.13	5.00	8.71	0.00	1.21	4.51	2.92	88.65	0.01794	15	Circular	1	8.65	0.00040	0.32	0.24	0.19	4.97	0.70	17.84	
4-01/4-02	4-01	78+86.91	4-02	78+95.20	0.00	0.00	0.00	0.13	5.30	8.59	0.00	1.19	2.83	2.25	36.00	0.01611	15	Circular	1	8.20	0.00040	0.32	0.25	0.19	4.76	0.67	7.56	
5580/5834	55-80		58-34		0.23	0.90	0.21	0.21	6.09	8.27	0.00	1.88	6.97	3.00	99.50	0.03990	15	Circular	1	12.90	0.00090	0.32	0.25	0.19	7.51	1.20	13.26	
5835/5834	58-35		58-34		1.43	0.70	1.00	1.18	10.14	7.02	0.00	9.15	3.02	2.46	104.00	0.00538	30	Circular	1	30.09	0.00050	0.95	1.70	0.51	5.38	1.39	19.34	
5834/4-02	58-34		4-02	78+95.20	0.62	0.55	0.34	1.73	10.46	6.94	0.00	13.20	2.46	1.97	274.64	0.00178	30	Circular	1	17.31	0.00110	1.64	3.40	0.72	3.88	1.87	70.75	
4-02/4-04	4-02	78+95.20	4-04	80+70.82	0.00	0.00	0.00	0.13	5.42	8.54	0.00	1.18	1.97	1.53	163.00	0.00270	30	Circular	1	21.31	0.00000	0.40	0.51	0.25	2.34	0.48	69.80	
4-00/4-03	4-00	79+40.88	4-03	80+42.40	0.59	0.58	0.34	0.34	7.23	7.86	0.00	2.93	2.60	1.20	92.00	0.01522	15	Circular	1	7.97	0.00220	0.53	0.49	0.28	6.00	1.08	15.34	
4-03/4-04	4-03	80+42.40	4-04	80+70.82	0.37	0.70	0.26	0.60	7.49	7.78	0.00	5.10	1.20	0.50	38.00	0.01842	18	Circular	1	14.26	0.00250	0.62	0.69	0.33	7.40	1.47	5.14	
5-01/5-02	5-01	87+07.34	5-02	86+80.60	0.75	0.90	0.68	0.68	9.57	7.17	0.00	5.32	3.80	3.20	52.00	0.01154	24	Circular	1	24.30	0.00060	0.64	0.86	0.36	6.20	1.23	8.39	
5-02/4-09	5-02	86+80.60	4-09	84+36.20	0.30	0.55	0.17	0.84	9.71	7.13	0.00	6.60	2.63	2.00	243.00	0.00259	36	Circular	1	33.94	0.00010	0.90	1.77	0.51	3.72	1.11	65.34	
4-09/4-08	4-09	84+36.20	4-08	83+16.77	0.19	0.50	0.09	0.94	10.90	6.83	0.00	7.03	2.00	1.10	116.00	0.00776	36	Circular	1	58.76	0.00010	0.70	1.26	0.42	5.60	1.19	20.72	
4-08/4-07	4-08	83+16.77	4-07	81+84.72	0.26	0.63	0.16	1.10	11.25	6.75	0.00	8.16	1.10	0.50	130.00	0.00462	36	Circular	1	45.34	0.00020	0.86	1.68	0.50	4.86	1.23	26.75	
4-07/4-04	4-07	81+84.72	4-04	80+70.82	0.44	0.48	0.21	1.31	11.69	6.65	0.00	9.57	0.50	0.10	106.00	0.00377	36	Circular	1	40.95	0.00020	0.99	2.02	0.55	4.73	1.33	22.43	
4-04/4-10	4-04	80+70.82	4-10	80+59.20	0.00	0.00	0.00	2.01	11.97	6.59	0.00	14.54	0.10	-0.20	56.00	0.00536	48	Circular	1	105.16	0.00010	1.01	2.47	0.59	5.88	1.54	9.52	
5842/4-10	58-42		4-10	80+54.82	13.31	0.50	6.68	6.68	38.03	3.82	0.00	28.06	2.02	1.22	120.00	0.00667	36	Circular	1	54.47	0.00180	1.53	3.61	0.76	7.76	2.46	15.46	
4-10/4-11	4-10	80+59.20	4-11	81+19.80	0.00	0.00	0.00	8.69	38.29	3.80	0.00	36.34	-0.20	-0.40	58.00	0.00345	48	Circular	1	84.37	0.00070	1.84	5.62	0.95	6.46	2.48	8.97	
4-11/4-12	4-11	81+19.80	4-12	83+42.69	0.00	0.00	0.00	8.69	38.44	3.80	0.00	36.27	-0.40	-0.90	223.00	0.00224	48	Circular	1	67.98	0.00070	2.08	6.60	1.02	5.50	2.55	40.57	
4-12/5-06	4-12	83+42.69	5-06	85+43.62	0.45	0.35	0.16	8.89	39.12	3.76	0.00	36.75	-0.90	-1.30	198.00	0.00202	48	Circular	1	64.56	0.00070	2.16	6.93	1.05	5.30	2.60	37.34	
5-06/5-07	5-06	85+43.62	5-07	86+37.10	0.34	0.35	0.12	9.01	39.74	3.73	0.00	36.92	-1.30	-1.50	90.00	0.00222	48	Circular	1	67.68	0.00070	2.11	6.71	1.03	5.50	2.58	16.36	
5-07/5-08	5-07	86+37.10	5-08	88+85.32	0.51	0.38	0.20	9.20	40.01	3.71	0.00	37.58	-1.50	-2.20	247.00	0.00283	60 X 38	Elliptical	1	74.07	0.00070	1.60	6.30	0.97	5.97	2.15	41.38	
5-08/5-09	5-08	88+85.32	5-09	89+36.73	0.00	0.00	0.00	9.20	40.70	3.68	0.00	37.23	-2.20	-2.30	48.00	0.00208	48	Circular	1	65.51	0.00070	2.16	6.92	1.05	5.38	2.61	8.92	
5-10/5-09	5-10	89+53.82	5-09	89+36.73	0.12	0.63	0.08	0.08	5.00	8.71	0.00	0.73	0.00	-0.50	27.00	0.01852	15	Circular	1	8.79	0.00010	0.24	0.17	0.15	4.34	0.54	6.23	
5-09/6-05	5-09	89+36.73	6-05	90+61.55	0.26	0.78	0.20	9.44	40.85	3.67	0.00	38.11	-2.30	-2.60	123.00	0.00244	48	Circular	1	70.96	0.00070	2.09	6.63	1.03	5.75	2.60	21.40	
6-05/6-06	6-05	90+61.55	6-06	91+25	0.00	0.00	0.00	9.61	41.20	3.65	0.00	38.61	-2.60	-2.75	61.00	0.00246	48	Circular	1	71.25	0.00070	2.10	6.68	1.03	5.78	2.62	10.55	
6-09/6-06	6-09	12+50	6-06	91+25	0.37	0.64	0.24	0.24	5.00	8.71	0.00	2.26	2.00	1.00	86.00	0.01163	15	Circular	1	6.97	0.00130	0.49	0.45	0.26	5.07	0.89	16.96	
6-06/6-07	6-06	91+25	6-07	91+89.93	0.44	0.90	0.40	10.24	41.38	3.65	0.00	41.06	-2.75	-2.95	76.00	0.00263	48	Circular	1	73.67	0.00080	2.13	6.82	1.04	6.02	2.70	12.62	
6-07/6-08	6-07	91+89.93	6-08	93+63.11	0.00	0.00	0.00	10.07	41.60	3.63	0.00	40.25	-2.95	-3.30	178.00	0.00197	54	Circular	1	87.28	0.00040	2.15	7.49	1.09	5.38	2.60	33.11	
6-01/6-02	6-01	92+35.77	6-02	92+34.15	0.40	0.90	0.36	0.36	5.00	8.71	0.00	3.45	3.03	2.00	55.00	0.01873	18	Circular	1	14.38	0.00110	0.50	0.52	0.28	6.69	1.20	8.23	
6022/6013	5C-01	11+13.73	5C-02	11+15	9.58	0.83	7.96	7.96	20.86	5.18	0.00	45.39	-1.56	-2.26	108.50	0.00645	42	Circular	1	80.80	0.00210	1.88	5.25	0.91	8.64	3.04	12.56	
6013/6-03	5C-02	11+15	6-03	91+52.70	7.85	0.80	6.28	14.24	21.84	5.07	0.00	79.44	-2.26	-2.39	129.00	0.00101	60	Circular	1	82.77	0.00100	3.93	16.55	1.52	4.80	4.29	26.87	
6-03/6-04	6-03	91+52.70	6-04	92+16.87	17.43	0.82	14.35	14.35	21.84	5.07	0.00	80.05	-2.39	-2.90	118.00	0.00432	60	Circular	1	171.18	0.00100	2.40	9.34	1.22	8.57	3.55	13.77	

Denotes existing pipes to remain in place

LD-347
HYDRAULIC GRADE LINE ANALYSIS

PROJECT: Elizabeth River Tunnels Project
Portsmouth Approach

DESIGNED BY: MJP

Checked: AMO

INCIDENCE PROBABILITY **25** **Year**

INLET OR JUNCTION	STA.	INVERT EL. OUTFLOW PIPE	DEPTH OF FLOW OUTFLOW PIPE	OUTLET WATER SURFACE ELEV.	DIA. PIPE Do (In/mm)	DESIGN DISCH. Qo (CFS/CMS)	LENGTH PIPE Lo (Ft/M)	FRICTION SLOPE, Sfo (FT/FT) (M/M)	FRICTION LOSS Hf (Ft/M)	JUNCTION LOSS Vo	Contr. Ho (Ft/M)	Vi	Vi*2/2g	Hi (Expn) 0.35*MAX. (Vi2/2g)	SKEW Angle	K	Bend H (Ft/M)	Sum HL (Ft/M)	SURFACE FLOW	Adj. Ht 1.3 Ht (Ft/M)	Inlet Shaping? Y/N	0.5 Ht (Ft/M)	FINAL H (Ft/M)	Inlet Water Surface Elevation	Top of MH Top of Inlet Elev. APPROX.	Adjustment?
(1)	(2)			(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)		(12)	(13)		(14)	(15)		(16)		(16)	(17)	(18)	(19)	
6-08																								2.700		
6-07	91+89.93	-3.300	4.50	2.700	54	40.252	178.00	0.00044	0.078	5.377	0.112	5.996	0.558	0.195	75.0	0.62	0.348	0.655	0.000	0.655	YES	0.328	0.406	3.106	6.200	O.K.
6-06	91+25	-2.950	4.00	3.106	48	40.374	76.00	0.00083	0.063	5.996	0.140	5.758	0.515	0.180	70.0	0.60	0.310	0.630	1.443	0.630	YES	0.315	0.378	3.483	4.300	O.K.
6-05	90+61.55	-2.750	4.00	3.483	48	37.923	61.00	0.00073	0.044	5.758	0.129	5.747	0.513	0.180	5.0	0.07	0.036	0.344	0.000	0.344	YES	0.172	0.216	3.700	5.000	O.K.
5-09	89+36.73	-2.600	4.00	3.700	48	38.110	123.00	0.00074	0.090	5.747	0.128	5.373	0.448	0.157	20.0	0.24	0.107	0.392	0.742	0.392	YES	0.196	0.286	3.986	6.500	O.K.
5-10	89+53.82	-0.500	1.25	3.986	15	0.728	27.00	0.00013	0.004	4.337	0.073	0.000	0.000	0.000	0.0	0.00	0.000	0.073	0.662	0.095	YES	0.047	0.051	4.037	6.800	O.K.
6-09	12+50	1.000	1.25	3.483	15	2.262	86.00	0.00128	0.110	5.071	0.100	0.000	0.000	0.000	0.0	0.00	0.000	0.100	2.057	0.130	NO	0.130	0.240	3.723	6.200	O.K.
5-08	88+85.32	-2.300	4.00	3.986	48	37.058	48.00	0.00070	0.033	5.373	0.112	5.969	0.553	0.194	20.0	0.24	0.132	0.437	0.000	0.437	YES	0.219	0.252	4.238	8.620	O.K.
5-07	86+37.10	-2.200	3.17	4.238	60 X 38	37.410	247.00	0.00072	0.178	5.969	0.138	5.497	0.469	0.164	7.0	0.09	0.044	0.347	0.724	0.347	YES	0.173	0.352	4.590	6.000	O.K.
5-06	85+43.62	-1.500	4.00	4.590	48	36.752	90.00	0.00068	0.062	5.497	0.117	5.297	0.436	0.152	0.0	0.00	0.000	0.270	0.444	0.270	YES	0.135	0.196	4.786	6.600	O.K.
4-12	83+42.69	-1.300	4.00	4.786	48	36.575	198.00	0.00068	0.134	5.297	0.109	5.497	0.469	0.164	5.0	0.07	0.033	0.306	0.594	0.306	YES	0.153	0.287	5.073	7.500	O.K.
4-11	81+19.80	-0.900	4.00	5.073	48	36.266	223.00	0.00067	0.149	5.497	0.117	6.464	0.649	0.227	7.0	0.09	0.061	0.405	0.000	0.405	YES	0.203	0.351	5.425	7.800	O.K.
4-10	80+59.20	-0.400	4.00	5.425	48	36.342	58.00	0.00067	0.039	6.464	0.162	7.764	0.936	0.328	79.0	0.64	0.596	1.086	0.000	1.086	YES	0.543	0.582	6.006	8.800	O.K.
4-04	80+70.82	-0.200	4.00	6.006	48	14.541	56.00	0.00011	0.006	5.880	0.134	4.706	0.344	0.120	48.0	0.48	0.407	0.662	0.000	0.662	YES	0.331	0.337	6.343	9.100	O.K.
4-03	80+42.40	0.500	1.50	6.343	18	5.099	38.00	0.00246	0.094	7.396	0.212	5.999	0.559	0.196	54.0	0.52	0.290	0.698	1.999	0.907	YES	0.454	0.547	6.890	7.000	O.K.
4-00	79+40.88	1.200	1.25	6.890	15	2.932	92.00	0.00215	0.198	5.999	0.140	0.000	0.000	0.000	0.0	0.00	0.000	0.140	2.665	0.182	YES	0.091	0.289	7.179	7.400	O.K.
58-42		1.220	3.00	6.006	36	28.058	120.00	0.00185	0.222	7.764	0.234	0.000	0.000	0.000	0.0	0.00	0.000	0.234	0.000	0.234	NO	0.234	0.456	6.462	7.920	O.K.
4-02	78+95.20	1.530	2.50	6.343	30	1.183	163.00	0.00001	0.001	2.335	0.021	3.882	0.234	0.082	84.0	0.65	0.229	0.332	0.000	0.332	YES	0.166	0.168	6.511	9.370	O.K.
4-01	78+86.91	2.250	1.25	6.511	15	1.190	36.00	0.00035	0.013	4.761	0.088	4.970	0.384	0.134	30.0	0.33	0.128	0.351	0.000	0.351	YES	0.175	0.188	6.699	9.960	O.K.
55-92		2.920	1.25	6.699	15	1.208	88.65	0.00037	0.032	4.970	0.096	0.000	0.000	0.000	0.0	0.00	0.000	0.096	1.098	0.125	NO	0.125	0.157	6.856	8.960	O.K.
4-07	81+84.72	0.100	3.00	6.343	36	9.420	106.00	0.00021	0.022	4.706	0.086	4.834	0.363	0.127	32.0	0.35	0.128	0.341	1.395	0.341	YES	0.170	0.193	6.536	6.790	O.K.
4-08	83+16.77	0.500	3.00	6.536	36	8.005	130.00	0.00015	0.020	4.834	0.091	5.564	0.481	0.168	16.0	0.20	0.094	0.353	1.104	0.353	YES	0.177	0.196	6.732	6.800	O.K.
4-09	84+36.20	1.100	3.00	6.732	36	6.871	116.00	0.00011	0.013	5.564	0.120	3.719	0.215	0.075	0.0	0.00	0.000	0.195	0.480	0.195	YES	0.098	0.111	6.842	7.050	O.K.
5-02	86+80.60	2.000	3.00	6.842	36	6.595	243.00	0.00010	0.025	3.719	0.054	6.196	0.596	0.209	90.0	0.70	0.417	0.680	1.183	0.680	YES	0.340	0.365	7.207	7.300	O.K.
5-01	87+07.34	3.200	2.00	7.207	24	5.321	52.00	0.00058	0.030	6.196	0.149	0.000	0.000	0.000	0.0	0.00	0.000	0.149	4.837	0.194	YES	0.097	0.127	7.334	8.420	O.K.
58-34		1.970	2.50	6.511	30	13.201	274.64	0.00108	0.297	3.882	0.059	5.377	0.449	0.157	48.0	0.48	0.419	0.635	2.345	0.635	NO	0.317	0.615	7.125	7.310	O.K.
58-35		2.460	2.50	7.125	30	9.145	104.00	0.00052	0.054	5.377	0.112	0.000	0.000	0.000	0.0	0.00	0.000	0.112	6.987	0.146	NO	0.146	0.200	7.325	7.360	O.K.

LD-347
HYDRAULIC GRADE LINE ANALYSIS

PROJECT: Elizabeth River Tunnels Project
Portsmouth Approach

DESIGNED BY: MJP

Checked: AMO

INCIDENCE PROBABILITY **25** **Year**

INLET OR JUNCTION	STA.	INVERT EL. OUTFLOW PIPE	DEPTH OF FLOW OUTFLOW PIPE	OUTLET WATER SURFACE ELEV.	DIA. PIPE Do (In/mm)	DESIGN DISCH. Qo (CFS/CMS)	LENGTH PIPE Lo (Ft/M)	FRICTION SLOPE, Sfo (FT/FT) (M/M)	FRICTION LOSS Hf (Ft/M)	JUNCTION LOSS Vo	Contr. Ho (Ft/M)	Vi	Vi*2/2g	Hi (Expn) 0.35*MAX. (Vi2/2g)	SKEW Angle	K	Bend H (Ft/M)	Sum HL (Ft/M)	SURFACE FLOW	Adj. Ht 1.3 Ht (Ft/M)	Inlet Shaping? Y/N	0.5 Ht (Ft/M)	FINAL H (Ft/M)	Inlet Water Surface Elevation	Top of MH Top of Inlet Elev. APPROX.	Adjustment?
(1)	(2)			(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)		(12)	(13)		(14)	(15)		(16)		(16)	(17)	(18)	(19)	
55-80		3.000	1.25	7.125	15	1.883	99.50	0.00089	0.088	7.505	0.219	0.000	0.000	0.000	0.0	0.00	0.000	0.219	1.712	0.284	NO	0.284	0.373	7.498	12.460	O.K.
6-02																								2.700		
6-01	92+35.77	2.000	1.50	3.200	18	3.451	55.00	0.00113	0.062	6.687	0.174	0.000	0.000	0.000	0.0	0.00	0.000	0.174	3.137	0.226	NO	0.226	0.288	3.488	5.700	O.K.
6-04																								2.700		
6-03	91+52.70	-2.900	5.00	2.700	60	78.667	118.00	0.00095	0.113	8.534	0.283	4.800	0.358	0.125	0.0	0.00	0.000	0.408	0.000	0.408	NO	0.408	0.520	3.220	6.000	O.K.
5C-02	11+15	-2.390	5.00	3.220	60	79.435	129.00	0.00097	0.125	4.800	0.089	8.642	1.160	0.406	35.0	0.38	0.439	0.935	31.838	1.215	NO	1.215	1.340	4.561	5.770	O.K.
5C-01	11+13.73	-2.260	3.50	4.561	42	45.394	108.50	0.00213	0.231	8.642	0.290	0.000	0.000	0.000	0.0	0.00	0.000	0.290	41.267	0.377	NO	0.377	0.608	4.760	4.800	O.K.
	Denotes Existing Inlets to Remain in Place																									
	Denotes Existing Inlets with New Top																									

STORMWATER INLET COMPUTATIONS

ROUTE Portsmouth Boat Section **PROJECT** Midtown Tunnel **DESIGNER:** MJP **DATE** 1/14/2013
CHECKED: LRW **UNITS** ENGLISH

INLET																													Sag Inlets Only				
NUMBER	TYPE	LENGTH (FT; M)	STATION	DRAINAGE AREA (AC; HA)	C	CA	ΣCA	I (IN/HR; mm/HR)	Q INCR. (CFS; CMS)	Qc CARRYOVER (CFS; CMS)	QT GUTTER FLOW (CFS; CMS)	S GUTTER SLOPE (FT/FT; M/M)	Sx CROSS SLOPE (FT/FT; M/M)	T (SPREAD) (FT; M)	W (GUTTER WIDTH) (FT; M)	W/T	Sw (GUTTER SLOPE) (FT/FT; M/M)	Sw/Sx	Eo (App. 9C-8)	a	Sw	Se	COMPUTED LENGTH L_T (FT; M)	INLET / GRATE LENGTH (FT; M)	L/LT	E (App. 9C-18)	Q INTERCEPTED (CFS; CMS) or d/h	Qb CARRYOVER (CFS; CMS)	d (FT; M)	h (FT; M)	d/h	T SPREAD @ SAG (FT; M)	REMARKS
4-05	DI-10K	12	82+23.82	0.100	0.90	0.09																											
							0.09	6.5	0.585	0	0.585	0.044	0.0208	1.791	2.000	1.117	0.0833	4.0048	1.000	3.50	0.1458	0.1666	6.834	2.000	1.756	1.000	0.585	0.000					
4-06	DI-10K	12	83+54.5	0.110	0.90	0.099																											
							0.099	6.5	0.644	0	0.644	0.044	0.0208	1.857	2.000	1.077	0.0833	4.0048	1.000	3.50	0.1458	0.1666	7.116	2.000	1.686	1.000	0.644	0.000					
5-03	DI-10K	8	84+70.26	0.095	0.90	0.0855																											
							0.086	6.5	0.559	0	0.559	0.044	0.0208	1.761	2.000	1.136	0.0833	4.0048	1.000	3.50	0.1458	0.1666	6.705	2.000	1.193	1.000	0.559	0.000					
5-04	DI-10K	8	86+10.48	0.110	0.90	0.099																											
							0.099	6.5	0.644	0	0.644	0.044	0.0208	1.857	2.000	1.077	0.0833	4.0048	1.000	3.50	0.1458	0.1666	7.116	2.000	1.124	1.000	0.644	0.000					
5-05	DI-10K	10	87+66.06	0.110	0.90	0.099																											
							0.099	6.5	0.644	0	0.644	0.044	0.0208	1.857	2.000	1.077	0.0833	4.0048	1.000	3.50	0.1458	0.1666	7.116	2.000	1.405	1.000	0.644	0.000					

LD-347
HYDRAULIC GRADE LINE ANALYSIS

PROJECT: Elizabeth River Tunnels Project
Portsmouth Boat Section

DESIGNED BY: MJP

Checked: LRW

INCIDENCE PROBABILITY **25** **Year**

INLET OR JUNCTION	STA.	INVERT EL. OUTFLOW PIPE	DEPTH OF FLOW OUTFLOW PIPE	OUTLET WATER SURFACE ELEV.	DIA. PIPE Do (In/mm)	DESIGN DISCH. Qo (CFS/CMS)	LENGTH PIPE Lo (Ft/M)	FRICTION SLOPE, Sfo (FT/FT) (M/M)	FRICTION LOSS Hf (Ft/M)	JUNCTION LOSS Vo	Contr. Ho (Ft/M)	Vi	Vi*2/2g	Hi (Expn) 0.35*MAX. (Vi2/2g)	SKEW Angle	K	Bend H (Ft/M)	Sum HL (Ft/M)	SURFACE FLOW	Adj. Ht 1.3 Ht (Ft/M)	Inlet Shaping? Y/N	0.5 Ht (Ft/M)	FINAL H (Ft/M)	Inlet Water Surface Elevation	Top of MH Top of Inlet Elev. APPROX.	Adjustment?
(1)	(2)			(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)		(12)	(13)		(14)	(15)		(16)		(16)	(17)	(18)	(19)	
5-12																								-18.360		
5-05	87+66.06	-19.430	1.33	-18.360	16	3.667	57.00	0.00337	0.192	6.851	0.182	9.032	1.267	0.443	0.0	0.00	0.000	0.626	0.903	0.813	YES	0.407	0.599	-17.761	-15.700	O.K.
5-04	86+10.48	-18.370	1.00	-17.570	12	2.711	147.00	0.00605	0.890	9.032	0.317	7.778	0.939	0.329	0.0	0.00	0.000	0.645	0.840	0.839	YES	0.420	1.309	-16.261	-8.830	O.K.
5-03	84+70.26	-11.330	1.00	-10.530	12	1.811	142.00	0.00270	0.384	7.778	0.235	6.746	0.707	0.247	0.0	0.00	0.000	0.482	0.723	0.627	YES	0.313	0.697	-9.833	-2.720	O.K.
4-06	83+54.50	-5.220	1.00	-4.420	12	1.030	113.00	0.00087	0.099	6.746	0.177	6.229	0.602	0.211	0.0	0.00	0.000	0.388	0.188	0.388	YES	0.194	0.292	-4.128	2.390	O.K.
4-05	82+23.82	-0.110	1.00	0.690	12	0.837	127.00	0.00058	0.073	6.229	0.151	0.000	0.000	0.000	0.0	0.00	0.000	0.151	0.761	0.196	YES	0.098	0.171	0.861	7.320	O.K.

Parsons Brinckerhoff		***Designed By:***	**MJP**
Project:	**Midtown Tunnel (Portsmouth Approach)**	***Date:***	**5/6/2013**
Location:	**Portsmouth, VA**	***QA/QC By:***	**AMO**
Design Phase:	**Final Design**	***Date:***	**4/29/2013**
Description:	**Roadside Ditch Analysis**		
Design Year:	**10 Year for Capacity Design**		

ROADSIDE DITCHES

Ditch	Stationing Based Off of	From Station	To Station	Invert In	Invert Out	Solve For	Friction Method	Roughness Coefficient	Channel Slope (ft/ft)	Normal Depth (ft)	Left Side Slope (ft/ft (H:V))	Right Side Slope (ft/ft (H:V))	Discharge (cfs)	Top Width (ft)	Velocity (fps)	Flow Type	Material	Width of Erosion Control FT
D 4-00	WB US 58	76+79.83	79+40.88	8.60	7.40	Normal Depth	Manning Formula	0.05	0.005	0.96	1.5	3	2.40	4.32	1.16	Subcritical	EC-2	7.5
D 4-03(1)	WB US 58	79+40.88	80+42.40	7.40	7.00	Normal Depth	Manning Formula	0.05	0.004	0.68	1.5	3	0.89	3.07	1.24	Subcritical	EC-2	5.0
D 4-03(2)	WB US 58	82+06.23	80+42.40	7.40	7.00	Normal Depth	Manning Formula	0.05	0.0024	0.76	1.5	3	0.92	3.41	0.71	Subcritical	EC-2	5.0
D 4-07(1)	WB US 58	79+28.85	81+84.72	9.20	6.79	Normal Depth	Manning Formula	0.05	0.009	0.58	3	3	1.23	3.48	1.22	Subcritical	EC-2	6.0
D 4-07(2)	WB US 58	85+52.84	81+84.72	9.20	6.79	Normal Depth	Manning Formula	0.05	0.007	0.63	3	1.5	0.91	2.82	1.03	Subcritical	EC-2	5.0
D 4-08(1)	WB US 58	82+06.23	83+16.77	7.40	6.80	Normal Depth	Manning Formula	0.05	0.006	0.62	1.5	3	0.82	2.8	0.94	Subcritical	EC-2	5.0
D 4-08(2)	WB US 58	84+36.20	83+16.77	7.05	6.80	Normal Depth	Manning Formula	0.05	0.004	0.64	1.5	3	0.75	2.9	0.80	Subcritical	EC-2	5.0
D 4-09	WB US 58	85+50	84+36.20	8.00	7.05	Normal Depth	Manning Formula	0.05	0.008	0.49	1.5	3	0.54	2.21	0.99	Subcritical	EC-2	5.0
D 4-12	WB US 58	81+30	83+42.69	8.50	7.50	Normal Depth	Manning Formula	0.03	0.005	0.53	3	3	1.15	3.19	1.35	Subcritical	N/A	N/A
D 5-01	WB US 58	85+52.84	87+06	9.20	8.42	Normal Depth	Manning Formula	0.05	0.005	0.69	3	1.5	1.05	3.11	0.98	Subcritical	EC-2	5.0
D 5-02(1)	WB US 58	85+50	86+80.6	8.00	7.30	Normal Depth	Manning Formula	0.05	0.0044	0.63	1.5	3	0.75	2.82	0.85	Subcritical	EC-2	5.0
D 5-02(2)	WB US 58	87+81.50	86+80.6	7.60	7.30	Normal Depth	Manning Formula	0.05	0.0032	0.50	1.5	3	0.35	2.25	0.62	Subcritical	EC-2	5.0
D 5-06	WB US 58	83+42.69	85+43.62	7.50	6.60	Normal Depth	Manning Formula	0.03	0.0045	0.49	3	3	0.91	2.95	1.25	Subcritical	N/A	N/A
D 5-07(1)	WB US 58	85+43.62	86+37.10	6.60	6.00	Normal Depth	Manning Formula	0.03	0.006	0.27	3	3	0.21	1.6	0.99	Subcritical	N/A	N/A
D 5-07(2)	WB US 58	87+50	86+37.10	7.00	6.00	Normal Depth	Manning Formula	0.03	0.009	0.49	3	3	1.28	2.95	1.76	Subcritical	N/A	N/A
D 5-09	Port Road A	13+82.50	15+00	7.21	6.50	Normal Depth	Manning Formula	0.03	0.006	0.60	3	3	1.79	3.6	1.66	Subcritical	N/A	N/A
D 58-34	WB US 58	77+18.50	76+00	8.30	7.31	Normal Depth	Manning Formula	0.05	0.008	0.86	3	3	3.30	5.15	1.49	Subcritical	EC-2	6.0
D 6-09	Port Road C	11+38.5	12+50	6.80	6.20	Normal Depth	Manning Formula	0.013	0.005	0.52	3	3	2.31	3.11	2.86	Supercritical	Concrete	N/A

ROUTE WB US 58, Driveway N1, ERT, EB US 58, Access Drive N, Ramp N, Ramp B **PROJECT** Elizabeth River Tunnels Project MTT Norfolk **DESIGNER:** AMO **CHECKED:** MJP **DATE** 5/22/2013 **UNITS** ENGLISH

INLET																													Sag Inlets Only				
NUMBER	TYPE	LENGTH (FT; M)	STATION	DRAINAGE AREA (AC; HA)	C	CA	ΣCA	I (IN/HR; mm/HR)	Q INCR. (CFS; CMS)	Qa CARRYOVER (CFS; CMS)	QT GUTTER FLOW (CFS; CMS)	S GUTTER SLOPE (FT/FT; M/M)	Sx CROSS SLOPE (FT/FT; M/M)	T (SPREAD) (FT; M)	W (GUTTER WIDTH) (FT; M)	W/T	Sw (GUTTER SLOPE) (FT/FT; M/M)	Sw/Sx	Eo (App. 9C-8)	a	S'w	Se	COMPUTED LENGTH L_T (FT; M)	INLET / GRATE LENGTH (FT; M)	L/LT	E (App. 9C-18)	Q INTERCEPTED (CFS; CMS) or d/h	Qb CARRYOVER (CFS; CMS)	d (FT; M)	h (FT; M)	d/h	T SPREAD @ SAG (FT; M)	REMARKS
12-01	DI-7	3.000	131+51.97	0.046	0.90	0.0414																											Back/Lt.
				0.017	0.35	0.006																											Back/Lt.
							0.047	4	0.188	0																							Back/Lt.
				0.097	0.90	0.0873																											Ahead/Rt.
				0.668	0.35	0.2338																											Ahead/Rt.
							0.321	4	1.284	0																							Ahead/Rt.
											1.472	0.001			3.000								3			1.472							
12-02	DI-7	3.000	131+05.59	0.011	0.90	0.0099																											Back/Lt.
				0.015	0.35	0.0053																											Back/Lt.
							0.015	4	0.06	0																							Back/Lt.
				0.024	0.90	0.0216																											Ahead/Rt.
				0.020	0.35	0.007																											Ahead/Rt.
							0.029	4	0.116	0																							Ahead/Rt.
											0.176	0.001			3.000								3			0.176							
12-03	DI-7	3.000	130+36.65	0.050	0.90	0.045																											Back/Lt.
				0.038	0.35	0.0133																											Back/Lt.
							0.058	4	0.232	0																							Back/Lt.
				0.071	0.90	0.0639																											Ahead/Rt.
				0.108	0.35	0.0378																											Ahead/Rt.
							0.102	4	0.408	0																							Ahead/Rt.
											0.640	0.001			3.000								3			0.640							
12-11	DI-7B	3.000	132+07.36	0.025	0.90	0.0225																											Back/Lt.
				0.149	0.35	0.0522																											Back/Lt.
							0.075	6.5	0.488	0																							Back/Lt.
				0.083	0.90	0.0747																											Ahead/Rt.
				0.207	0.35	0.0725																											Ahead/Rt.
							0.147	6.5	0.956	0																							Ahead/Rt.
											1.443	0.001			3.000								3			1.443							
12-12	DI-7B	3.000	130+09.16	0.075	0.90	0.0675																											Back/Lt.
				0.165	0.35	0.0578																											Back/Lt.
							0.125	6.5	0.813	0																							Back/Lt.
				0.024	0.90	0.0216																											Ahead/Rt.
				0.249	0.35	0.0872																											Ahead/Rt.
							0.109	6.5	0.709	0																							Ahead/Rt.
											1.521	0.001			3.000								3			1.521							
12-13	DI-1	2.500	128+84.00	0.060	0.90	0.054																											Back/Lt.
				0.025	0.35	0.0088																											Back/Lt.
							0.063	6.5	0.41	0																							Back/Lt.
				2.210	0.90	1.989																											Ahead/Rt.
				0.036	0.35	0.0126																											Ahead/Rt.
							2.002	6.5	13.013	0																							Ahead/Rt.
											13.423	0.0100			2.500								2.5			13.423							

ROUTE WB US 58, Driveway N1, ERT, EB US 58, Access Drive N, Ramp N, Ramp B **PROJECT** Elizabeth River Tunnels Project MTT Norfolk **DESIGNER:** AMO **CHECKED:** MJP **DATE** 5/22/2013 **UNITS** ENGLISH

INLET																													Sag Inlets Only				
NUMBER	TYPE	LENGTH (FT; M)	STATION	DRAINAGE AREA (AC; HA)	C	CA	ΣCA	I (IN/HR; mm/HR)	Q INCR. (CFS; CMS)	Qa CARRYOVER (CFS; CMS)	QT GUTTER FLOW (CFS; CMS)	S GUTTER SLOPE (FT/FT; M/M)	Sx CROSS SLOPE (FT/FT; M/M)	T (SPREAD) (FT; M)	W (GUTTER WIDTH) (FT; M)	W/T	Sw (GUTTER SLOPE) (FT/FT; M/M)	Sw/Sx	Eo (App. 9C-8)	a	S'w	Se	COMPUTED LENGTH L_T (FT; M)	INLET / GRATE LENGTH (FT; M)	L/LT	E (App. 9C-18)	Q INTERCEPTED (CFS; CMS) or d/h	Qb CARRYOVER (CFS; CMS)	d (FT; M)	h (FT; M)	d/h	T SPREAD @ SAG (FT; M)	REMARKS
12-14	DI-7	3.000	127+62	0.134	0.90	0.1206																											Back/Lt.
				0.134	0.35	0.0469																											Back/Lt.
							0.168	6.5	1.092	0																							Back/Lt.
				0.209	0.90	0.1881																											Ahead/Rt.
				0.083	0.35	0.0291																											Ahead/Rt.
							0.217	6.5	1.411	0																							Ahead/Rt.
											2.503	0.001			3.000									3			2.503						
12-15	DI-7	3.000	127+15	0.006	0.90	0.0054																											Back/Lt.
				0.054	0.35	0.0189																											Back/Lt.
							0.024	6.5	0.156	0																							Back/Lt.
				0.880	0.90	0.792																											Ahead/Rt.
				0.029	0.35	0.0102																											Ahead/Rt.
							0.802	6.5	5.213	0																							Ahead/Rt.
											5.369	0.001			3.000									3			5.369						
12-16	DI-7	3.000	130+99.23	0.008	0.90	0.0072																											Back/Lt.
				0.026	0.35	0.0091																											Back/Lt.
							0.016	7.67	0.123	0																							Back/Lt.
				0.032	0.90	0.0288																											Ahead/Rt.
				0.037	0.35	0.013																											Ahead/Rt.
							0.042	7.67	0.322	0																							Ahead/Rt.
											0.445	0.0100			3.000									3			0.445						
12-23	DI-7	3.000	23+30.74	0.024	0.90	0.0216																											Back/Lt.
				0.016	0.35	0.0056																											Back/Lt.
							0.027	4	0.108	0																							Back/Lt.
				0.019	0.90	0.0171																											Ahead/Rt.
				0.026	0.35	0.0091																											Ahead/Rt.
							0.026	4	0.104	0																							Ahead/Rt.
											0.212	0.001			3.000									3			0.212						
12H-02	DI-7	3.000	17+42.26	0.021	0.90	0.0189																											Back/Lt.
				0.337	0.35	0.118																											Back/Lt.
							0.137	6.5	0.891	0																							Back/Lt.
				0.024	0.90	0.0216																											Ahead/Rt.
				0.239	0.35	0.0837																											Ahead/Rt.
							0.105	6.5	0.683	0																							Ahead/Rt.
											1.573	0.001			3.000									3			1.573						
13-01	DI-3B	8.000	138+09	0.059	0.90	0.0531																											
							0.053	7.67	0.407	0	0.407	0.004	0.0208	5.835	0.000	0.000	0.0208	1	0.674	2.00	0.0833	0.0770	4.543	8.000	1.761	1.000	0.407	0.000					
13-02	DI-3B	8.000	138+09	0.061	0.90	0.0549																											
				0.034	0.35	0.0119																											
							0.067	7.67	0.514	0.021	0.535	0.004	0.0208	6.500	0.000	0.000	0.0208	1	0.625	2.00	0.0833	0.0729	5.297	8.000	1.510	1.000	0.543	0.000					

ROUTE WB US 58, Driveway N1, ERT, EB US 58, Access Drive N, Ramp N, Ramp B **PROJECT** Elizabeth River Tunnels Project MTT Norfolk **DESIGNER:** AMO **CHECKED:** MJP **DATE** 5/22/2013 **UNITS** ENGLISH

INLET																													Sag Inlets Only				
NUMBER	TYPE	LENGTH (FT; M)	STATION	DRAINAGE AREA (AC; HA)	C	CA	ΣCA	I (IN/HR; mm/HR)	Q INCR. (CFS; CMS)	Qa CARRYOVER (CFS; CMS)	QT GUTTER FLOW (CFS; CMS)	S GUTTER SLOPE (FT/FT; M/M)	Sx CROSS SLOPE (FT/FT; M/M)	T (SPREAD) (FT; M)	W (GUTTER WIDTH) (FT; M)	W/T	Sw (GUTTER SLOPE) (FT/FT; M/M)	Sw/Sx	Eo (App. 9C-8)	a	S'w	Se	COMPUTED LENGTH L_T (FT; M)	INLET / GRATE LENGTH (FT; M)	L/LT	E (App. 9C-18)	Q INTERCEPTED (CFS; CMS) or d/h	Qb CARRYOVER (CFS; CMS)	d (FT; M)	h (FT; M)	d/h	T SPREAD @ SAG (FT; M)	REMARKS
13-03	DI-10L	10.000	137+93.53	0.035	0.35	0.0123																											Back/Lt.
							0.012	7.67	0.092	0																							Back/Lt.
				0.084	0.35	0.0294																											Ahead/Rt.
							0.029	7.67	0.222	0		0.002	0.0265	4.550	0.000	0.000	0.0265	1		2.00													Ahead/Rt.
											0.431	0.002			2.167									10			0.431		0.1007	0.3333	0.3033	3.797	Weir Flow
13-04	DI-1	2.500	137+84.13	0.120	0.35	0.042																											
							0.042	7.67	0.322	0	0.322	0.004	0.0208	5.345	0.000	0.000	0.0208	1	0.814	2.00	0.0833	0.0887	3.782	2.500	0.661	0.907	0.292	0.030					
13-06	DI-3B	10.000	137+31.81	0.181	0.90	0.1629																											
				0.007	0.35	0.0025																											
							0.165	7.67	1.266	0	1.266	0.014	0.0150	8.660	10.000	1.155	0.0150	1	1.000	2.00	0.0833	0.0983	9.199	10.000	1.087	1.000	1.266	0.000					
13-07	DI-3B	10.000	10+50	0.169	0.90	0.1521																											
							0.152	7.67	1.166	0	1.166	0.008	0.0200	11.570	10.000	0.864	0.0080	0.4	0.986	0.56	0.0000	0.0200	19.535	10.000	0.512	0.725	0.845	0.321					
13-08	DI-7A	3.000	201+43.02	0.150	0.90	0.135																											
				0.076	0.35	0.0266																											
							0.162	7.67	1.243	0	1.243	0.021			3.000									3.000		1.000	1.243	0.000	0.3768				BHt.=0.105'
13-10	DI-7	3.000	200+69	0.200	0.90	0.18																											Back/Lt.
				0.162	0.35	0.0567																											Back/Lt.
							0.237	7.67	1.818	0.01																							Back/Lt.
				0.138	0.90	0.1242																											Ahead/Rt.
				0.006	0.35	0.0021																											Ahead/Rt.
							0.126	7.67	0.966	0																							Ahead/Rt.
											2.794	0.001			3.000									3			2.794						
13-11	DI-7	3.000	136+80.36	0.379	0.90	0.3411																											Back/Lt.
							0.341	4	1.364	0																							Back/Lt.
				0.071	0.90	0.0639																											Ahead/Rt.
							0.064	4	0.256	0																							Ahead/Rt.
											1.620	0.001			3.000									3			1.620						
13-12	DI-2BB	6	135+12.22	0.069	0.90	0.0621																											
				0.014	0.35	0.0049																											
							0.067	4	0.268	0	0.268	0.009	0.0208	1.800	2.000	1.111	0.0833	4.0048	1.000	3.50	0.1458	0.1666	3.059	2.000	1.961	1.000	0.268	0.000					
13-13	DI-2BB	8	135+12.88	0.519	0.90	0.4671																											
							0.467	4	1.868	0	1.868	0.009	0.0208	7.589	2.000	0.264	0.0833	4.0048	0.709	3.50	0.1458	0.1241	8.249	2.000	0.970	0.998	1.865	0.003					
13-14	DI-7A	3.000	134+01.25	0.382	0.90	0.3438																											
				0.026	0.35	0.0091																											
							0.353	4	1.412	0	1.412	0.002			3.000									3.000		1.000	1.412	0.000	0.5198				BHt.=0.114'

ROUTE WB US 58, Driveway N1, ERT, EB US 58, Access Drive N, Ramp N, Ramp B **PROJECT** Elizabeth River Tunnels Project MTT Norfolk **DESIGNER:** AMO **CHECKED:** MJP **DATE** 5/22/2013 **UNITS** ENGLISH

INLET																													Sag Inlets Only				
NUMBER	TYPE	LENGTH (FT; M)	STATION	DRAINAGE AREA (AC; HA)	C	CA	ΣCA	I (IN/HR; mm/HR)	Q INCR. (CFS; CMS)	Qe CARRYOVER (CFS; CMS)	QT GUTTER FLOW (CFS; CMS)	S GUTTER SLOPE (FT/FT; M/M)	Sx CROSS SLOPE (FT/FT; M/M)	T (SPREAD) (FT; M)	W (GUTTER WIDTH) (FT; M)	W/T	Sw (GUTTER SLOPE) (FT/FT; M/M)	Sw/Sx	Eo (App. 9C-8)	a	S'w	Se	COMPUTED LENGTH L_T (FT; M)	INLET / GRATE LENGTH (FT; M)	L/LT	E (App. 9C-18)	Q INTERCEPTED (CFS; CMS) or d/h	Qb CARRYOVER (CFS; CMS)	d (FT; M)	h (FT; M)	d/h	T SPREAD @ SAG (FT; M)	REMARKS
13-20	DI-7A	3.000	133+04.14	0.150	0.90	0.135																											
				0.103	0.35	0.0361																											
							0.171	7.67	1.312	0	1.312	0.0100			3.000									3.000		1.000	1.312	0.000	0.1847				BHt.=0.109'
13-22	DI-7	3.000	133+45.59	0.044	0.35	0.0154																											Back/Lt.
							0.015	7.67	0.115	0																							Back/Lt.
				0.012	0.90	0.0108																											Ahead/Rt.
				0.103	0.35	0.0361																											Ahead/Rt.
							0.047	7.67	0.36	0																							Ahead/Rt.
											0.476	0.001			3.000									3			0.476						
13-24	DI-3BB	6.000	137+79	0.002	0.90	0.0018																											
							0.002	7.67	0.015	0	0.015	0.008	0.0208	0.625	2.000	3.200	0.0833	4.0048	1.000	3.50	0.1458	0.1666	0.880	6.000	6.818	1.000	0.015	0.000					
13-28	DI-10K	6	135+23.79	0.024	0.90	0.0216																											
				0.155	0.35	0.0543																											
							0.076	7.67	0.641	0	0.641	0.0100	0.0208	3.686	2.000	0.543	0.0833	4.0048	0.964	3.50	0.1458	0.1613	4.643	2.000	1.292	1.000	0.641	0.000					
13-29	DI-10K	6	136+66.40	0.056	0.90	0.0504																											
							0.05	7.67	0.422	0	0.422	0.017	0.0208	1.894	2.000	1.056	0.0833	4.0048	1.000	3.50	0.1458	0.1666	4.479	2.000	1.340	1.000	0.422	0.000					
13-32	DI-1	2.500	18+63.97	0.051	0.35	0.0179																											
							0.018	7.67	0.138	0	0.138	0.002	0.0208	4.431	0.000	0.000	0.0208	1	0.891	2.00	0.0833	0.0951	2.064	2.500	1.211	0.967	0.133	0.005					
13E-01	DI-7	3.000	13+14	0.383	0.90	0.3447																											Back/Lt.
				0.563	0.35	0.1971																											Back/Lt.
							0.542	7.67	4.157	0																							Back/Lt.
				0.229	0.90	0.2061																											Ahead/Rt.
				0.314	0.35	0.1099																											Ahead/Rt.
							0.316	7.67	2.424	0																							Ahead/Rt.
											6.581	0.0100			3.000									3			6.581						
13E-02	DI-3B	8.000	14+00.00	0.291	0.90	0.2619																											
				0.055	0.35	0.0193																											
							0.281	7.67	2.155	0	2.155	0.010	0.0250	7.133	2.000	0.280	0.0833	3.332	0.712	3.40	0.1416	0.1258	8.969	8.000	0.892	0.982	2.116	0.039					
13E-04	DI-3C	12.000	13+51.48	0.043	0.90	0.0387																											Back/Lt.
				0.089	0.35	0.0312																											Back/Lt.
							0.07	4	0.28	0																							Back/Lt.
				0.168	0.90	0.1512																											Ahead/Rt.
							0.151	4	0.604	0		0.013	0.0130	7.279	0.000	0.000	0.0130	1		2.00													Ahead/Rt.
											0.884	0.013												12			0.884		0.0846	0.3333	0.25526	6.505	Weir Flow
13E-05	DI-7	3.000	13+68.80	0.002	0.90	0.0018																											Back/Lt.
				0.054	0.35	0.0189																											Back/Lt.

ROUTE WB US 58, Driveway N1, ERT, EB US 58, Access Drive N, Ramp N, Ramp B **PROJECT** Elizabeth River Tunnels Project MTT Norfolk **DESIGNER:** AMO **CHECKED:** MJP **DATE** 5/22/2013 **UNITS** ENGLISH

INLET																													Sag Inlets Only				
NUMBER	TYPE	LENGTH (FT; M)	STATION	DRAINAGE AREA (AC; HA)	C	CA	ΣCA	I (IN/HR; mm/HR)	Q INCR. (CFS; CMS)	Qc CARRYOVER (CFS; CMS)	QT GUTTER FLOW (CFS; CMS)	S GUTTER SLOPE (FT/FT; M/M)	Sx CROSS SLOPE (FT/FT; M/M)	T (SPREAD) (FT; M)	W (GUTTER WIDTH) (FT; M)	W/T	Sw (GUTTER SLOPE) (FT/FT; M/M)	Sw/Sx	Eo (App. 9C-8)	a	S'w	Se	COMPUTED LENGTH L_T (FT; M)	INLET / GRATE LENGTH (FT; M)	L/LT	E (App. 9C-18)	Q INTERCEPTED (CFS; CMS) or d/h	Qb CARRYOVER (CFS; CMS)	d (FT; M)	h (FT; M)	d/h	T SPREAD @ SAG (FT; M)	REMARKS
							0.021	7.67	0.161	0																							Back/Lt.
				0.055	0.90	0.0495																											Ahead/Rt.
				0.096	0.35	0.0336																											Ahead/Rt.
							0.083	7.67	0.637	0																							Ahead/Rt.
											0.798	0.001			3.000									3			0.798						
13E-06	DI-7	3.000	12+62.88	0.072	0.90	0.0648																											Back/Lt.
				0.139	0.35	0.0487																											Back/Lt.
							0.113	7.67	0.867	0																							Back/Lt.
				0.063	0.90	0.0567																											Ahead/Rt.
				0.319	0.35	0.1117																											Ahead/Rt.
							0.168	7.67	1.289	0																							Ahead/Rt.
											2.155	0.001			3.000									3			2.155						
13E-08	DI-7	3.000	18+60.07	0.045	0.90	0.0405																											Back/Lt.
				0.414	0.35	0.1449																											Back/Lt.
							0.185	6.5	1.203	0																							Back/Lt.
				0.194	0.35	0.0679																											Ahead/Rt.
							0.068	6.5	0.442	0																							Ahead/Rt.
											1.645	0.001			3.000									3			1.645						
13E-10	DI-7	3.000	14+13.60	0.066	0.90	0.0594																											Back/Lt.
				0.055	0.35	0.0193																											Back/Lt.
							0.079	6.5	0.514	0																							Back/Lt.
				0.006	0.90	0.0054																											Ahead/Rt.
				0.071	0.35	0.0249																											Ahead/Rt.
							0.03	6.5	0.195	0																							Ahead/Rt.
											0.709	0.001			3.000									3			0.709						
72-9	DI-3B	2.000	13+88.58	0.208	0.90	0.1872																											
							0.187	7.67	1.434	0	1.434	0.043	0.0208	3.930	2.000	0.509	0.0833	4.0048	0.951	3.50	0.1458	0.1596	10.152	2.000	0.197	0.326	0.468	0.966					
14-01	DI-10K	8	140+16.31	0.064	0.90	0.0576																											
				0.057	0.35	0.02																											
							0.078	7.67	0.598	0	0.598	0.009	0.0208	5.790	0.000	0.000	0.0208	1	0.779	2.00	0.0833	0.0857	6.385	2.500	1.253	1.000	0.598	0.000					
14-02	DI-3B	6.000	139+05.86	0.102	0.90	0.0918																											
							0.092	7.67	0.706	0	0.706	0.007	0.0208	6.458	0.000	0.000	0.0208	1	0.628	2.00	0.0833	0.0732	6.982	6.000	0.859	0.971	0.685	0.021					
14-03	DI-7	3.000	139+17.25	0.019	0.90	0.0171																											Back/Lt.
				0.081	0.35	0.0284																											Back/Lt.
							0.045	6.5	0.293	0																							Back/Lt.
				0.111	0.35	0.0389																											Ahead/Rt.
							0.039	6.5	0.254	0																							Ahead/Rt.
											0.546	0.001			3.000									3			0.546						
14B-01	DI-2BB	6	202+23.24	0.048	0.90	0.0432																											

STORMWATER INLET COMPUTATIONS

ROUTE WB US 58, Driveway N1, ERT, EB US 58, Access Drive N, Ramp N, Ramp B

PROJECT Elizabeth River Tunnels Project MTT Norfolk

DESIGNER: AMO
CHECKED: MJP

DATE 5/22/2013
UNITS ENGLISH

INLET																													Sag Inlets Only				
NUMBER	TYPE	LENGTH (FT; M)	STATION	DRAINAGE AREA (AC; HA)	C	CA	ΣCA	I (IN/HR; mm/HR)	Q INCR. (CFS; CMS)	Qc CARRYOVER (CFS; CMS)	QT GUTTER FLOW (CFS; CMS)	S GUTTER SLOPE (FT/FT; M/M)	Sx CROSS SLOPE (FT/FT; M/M)	T (SPREAD) (FT; M)	W (GUTTER WIDTH) (FT; M)	W/T	Sw (GUTTER SLOPE) (FT/FT; M/M)	Sw/Sx	Eo (App. 9C-8)	a	S'w	Se	COMPUTED LENGTH L_T (FT; M)	INLET / GRATE LENGTH (FT; M)	L/LT	E (App. 9C-18)	Q INTERCEPTED (CFS; CMS) or d/h	Qb CARRYOVER (CFS; CMS)	d (FT; M)	h (FT; M)	d/h	T SPREAD @ SAG (FT; M)	REMARKS
							0.043	7.67	0.33	0	0.330	0.047	0.0208	3.400	0.000	0.000	0.0208	1	0.906	2.00	0.0833	0.0963	7.614	2.000	0.788	0.939	0.310	0.020					
14B-02	DI-7	3.000	138+37.62	0.461	0.90	0.4149																											Back/Lt.
				0.048	0.35	0.0168																											Back/Lt.
							0.432	4	1.728	0																							Back/Lt.
				0.478	0.90	0.4302																											Ahead/Rt.
				0.013	0.35	0.0046																											Ahead/Rt.
							0.435	4	1.74	0																							Ahead/Rt.
											3.468	0.0100			3.000									3			3.468						

LD-229
STORM SEWER DESIGN COMPUTATIONS

STORM FREQUENCY **10/25**

PROJECT: Elizabeth River Tunnels Project
LOCATION: MTT Norfolk
COUNTY: Norfolk (city)

Designed by: AMO
Checked by: MJP

UNITS **ENGLISH**

PIPE NO.	FROM POINT REFERENCE (1)	FROM POINT STA.	TO POINT REFERENCE (2)	TO POINT STA.	DRAIN. AREA "A" Acre (3)	RUNOFF COEFF. "C" (4)	CA INCRE-MENT (5)	CA ACCUM-ULATED (6)	TOTAL INLET TIME Minutes (7)	RAIN FALL In/Hr (8)	RUNOFF Lateral CFS	RUNOFF Total Q CFS (9)	INVERT ELEVATIONS UPPER END (10)	INVERT ELEVATIONS LOWER END (11)	LENGTH of Pipe Ft. (12)	SLOPE Ft./Ft. (13)	SIZE (Dia. Or Span/Rise) In. (14)	SHAPE	Number of Pipes	Capacity CFS (15)	Friction Slope Ft./Ft.	NORMAL FLOW Depth of Flow, dn Ft.	NORMAL FLOW Area of Flow, An SqFt	NORMAL FLOW Hrn Ft.	NORMAL FLOW Vn Ft/Sec (16)	NORMAL FLOW En Ft.	FLOW TIME Sec. (17)	REMARKS (18)
12-13/12-14	12-13	128+84.00	12-14	127+62	2.33	0.89	2.07	2.07	5.00	7.67	0.00	15.83	1.80	1.20	120.00	0.00500	24	Circular	1	16.00	0.00510	1.62	2.73	0.61	5.81	2.14	20.67	
12-14/12-15	12-14	127+62	12-15	127+15	0.56	0.69	0.39	2.45	5.35	7.54	0.00	18.46	1.10	0.75	48.00	0.00729	24	Circular	1	19.32	0.00690	1.57	2.64	0.61	7.00	2.33	6.86	
12-15/11-01	12-15	127+15	11-01	126+58.77	0.97	0.85	0.83	3.28	5.46	7.47	0.00	24.46	0.14	0.00	64.00	0.00219	36	Circular	1	31.21	0.00140	2.00	5.01	0.87	4.89	2.37	13.10	
12-11/12-12	12-11	132+07.36	12-12	130+09.16	0.46	0.48	0.22	0.22	5.00	7.67	0.00	1.70	0.83	0.38	196.00	0.00230	15	Circular	1	3.10	0.00070	0.66	0.66	0.32	2.59	0.77	75.83	
12-12/12-19	12-12	130+09.16	12-19	129+22	0.51	0.46	0.23	0.46	6.26	7.21	0.00	3.29	0.28	-0.12	84.00	0.00476	15	Circular	1	4.46	0.00270	0.80	0.83	0.36	3.97	1.04	21.14	
12-19/12-20	12-19	129+22	12-20	129+22	0.00		0.00	0.46	6.62	7.10	0.00	3.24	-8.90	-9.00	24.00	0.00417	15	Circular	1	4.17	0.00260	0.83	0.86	0.36	3.76	1.05	6.39	
14B-02/13-11	14B-02	138+37.62	13-11	136+80.36	0.99	0.78	0.77	0.77	5.00	7.67	0.00	5.93	0.56	0.00	162.00	0.00346	24	Circular	1	13.31	0.00070	0.94	1.44	0.48	4.12	1.20	39.37	
13-11/13-12	13-11	136+80.36	13-12	135+12.22	0.45	0.90	0.41	1.18	5.66	7.42	0.00	8.75	-0.50	-1.15	162.00	0.00401	24	Circular	1	14.33	0.00160	1.13	1.83	0.54	4.79	1.49	33.85	
13-13/13-12	13-13	135+12.88	13-12	135+12.22	0.52	0.90	0.47	0.47	5.00	7.67	0.00	3.58	-1.13	-1.15	4.00	0.00500	15	Circular	1	4.57	0.00320	0.83	0.87	0.36	4.12	1.10	0.97	
13-12/13-14	13-12	135+12.22	13-14	134+01.25	0.08	0.81	0.07	1.71	6.22	7.23	0.00	12.38	-1.15	-1.65	107.00	0.00467	24	Circular	1	15.46	0.00310	1.35	2.26	0.59	5.47	1.82	19.57	
13-14/12-01A	13-14	134+01.25	12-01A	131+52.25	0.41	0.87	0.35	2.07	6.55	7.12	0.00	14.71	-1.65	-2.17	245.00	0.00212	30	Circular	1	18.89	0.00130	1.66	3.46	0.73	4.25	1.94	57.60	
12-01/12-01A	12-01	131+51.97	12-01A	131+52.25	0.83	0.44	0.37	0.37	5.00	7.67	0.00	2.82	1.40	1.37	15.00	0.00200	15	Circular	1	2.89	0.00200	1.00	1.05	0.38	2.68	1.11	5.59	
12-01A/12-02	12-01A	131+52.25	12-02	131+05.59	0.00		0.00	2.43	7.51	6.82	0.00	16.61	-2.17	-2.27	46.00	0.00217	30	Circular	1	19.11	0.00170	1.80	3.79	0.75	4.38	2.10	10.49	
12-17/12-23	12-17	23+33.63	12-23	23+30.74	0.23	0.78	0.18	0.18	5.00	7.67	0.00	1.36	1.80	1.70	21.00	0.00476	15	Circular	1	4.46	0.00050	0.47	0.43	0.26	3.19	0.63	6.58	
12-23/12-02	12-23	23+30.74	12-02	131+05.59	0.09	0.62	0.05	0.23	5.11	7.62	0.00	1.76	1.60	1.40	104.00	0.00192	15	Circular	1	2.83	0.00080	0.71	0.72	0.34	2.43	0.81	42.77	
12-02/12-03	12-02	131+05.59	12-03	130+36.65	0.07	0.63	0.04	2.48	7.68	6.77	0.00	16.78	-2.27	-2.40	65.00	0.00200	30	Circular	1	18.34	0.00170	1.88	3.96	0.76	4.24	2.16	15.34	
12-03/12-04	12-03	130+36.65	12-04	129+79.61	0.27	0.60	0.16	2.64	7.94	6.70	0.00	17.67	-2.40	-2.60	91.00	0.00220	30	Circular	1	19.24	0.00190	1.89	3.98	0.76	4.45	2.19	20.47	
13E-10/13E-09	13E-10	14+13.60	13E-09	14+13.8	0.20	0.55	0.11	0.11	5.00	7.67	0.00	0.84	0.60	0.50	29.00	0.00345	18	Circular	1	6.17	0.00010	0.37	0.34	0.22	2.44	0.47	11.89	
13E-09/13E-08	13E-09	14+13.8	13E-08	18+60.07	0.00		0.00	0.11	5.20	7.59	0.00	0.83	0.40	0.10	46.00	0.00652	18	Circular	1	8.48	0.00010	0.32	0.27	0.19	3.05	0.46	15.09	
13E-08/12H-02	13E-08	18+60.07	12H-02	17+42.26	0.65	0.39	0.25	0.36	5.45	7.50	0.00	2.71	0.00	-0.50	139.00	0.00360	18	Circular	1	6.30	0.00070	0.69	0.79	0.35	3.43	0.87	40.48	
12H-02/EX	12H-02	17+42.26	EX	17+19.89	0.62	0.39	0.24	0.60	6.12	7.26	0.00	4.38	-0.81	-0.90	31.00	0.00290	18	Circular	1	5.66	0.00180	0.99	1.24	0.44	3.54	1.19	8.77	
13-32/13-10	13-32	18+63.97	13-10	200+69	0.05	0.35	0.02	0.02	5.00	7.67	0.00	0.14	1.03	0.45	67.00	0.00866	15	Circular	1	6.01	0.00000	0.13	0.07	0.08	2.03	0.19	32.99	
13-10/13-09	13-10	200+69	13-09	200+90.00	0.51	0.72	0.36	0.38	5.55	7.46	0.00	2.84	0.45	0.41	16.00	0.00250	15	Circular	1	3.23	0.00200	0.91	0.96	0.38	2.97	1.05	5.39	
14B-01/13-08	14B-01	202+23.24	13-08	201+43.02	0.05	0.90	0.04	0.04	5.00	8.71	0.00	0.41	1.30	0.80	90.00	0.00556	15	Circular	1	4.82	0.00000	0.25	0.17	0.15	2.40	0.34	37.49	
13-08/13-09	13-08	201+43.02	13-09	200+90.00	0.23	0.72	0.16	0.21	5.63	8.45	0.00	1.91	0.70	0.51	48.00	0.00396	15	Circular	1	4.07	0.00090	0.60	0.59	0.31	3.26	0.77	14.72	
13-09/13-24	13-09	200+90.00	13-24	137+79	0.00		0.00	0.59	5.87	8.36	0.00	5.39	0.41	0.00	75.00	0.00547	15	Circular	1	4.78	0.00730	1.25	1.23	0.31	4.39	1.55	17.09	Pressure Flow
13-24/13-04	13-24	137+79	13-04	137+84.21	0.00	1.00	0.00	0.59	6.16	8.25	0.00	5.33	0.00	-0.05	6.00	0.00833	15	Circular	1	5.90	0.00710	0.93	0.98	0.38	5.44	1.39	1.10	
13-29/13-04	13-29	136+66.40	13-04	137+84.13	0.06	0.89	0.05	0.05	5.00	8.71	0.00	0.48	0.31	-0.13	111.50	0.00395	15	Circular	1	4.06	0.00010	0.29	0.22	0.17	2.22	0.37	50.17	
13-04/13-03	13-04	137+84.13	13-03	137+93.53	0.12	0.35	0.04	0.68	6.17	8.24	0.00	6.16	-0.16	-0.30	72.00	0.00194	18	Circular	1	4.63	0.00360	1.50	1.77	0.38	3.49	1.69	20.64	Pressure Flow
13-01/13-02	13-01	138+09	13-02	138+09	0.06	0.90	0.05	0.05	5.00	8.71	0.00	0.51	5.10	5.00	15.00	0.00667	15	Circular	1	5.28	0.00010	0.26	0.19	0.16	2.72	0.38	5.51	
13-02/14-02	13-02	138+09	14-02	138+05.86	0.10	0.71	0.07	0.12	5.09	8.67	0.00	1.15	4.90	4.55	94.00	0.00372	15	Circular	1	3.94	0.00030	0.46	0.41	0.25	2.78	0.58	33.77	

LD-229
STORM SEWER DESIGN COMPUTATIONS

STORM FREQUENCY **10/25**

PROJECT: Elizabeth River Tunnels Project
LOCATION: MTT Norfolk
COUNTY: Norfolk (city)

Designed by: AMO
Checked by: MJP

UNITS **ENGLISH**

PIPE NO.	FROM POINT REFERENCE (1)	FROM POINT STA.	TO POINT REFERENCE (2)	TO POINT STA.	DRAIN. AREA "A" Acre (3)	RUNOFF COEFF. "C" (4)	CA INCRE-MENT (5)	CA ACCUM-ULATED (6)	TOTAL INLET TIME Minutes (7)	RAIN FALL In/Hr (8)	RUNOFF Lateral CFS	RUNOFF Total Q CFS (9)	INVERT ELEVATIONS UPPER END (10)	INVERT ELEVATIONS LOWER END (11)	LENGTH of Pipe Ft. (12)	SLOPE Ft./Ft. (13)	SIZE (Dia. Or Span/Rise) In. (14)	SHAPE	Number of Pipes	Capacity CFS (15)	Friction Slope Ft./Ft.	NORMAL FLOW Depth of Flow, dn Ft.	NORMAL FLOW Area of Flow, An SqFt	NORMAL FLOW Hrn Ft.	NORMAL FLOW Vn Ft/Sec (16)	NORMAL FLOW En Ft.	FLOW TIME Sec. (17)	REMARKS (18)
14-03/14-02	14-03	139+17.25	14-02	139+05.86	0.21	0.40	0.08	0.32	6.10	7.27	0.00	2.34	2.16	2.13	12.00	0.00250	15	Circular	1	3.23	0.00140	0.79	0.82	0.36	2.87	0.92	4.18	
14-01/14-02	14-01	140+16.31	14-02	138+05.86	0.12	0.65	0.08	0.08	5.00	8.71	0.00	0.75	5.00	4.55	108.00	0.00417	15	Circular	1	4.17	0.00010	0.36	0.29	0.21	2.58	0.46	41.95	
14-02/13-03	14-02	139+05.86	13-03	137+93.53	0.10	0.90	0.09	0.61	6.17	8.24	0.00	5.55	2.03	-0.34	140.00	0.01693	18	Circular	1	13.67	0.00290	0.67	0.76	0.35	7.33	1.50	19.09	
13-03/13-05	13-03	137+93.53	13-05	137+91.99	0.12	0.35	0.04	1.33	6.52	8.11	0.00	11.90	-0.30	-0.33	31.00	0.00097	18	Circular	1	3.27	0.01340	1.50	1.77	0.38	6.73	2.20	4.60	Pressure Flow
13E-01/13-05	13E-01	13+14	13-05	137+91.99	1.49	0.58	0.86	0.86	5.00	7.67	0.00	6.58	-0.45	-1.10	155.00	0.00419	18	Circular	1	6.80	0.00410	1.19	1.50	0.46	4.38	1.49	35.36	
13-05/13-06	13-05	137+91.99	13-06	137+31.81	0.00		0.00	2.19	6.59	8.09	0.00	19.49	-1.07	-1.50	57.00	0.00754	24	Circular	1	19.64	0.00770	1.63	2.73	0.61	7.13	2.41	8.00	
13-06/13E-11	13-06	137+31.81	13E-11	11+48.04	0.19	0.88	0.17	2.36	6.73	8.04	0.00	20.83	-1.60	-1.80	78.00	0.00256	36	Circular	1	33.75	0.00100	1.71	4.15	0.81	5.02	2.10	15.53	
13E-02/13E-05	13E-02	14+00.00	13E-05	13+68.80	0.35	0.81	0.28	0.28	5.00	7.67	0.00	2.15	0.15	0.00	60.00	0.00250	15	Circular	1	3.23	0.00120	0.75	0.76	0.35	2.82	0.87	21.29	
13E-04/13E-05	13E-04	13+51.48	13E-05	13+68.80	0.30	0.74	0.22	0.22	5.00	7.67	0.00	1.69	0.00	-0.10	22.00	0.00455	15	Circular	1	4.36	0.00070	0.54	0.51	0.28	3.33	0.71	6.61	
13E-05/13E-06	13E-05	13+68.80	13E-06	12+62.88	0.21	0.50	0.10	0.61	5.36	7.53	0.00	4.56	-0.10	-0.55	83.00	0.00542	15	Circular	1	4.76	0.00520	0.98	1.03	0.38	4.41	1.28	18.80	
13E-06/13E-11	13E-06	12+62.88	13E-11	11+48.04	0.59	0.47	0.28	0.89	5.59	8.47	0.00	8.26	-0.90	-1.10	83.00	0.00241	24	Circular	1	11.11	0.00140	1.29	2.13	0.57	3.87	1.52	21.43	
13E-11/13-07	13E-11	11+48.04	13-07	10+50	0.00		0.00	3.24	6.99	7.95	0.00	28.35	-2.10	-2.30	91.00	0.00220	36	Circular	1	31.28	0.00190	2.24	5.66	0.90	5.01	2.63	18.15	
12-16/13-20	12-16	130+99.23	13-20	133+04.14	0.10	0.56	0.06	0.06	5.00	8.71	0.00	0.56	1.30	0.16	205.00	0.00556	15	Circular	1	4.82	0.00010	0.29	0.21	0.17	2.62	0.39	78.27	
13-20/13-21	13-20	133+04.14	13-21	133+69.62	0.25	0.68	0.17	0.23	6.30	8.19	0.00	2.06	0.16	0.00	63.00	0.00254	15	Circular	1	3.26	0.00110	0.72	0.73	0.34	2.81	0.85	22.43	
13-22/13-21	13-22	133+45.59	13-21	133+69.62	0.16	0.39	0.06	0.06	5.00	7.67	0.00	0.48	-2.62	-2.63	42.00	0.00024	18	Circular	1	1.63	0.00000	0.55	0.59	0.30	0.80	0.56	52.49	
13-21/13-31	13-21	133+69.62	13-31	135+44.55	0.00		0.00	0.29	6.68	7.08	0.00	2.06	-2.60	-2.61	204.00	0.00005	18	Circular	1	0.74	0.00040	1.50	1.77	0.38	1.17	1.52	175.08	Pressure Flow
13-28/13-31	13-28	135+23.79	13-31	135+44.55	0.18	0.43	0.08	0.08	5.00	8.71	0.00	0.73	0.25	0.00	46.00	0.00543	18	Circular	1	7.74	0.00010	0.31	0.26	0.19	2.75	0.43	16.71	
72-20/13-31	72-20	17+08.00	13-31	135+44.55	0.32	0.65	0.21	0.21	5.00	7.67	0.00	1.60	-1.63	-1.64	19.00	0.00053	15	Circular	1	1.49	0.00060	1.25	1.23	0.31	1.30	1.28	14.62	Pressure Flow
13-31/72-18	13-31	135+44.55	72-18	135+51.16	0.00		0.00	0.58	9.60	6.27	0.00	3.61	-2.44	-2.45	13.00	0.00077	15	Circular	1	1.79	0.00330	1.25	1.23	0.31	2.94	1.38	4.43	Pressure Flow
72-18/72-17	72-18	135+51.16	72-17	135+74.38	0.04	0.74	0.03	0.60	9.67	6.25	0.00	3.77	-1.23	-1.24	15.00	0.00067	15	Circular	1	1.67	0.00360	1.25	1.23	0.31	3.07	1.40	4.88	Pressure Flow
72-17/13-07	72-17	135+74.38	13-07	10+50	0.00		0.00	0.60	9.75	6.23	0.00	3.76	-0.78	-0.79	14.00	0.00071	15	Circular	1	1.72	0.00350	1.25	1.23	0.31	3.06	1.40	4.57	Pressure Flow
13-07/13E-07	13-07	10+50	13E-07	10+00	0.17	0.90	0.15	4.00	9.83	7.10	0.00	31.22	-3.60	-3.90	96.00	0.00313	36	Circular	1	37.32	0.00230	2.10	5.28	0.89	5.91	2.64	16.24	
13E-07/13E-12	13E-07	10+00	13E-12	10+00	0.00		0.00	4.00	10.10	7.03	0.00	30.92	-4.00	-4.04	17.00	0.00235	36	Circular	1	32.33	0.00220	2.35	5.94	0.91	5.21	2.77	3.26	
72-8/13E-13	72-8	13+93.14	13E-13	13+88.58	0.21	0.83	0.18	0.18	5.00	8.71	0.00	1.68	10.88	10.42	42.00	0.01095	15	Circular	1	6.76	0.00070	0.42	0.37	0.24	4.57	0.75	9.19	
13E-13/13E-14	13E-13	13+88.58	13E-14	13+47.48	0.21	0.90	0.19	0.36	5.15	8.65	0.00	3.44	10.02	9.70	53.00	0.00604	15	Circular	1	5.02	0.00300	0.76	0.78	0.35	4.41	1.06	12.03	
13E-14/13E-15	13E-14	13+47.48	13E-15	13+34.36	0.00		0.00	0.36	5.35	7.53	0.00	2.73	3.15	3.06	21.00	0.00429	15	Circular	1	4.23	0.00190	0.73	0.74	0.34	3.66	0.94	5.73	

Denotes existing pipes or structures to remain in place

LD-347
HYDRAULIC GRADE LINE ANALYSIS

PROJECT: Elizabeth River Tunnels Project
MTT Norfolk

DESIGNED BY: AMO
Checked: MJP

INCIDENCE PROBABILITY **10/25** **Year**

INLET OR JUNCTION	STA.	INVERT EL. OUTFLOW PIPE	DEPTH OF FLOW OUTFLOW PIPE	OUTLET WATER SURFACE ELEV.	DIA. PIPE Do (In/mm)	DESIGN DISCH. Qo (CFS/CMS)	LENGTH PIPE Lo (Ft/M)	FRICTION SLOPE, Sfo (FT/FT) (M/M)	FRICTION LOSS Hf (Ft/M)	JUNCTION LOSS Vo	Contr. Ho (Ft/M)	Vi	Vi*2/2g	Hi (Expn) 0.35*MAX. (Vi2/2g)	SKEW Angle	K	Bend H (Ft/M)	Sum HL (Ft/M)	SURFACE FLOW	Adj. Ht 1.3 Ht (Ft/M)	Inlet Shaping? Y/N	0.5 Ht (Ft/M)	FINAL H (Ft/M)	Inlet Water Surface Elevation	Top of MH Top of Inlet Elev. APPROX.	Adjustment?
(1)	(2)			(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)		(12)	(13)		(14)	(15)		(16)		(16)	(17)	(18)	(19)	
11-01																								2.700		
12-15	127+15	0.000	3.00	2.700	36	24.459	64.00	0.00141	0.090	4.887	0.093	7.000	0.761	0.266	0.0	0.00	0.000	0.359	6.167	0.467	YES	0.233	0.323	3.023	4.500	O.K.
12-14	127+62	0.750	2.00	3.023	24	18.461	48.00	0.00696	0.334	7.000	0.190	5.805	0.523	0.183	23.0	0.27	0.140	0.514	2.901	0.514	YES	0.257	0.591	3.614	6.200	O.K.
12-13	128+84.00	1.200	2.00	3.614	24	15.830	120.00	0.00512	0.614	5.805	0.131	0.000	0.000	0.000	0.0	0.00	0.000	0.131	15.830	0.170	YES	0.085	0.699	4.314	7.000	O.K.
12H-02																								0.700		
13E-08	18+60.07	-0.500	1.50	0.700	18	2.714	139.00	0.00070	0.097	3.434	0.046	3.049	0.144	0.051	0.0	0.00	0.000	0.096	1.897	0.125	YES	0.063	0.160	0.860	3.000	O.K.
13E-09	14+13.8	0.100	1.50	1.300	18	0.827	46.00	0.00006	0.003	3.049	0.036	2.440	0.092	0.032	0.0	0.00	0.000	0.068	0.000	0.068	YES	0.034	0.037	1.337	5.790	O.K.
13E-10	14+13.60	0.500	1.50	1.700	18	0.836	29.00	0.00007	0.002	2.440	0.023	0.000	0.000	0.000	0.0	0.00	0.000	0.023	0.836	0.030	YES	0.015	0.017	1.717	3.840	O.K.
12-20																								-7.930		
12-19	129+22	-9.000	1.25	-7.930	15	3.236	24.00	0.00262	0.063	3.756	0.055	3.973	0.245	0.086	0.0	0.00	0.000	0.141	0.000	0.141	YES	0.070	0.133	-7.797	9.430	O.K.
12-12	130+09.16	-0.120	1.25	0.880	15	3.288	84.00	0.00271	0.227	3.973	0.061	2.585	0.104	0.036	0.0	0.00	0.000	0.098	1.687	0.127	YES	0.063	0.291	1.171	3.420	O.K.
12-11	132+07.36	0.380	1.25	1.380	15	1.702	196.00	0.00073	0.142	2.585	0.026	2.538	0.100	0.035	3.0	0.05	0.005	0.065	1.702	0.085	YES	0.043	0.185	1.565	3.600	O.K.
12-04																								2.700		
12-03	130+36.65	-2.600	2.50	2.700	30	19.219	91.00	0.00229	0.209	4.468	0.077	4.260	0.282	0.099	155.0	0.53	0.151	0.327	1.072	0.327	YES	0.163	0.372	3.072	5.920	O.K.
12-02	131+05.59	-2.400	2.50	3.072	30	18.342	65.00	0.00209	0.136	4.260	0.070	4.384	0.298	0.104	149.5	0.57	0.169	0.344	0.298	0.344	YES	0.172	0.308	3.380	3.780	O.K.
12-01A	131+52.25	-2.270	2.50	3.380	30	16.605	46.00	0.00171	0.079	4.384	0.075	4.253	0.281	0.098	5.0	0.07	0.020	0.193	0.000	0.193	YES	0.096	0.175	3.555	7.900	O.K.
13-14	134+01.25	-2.170	2.50	3.555	30	14.706	245.00	0.00134	0.329	4.253	0.070	5.468	0.464	0.162	3.0	0.05	0.021	0.254	2.513	0.254	YES	0.127	0.456	4.011	5.680	O.K.
13-12	135+12.22	-1.650	2.00	4.011	24	12.378	107.00	0.00313	0.335	5.468	0.116	4.786	0.356	0.124	22.0	0.26	0.092	0.332	0.484	0.332	YES	0.166	0.501	4.512	6.920	O.K.
13-13	135+12.88	-1.150	1.25	4.512	15	3.580	4.00	0.00321	0.013	4.120	0.066	0.000	0.000	0.000	0.0	0.00	0.000	0.066	3.580	0.086	YES	0.043	0.056	4.568	6.470	O.K.
12-23	23+30.74	1.400	1.25	3.380	15	1.760	104.00	0.00078	0.081	2.432	0.023	3.193	0.158	0.055	0.0	0.00	0.000	0.078	0.404	0.102	YES	0.051	0.132	3.512	4.000	O.K.
12-17	23+33.63	1.700	1.25	3.512	15	1.364	21.00	0.00047	0.010	3.193	0.040	0.000	0.000	0.000	0.0	0.00	0.000	0.040	0.000	0.040	NO	0.040	0.049	3.561	3.750	O.K.
12-01	131+51.97	1.370	1.25	3.555	15	2.821	15.00	0.00199	0.030	2.684	0.028	0.000	0.000	0.000	0.0	0.00	0.000	0.028	2.821	0.036	NO	0.036	0.066	3.621	3.700	O.K.
13-11	136+80.36	-1.150	2.00	4.512	24	8.751	162.00	0.00156	0.253	4.786	0.089	4.235	0.278	0.097	0.0	0.00	0.000	0.186	3.006	0.242	YES	0.121	0.375	4.887	6.540	O.K.
14B-02	138+37.62	0.000	2.00	4.887	24	6.646	162.00	0.00090	0.146	4.235	0.070	0.000	0.000	0.000	0.0	0.00	0.000	0.070	6.646	0.091	YES	0.045	0.191	5.078	5.100	O.K.
13E-12																								-1.640		
13E-07	10+00	-4.040	3.00	-1.640	36	30.915	17.00	0.00225	0.038	5.208	0.105	5.911	0.543	0.190	0.0	0.00	0.000	0.295	0.000	0.295	YES	0.148	0.186	-1.454	5.120	O.K.

LD-347
HYDRAULIC GRADE LINE ANALYSIS

PROJECT: Elizabeth River Tunnels Project
MTT Norfolk

DESIGNED BY: AMO
Checked: MJP

INCIDENCE PROBABILITY **10/25** **Year**

INLET OR JUNCTION	STA.	INVERT EL. OUTFLOW PIPE	DEPTH OF FLOW OUTFLOW PIPE	OUTLET WATER SURFACE ELEV.	DIA. PIPE Do (In/mm)	DESIGN DISCH. Qo (CFS/CMS)	LENGTH PIPE Lo (Ft/M)	FRICTION SLOPE, Sfo (FT/FT) (M/M)	FRICTION LOSS Hf (Ft/M)	JUNCTION LOSS Vo	Contr. Ho (Ft/M)	Vi	Vi*2/2g	Hi (Expn) 0.35*MAX. (Vi2/2g)	SKEW Angle	K	Bend H (Ft/M)	Sum HL (Ft/M)	SURFACE FLOW	Adj. Ht 1.3 Ht (Ft/M)	Inlet Shaping? Y/N	0.5 Ht (Ft/M)	FINAL H (Ft/M)	Inlet Water Surface Elevation	Top of MH Top of Inlet Elev. APPROX.	Adjustment?
(1)	(2)			(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)		(12)	(13)		(14)	(15)		(16)		(16)	(17)	(18)	(19)	
13-07	10+50	-3.900	3.00	-1.454	36	31.223	96.00	0.00229	0.220	5.911	0.136	5.013	0.390	0.137	0.0	0.00	0.000	0.272	1.079	0.272	YES	0.136	0.356	-1.098	4.810	O.K.
13E-11	11+48.04	-2.300	3.00	0.100	36	28.353	91.00	0.00189	0.172	5.013	0.098	5.023	0.392	0.137	0.0	0.00	0.000	0.235	0.000	0.235	YES	0.117	0.289	0.389	5.570	O.K.
13E-06	12+62.88	-1.100	2.00	0.500	24	8.261	83.00	0.00139	0.116	3.873	0.058	5.505	0.471	0.165	0.0	0.00	0.000	0.223	2.379	0.290	YES	0.145	0.261	0.761	2.770	O.K.
13E-05	13+68.80	-0.800	1.25	0.761	15	5.713	83.00	0.00818	0.679	5.505	0.118	2.946	0.135	0.047	22.0	0.26	0.044	0.209	0.891	0.209	YES	0.105	0.783	1.544	3.330	O.K.
13E-02	14+00.00	0.000	1.25	1.544	15	2.693	60.00	0.00182	0.109	2.946	0.034	0.000	0.000	0.000	0.0	0.00	0.000	0.034	2.449	0.044	NO	0.044	0.153	1.697	4.320	O.K.
72-17	135+74.38	-0.790	1.25	0.460	15	3.758	14.00	0.00354	0.050	3.062	0.036	3.071	0.146	0.051	0.0	0.00	0.000	0.088	0.000	0.088	NO	0.088	0.137	0.597	4.480	O.K.
72-18	135+51.16	-1.240	1.25	0.597	15	3.769	15.00	0.00356	0.053	3.071	0.037	2.938	0.134	0.047	0.0	0.00	0.000	0.084	0.175	0.084	NO	0.084	0.137	0.734	4.290	O.K.
13-31	135+44.55	-2.450	1.25	0.734	15	3.605	13.00	0.00326	0.042	2.938	0.034	1.165	0.021	0.007	29.0	0.33	0.038	0.079	0.000	0.079	NO	0.079	0.122	0.856	4.330	O.K.
13-21	133+69.62	-2.610	1.50	0.856	18	2.059	204.00	0.00040	0.082	1.165	0.005	2.809	0.123	0.043	0.0	0.00	0.000	0.048	0.000	0.048	NO	0.048	0.130	0.986	8.840	O.K.
13-20	133+04.14	0.000	1.25	1.000	15	2.063	63.00	0.00107	0.067	2.809	0.031	2.619	0.107	0.037	0.0	0.00	0.000	0.068	1.401	0.088	NO	0.088	0.155	1.155	3.390	O.K.
12-16	130+99.23	0.160	1.25	1.160	15	0.556	205.00	0.00008	0.016	2.619	0.027	0.000	0.000	0.000	0.0	0.00	0.000	0.027	0.505	0.035	YES	0.017	0.033	1.193	4.110	O.K.
13-06	137+31.81	-1.800	3.00	0.600	36	20.832	78.00	0.00102	0.080	5.023	0.098	7.128	0.789	0.276	0.0	0.00	0.000	0.374	1.326	0.374	YES	0.187	0.267	0.867	6.050	O.K.
13-05	137+91.99	-1.500	2.00	0.867	24	19.489	57.00	0.00776	0.442	7.128	0.197	6.733	0.704	0.246	0.0	0.00	0.000	0.444	0.000	0.444	YES	0.222	0.664	1.531	5.930	O.K.
13E-01	13+14	-1.100	1.50	1.531	18	6.577	155.00	0.00410	0.635	4.384	0.075	0.000	0.000	0.000	0.0	0.00	0.000	0.075	6.577	0.097	YES	0.048	0.684	2.214	2.600	O.K.
13E-04	13+51.48	-0.100	1.25	1.544	15	1.694	22.00	0.00072	0.016	3.329	0.043	0.000	0.000	0.000	0.0	0.00	0.000	0.043	1.694	0.056	YES	0.028	0.044	1.588	4.030	O.K.
72-20	17+08.00	-1.640	1.25	0.856	15	1.595	19.00	0.00064	0.012	1.300	0.007	0.000	0.000	0.000	0.0	0.00	0.000	0.007	1.595	0.009	NO	0.009	0.021	0.876	4.310	O.K.
13-28	135+23.79	0.000	1.50	1.200	18	0.728	46.00	0.00005	0.002	2.753	0.029	0.000	0.000	0.000	0.0	0.00	0.000	0.029	0.662	0.038	NO	0.038	0.041	1.241	4.140	O.K.
13-22	133+45.59	-2.630	1.50	0.986	18	0.475	42.00	0.00002	0.001	0.800	0.002	0.000	0.000	0.000	0.0	0.00	0.000	0.002	0.475	0.003	NO	0.003	0.004	0.990	4.770	O.K.
13-03	137+93.53	-0.330	1.50	1.531	18	11.898	31.00	0.01341	0.416	6.733	0.176	7.333	0.835	0.292	0.0	0.00	0.000	0.468	0.333	0.468	NO	0.468	0.884	2.415	6.570	O.K.
13-04	137+84.13	-0.300	1.50	2.415	18	6.164	72.00	0.00360	0.259	3.488	0.047	5.441	0.460	0.161	0.0	0.00	0.000	0.208	0.346	0.208	YES	0.104	0.363	2.778	6.880	O.K.
13-24	137+79	-0.050	1.25	2.778	15	5.334	6.00	0.00713	0.043	5.441	0.115	4.389	0.299	0.105	0.0	0.00	0.000	0.220	0.016	0.220	YES	0.110	0.153	2.930	6.460	O.K.
13-09	200+90.00	0.000	1.25	2.930	15	5.386	75.00	0.00727	0.545	4.389	0.075	2.970	0.137	0.048	0.0	0.00	0.000	0.123	0.000	0.123	YES	0.061	0.606	3.537	6.690	O.K.
13-08	201+43.02	0.510	1.25	3.537	15	1.906	48.00	0.00091	0.044	3.260	0.041	2.400	0.089	0.031	141.0	0.61	0.054	0.127	1.369	0.165	YES	0.082	0.126	3.663	4.410	O.K.
14B-01	202+23.24	0.800	1.25	3.663	15	0.412	90.00	0.00004	0.004	2.400	0.022	0.000	0.000	0.000	0.0	0.00	0.000	0.022	0.375	0.029	NO	0.029	0.033	3.696	10.940	O.K.
14-02	139+05.86	-0.340	1.50	2.415	18	5.552	140.00	0.00292	0.409	7.333	0.209	2.870	0.128	0.045	90.0	0.70	0.084	0.338	0.758	0.338	NO	0.338	0.747	3.161	8.500	O.K.

LD-347
HYDRAULIC GRADE LINE ANALYSIS

PROJECT: Elizabeth River Tunnels Project
MTT Norfolk

DESIGNED BY: AMO
Checked: MJP

INCIDENCE PROBABILITY **10/25 Year**

INLET OR JUNCTION	STA.	INVERT EL. OUTFLOW PIPE	DEPTH OF FLOW OUTFLOW PIPE	OUTLET WATER SURFACE ELEV.	DIA. PIPE Do (In/mm)	DESIGN DISCH. Qo (CFS/CMS)	LENGTH PIPE Lo (Ft/M)	FRICTION SLOPE, Sfo (FT/FT) (M/M)	FRICTION LOSS Hf (Ft/M)	JUNCTION LOSS Vo	Contr. Ho (Ft/M)	Vi	Vi*2/2g	Hi (Expn) 0.35*MAX. (Vi2/2g)	SKEW Angle	K	Bend H (Ft/M)	Sum HL (Ft/M)	SURFACE FLOW	Adj. Ht 1.3 Ht (Ft/M)	Inlet Shaping? Y/N	0.5 Ht (Ft/M)	FINAL H (Ft/M)	Inlet Water Surface Elevation	Top of MH Top of Inlet Elev. APPROX.	Adjustment?
(1)	(2)			(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)		(12)	(13)		(14)	(15)		(16)		(16)	(17)	(18)	(19)	
14-01	140+16.31	4.550	1.25	5.550	15	0.748	108.00	0.00014	0.015	2.575	0.026	0.000	0.000	0.000	0.0	0.00	0.000	0.026	0.680	0.033	YES	0.017	0.032	5.582	10.170	O.K.
13-29	136+66.40	-0.130	1.25	2.778	15	0.479	111.50	0.00006	0.006	2.222	0.019	0.000	0.000	0.000	0.0	0.00	0.000	0.019	0.436	0.025	NO	0.025	0.031	2.809	4.230	O.K.
13-10	200+69	0.410	1.25	3.537	15	2.842	16.00	0.00202	0.032	2.970	0.034	2.031	0.064	0.022	0.0	0.00	0.000	0.057	2.708	0.074	YES	0.037	0.069	3.606	5.800	O.K.
13-32	18+63.97	0.450	1.25	3.606	15	0.138	67.00	0.00000	0.000	2.031	0.016	0.000	0.000	0.000	0.0	0.00	0.000	0.016	0.138	0.021	NO	0.021	0.021	3.627	4.400	O.K.
13-02	138+09	4.550	1.25	5.550	15	1.145	94.00	0.00033	0.031	2.784	0.030	2.722	0.115	0.040	0.0	0.00	0.000	0.070	0.581	0.091	YES	0.046	0.077	5.627	8.560	O.K.
13-01	138+09	5.000	1.25	6.000	15	0.508	15.00	0.00006	0.001	2.722	0.029	0.000	0.000	0.000	0.0	0.00	0.000	0.029	0.462	0.037	YES	0.019	0.020	6.020	8.880	O.K.
14-03	139+17.25	2.130	1.25	3.161	15	2.343	12.00	0.00138	0.017	2.870	0.032	7.341	0.837	0.293	0.0	0.00	0.000	0.325	0.611	0.422	NO	0.422	0.439	3.600	8.200	O.K.
71-15	203+29.46	2.900	1.25	3.900	15	1.751	98.00	0.00077	0.075	7.341	0.209	9.568	1.422	0.498	0.0	0.00	0.000	0.707	0.165	0.707	NO	0.707	0.782	4.682	14.240	O.K.
71-16	205+15.52	10.840	1.50	12.040	18	1.125	197.50	0.00012	0.024	3.761	0.055	0.000	0.000	0.000	0.0	0.00	0.000	0.055	1.125	0.071	NO	0.071	0.095	12.135	15.180	O.K.
71-17	203+64.81	6.800	1.25	7.800	15	0.531	50.75	0.00007	0.004	9.568	0.355	0.000	0.000	0.000	0.0	0.00	0.000	0.355	0.531	0.462	NO	0.462	0.466	8.266	18.540	O.K.
13E-15																								4.060		
13E-14	13+47.48	3.060	1.25	4.060	15	2.727	21.00	0.00186	0.039	3.664	0.052	4.408	0.302	0.106	115.0	0.67	0.204	0.361	0.000	0.361	YES	0.181	0.220	4.280	13.000	O.K.
13E-13	13+88.58	9.700	1.25	10.700	15	3.444	53.00	0.00297	0.157	4.408	0.075	4.570	0.324	0.114	0.0	0.00	0.000	0.189	1.617	0.246	NO	0.123	0.280	10.980	14.320	O.K.
72-8	13+93.14	10.420	1.25	11.420	15	1.677	42.00	0.00070	0.030	4.570	0.081	0.000	0.000	0.000	0.0	0.00	0.000	0.081	1.525	0.105	NO	0.105	0.135	11.555	16.780	O.K.

Denotes existing pipes or structures to remain in place

Parsons Brinckerhoff

Project:	**Elizabeth River Tunnels Project**	***Designed By:***	**AMO**
Location:	**MTT Norfolk, VA**	***Date:***	**4/25/2013**
Design Phase:	**Final Design**	***Checked By:***	
Description:	**Roadside Ditch Analysis**	***Date:***	
Design Year:	**10 Year for Capacity Design**	***QA/QC By:***	**MJP**
	2 Year for Capacity Design at Bike Path	***Date:***	**4/29/2013**

ROADSIDE DITCHES

Ditch	Stationing Based Off of	From Station	To Station	Invert In	Invert Out	Solve For	Friction Method	Roughness Coefficient	Channel Slope (ft/ft)	Normal Depth (ft)	Left Side Slope (ft/ft (H:V))	Right Side Slope (ft/ft (H:V))	Discharge (ft^3/s)	Flow Area (ft^2)	Wetted Perimeter (ft)	Hydraulic Radius (ft)	Top Width (ft)	Critical Depth (ft)	Design Critical Slope (ft/ft)	Velocity (ft/s)	Velocity Head (ft)	Specific Energy (ft)	Froude Number	Flow Type	Material	Width of Erosion Control Lining FT
D12-18	Drive N1	11+00.00	10+11.55	4.85	4.75	Normal Depth	Manning's	0.03	0.003	0.43	3	3	0.52	0.55	2.72	0.2	2.58	0.28	0.027	0.94	0.01	0.44	0.36	Subcritical	N/A	N/A
D12-12(1)	Access Drive N	10+21.29	10+76.42	4.65	3.42	Normal Depth	Manning's	0.05	0.016	0.47	3	3	0.92	0.67	2.98	0.22	2.83	0.36	0.069	1.38	0.03	0.5	0.5	Subcritical	EC-2	9.5
(D12-12(2))	WB US 58	130+19.89	131+01.25	3.65	3.42	Normal Depth	Manning's	0.03	0.003	0.16	3	3	0.04	0.08	1.03	0.08	0.98	0.1	0.038	0.48	0	0.17	0.29	Subcritical	N/A	N/A
(D12-11(1))	WB US 58	131+34.72	131+96.07	3.75	3.60	Normal Depth	Manning's	0.03	0.002	0.34	3	3	0.26	0.36	2.18	0.16	2.07	0.22	0.03	0.73	0.01	0.35	0.31	Subcritical	N/A	N/A
(D12-11(2))	WB US 58	132+17.29	133+02.01	3.82	3.60	Normal Depth	Manning's	0.03	0.004	0.41	3	3	0.5	0.51	2.6	0.19	2.46	0.28	0.027	0.99	0.02	0.43	0.39	Subcritical	N/A	N/A
(D12-16)	WB US 58	130+14.05	130+96.85	4.54	4.12	Normal Depth	Manning's	0.05	0.005	0.53	1.5	2	0.38	0.49	2.13	0.23	1.84	0.31	0.082	0.78	0.01	0.54	0.27	Subcritical	EC-2	5
(D13-20)	WB US 58	131+45.81	132+93.58	4.17	3.46	Normal Depth	Manning's	0.05	0.005	0.83	2	2	1.48	1.39	3.72	0.37	3.33	0.51	0.067	1.07	0.02	0.85	0.29	Subcritical	EC-2	7.5
(D13-32)	Access Drive N	17+68.86	19+17.54	5.40	5.05	Normal Depth	Manning's	0.05	0.002	0.36	2	2	0.11	0.26	1.62	0.16	1.45	0.18	0.095	0.41	0	0.36	0.17	Subcritical	EC-2	5.6
(D13-08)	Ramp N	202+31.35	201+54.02	6.00	4.41	Normal Depth	Manning's	0.05	0.021	1.1	2	2	6.49	2.42	4.92	0.49	4.4	0.92	0.055	2.68	0.11	1.21	0.64	Subcritical	EC-2	4.1
(D16-11(1))	Bike Path	10+50	11+75	5.50	4.92	Normal Depth	Manning's	0.03	0.005	0.66	2	2	1.3	0.87	2.96	0.3	2.64	0.48	0.024	1.49	0.03	0.7	0.46	Subcritical	N/A	N/A
(D16-11(2))	Bike Path	13+85	11+75	6.00	4.92	Normal Depth	Manning's	0.03	0.005	0.83	2	2	2.5	1.37	3.7	0.37	3.31	0.63	0.022	1.83	0.05	0.88	0.5	Subcritical	N/A	N/A
(D12F)	Bike Path	14+25	16+50	5.03	3.60	Normal Depth	Manning's	0.03	0.006	0.54	2	2	0.88	0.58	2.4	0.24	2.15	0.41	0.026	1.52	0.04	0.57	0.52	Subcritical	N/A	N/A

STORMWATER INLET COMPUTATIONS

ROUTE MTT WB **PROJECT** Elizabeth River Tunnels Project **DESIGNER:** AMO **DATE** 5/23/2013
CHECKED: LRW **UNITS** ENGLISH

INLET NUMBER	INLET TYPE	INLET LENGTH (FT; M)	STATION	DRAINAGE AREA (AC; HA)	C	CA	ΣCA	I (IN/HR; mm/HR)	Q INCR. (CFS; CMS)	Qc CARRYOVER (CFS; CMS)	QT GUTTER FLOW (CFS; CMS)	S GUTTER SLOPE (FT/FT; M/M)	Sx CROSS SLOPE (FT/FT; M/M)	T (SPREAD) (FT; M)	W (GUTTER WIDTH) (FT; M)	W/T	Sw (GUTTER SLOPE) (FT/FT; M/M)	Sw/Sx	Eo (App. 9C-8)	a	S'w	Se	COMPUTED LENGTH L_T (FT; M)	INLET / GRATE LENGTH (FT; M)	L/LT	E (App. 9C-18)	Q INTERCEPTED (CFS; CMS) or d/h	Qb CARRYOVER (CFS; CMS)	Sag Inlets Only d (FT; M)	Sag Inlets Only h (FT; M)	Sag Inlets Only d/h	Sag Inlets Only T SPREAD @ SAG (FT; M)	REMARKS
12-05	DI-10H	12.167	132+38.16	0.098	0.90	0.0882																											
							0.088	7.67	0.675	0	0.675	0.030	0.0208	4.836	0.000	0.000	0.0208	1	0.760	1.00	0.0417	0.0524	12.945	2.167	0.940	0.994	0.671	0.004					
12-06	DI-10H	12.167	131+50.07	0.079	0.90	0.0711																											
							0.071	7.67	0.545	0	0.545	0.030	0.0208	4.463	0.000	0.000	0.0208	1	0.795	1.00	0.0417	0.0539	11.635	2.167	1.046	1.000	0.545	0.000					
12-07	DI-10H	12.167	130+50.97	0.074	0.90	0.0666																											
							0.067	7.67	0.514	0	0.514	0.030	0.0176	4.847	0.000	0.000	0.0176	1	0.758	1.00	0.0417	0.0492	11.996	2.167	1.014	1.000	0.514	0.000					
12-08	DI-10H	12.167	129+18.00	0.001	0.90	0.0009																											
							0.001	7.67	0.008	0	0.008	0.045	0.0101	1.337	0.000	0.000	0.0101	1	1.000	1.00	0.0417	0.0518	2.287	2.167	5.320	1.000	0.008	0.000					
12-21	DI-10H	12.167	129+99.31	0.041	0.90	0.0369																											
							0.037	7.67	0.312	0	0.312	0.030	0.0126	4.955	0.000	0.000	0.0126	1	0.748	1.00	0.0417	0.0438	10.433	2.167	1.166	1.000	0.312	0.000					
12-22	DI-10H	12.167	129+56.77	0.031	0.90	0.0279																											
							0.028	7.67	0.236	0	0.236	0.045	0.0100	4.781	0.000	0.000	0.0100	1	0.765	1.00	0.0417	0.0419	10.764	2.167	1.130	1.000	0.236	0.000					
13-15	DI-10H	12.167	135+44.45	0.091	0.90	0.0819																											
							0.082	7.67	0.629	0	0.629	0.030	0.0200	4.826	0.000	0.000	0.0200	1	0.760	1.00	0.0417	0.0517	12.678	2.167	0.960	0.997	0.627	0.002					
13-16	DI-10H	12.167	134+96.32	0.086	0.90	0.0774																											
							0.077	7.67	0.591	0.002	0.593	0.030	0.0200	4.721	0.000	0.000	0.0200	1	0.770	1.00	0.0417	0.0521	12.309	2.167	0.988	1.000	0.593	0.000					
13-17	DI-10H	12.167	133+95.64	0.085	0.90	0.0765																											
							0.077	7.67	0.591	0.005	0.596	0.030	0.0208	4.615	0.000	0.000	0.0208	1	0.781	1.00	0.0417	0.0533	12.164	2.167	1.000	1.000	0.596	0.000					
13-18	DI-10H	12.167	133+10.40	0.084	0.90	0.0756																											
							0.076	7.67	0.583	0	0.583	0.030	0.0200	4.806	0.000	0.000	0.0200	1	0.762	1.00	0.0417	0.0518	11.803	2.167	1.031	1.000	0.583	0.000					
13-19	DI-10H	12.167	11+64.30	0.061	0.90	0.0549																											
							0.055	7.67	0.422	0.09	0.512	0.018	0.0200	4.917	0.000	0.000	0.0200	1	0.752	1.00	0.0358	0.0469	10.576	2.167	1.150	1.000	0.512	0.000					
13-23	DI-7	3.000	134+73.00	0.092	0.90	0.0828																											Back/Lt.
							0.083	7.67	0.637	0																							Back/Lt.
				0.156	0.90	0.1404																											Ahead/Rt.
							0.14	7.67	1.074	0																							Ahead/Rt.
											1.710	0.001			3.000									3			1.710						
13-26	DI-10H	14.167	136+12.78	0.096	0.90	0.0864																											
							0.086	7.67	0.66	0	0.660	0.030	0.0208	4.795	0.000	0.000	0.0208	1	0.763	1.00	0.0417	0.0526	12.800	2.167	1.107	1.000	0.660	0.000					
13-27	DI-10H	14.167	12+42.62	0.142	0.90	0.1278																											
							0.128	7.67	0.982	0	0.982	0.052	0.0200	5.145	0.000	0.000	0.0200	1	0.731	1.00	0.0358	0.0462	19.295	2.167	0.734	0.908	0.892	0.090					

LD-347
HYDRAULIC GRADE LINE ANALYSIS

PROJECT: MTT

DESIGNED BY: AMO

Checked: LRW

INCIDENCE PROBABILITY **25** **Year**

INLET OR JUNCTION	STA.	INVERT EL. OUTFLOW PIPE	DEPTH OF FLOW OUTFLOW PIPE	OUTLET WATER SURFACE ELEV.	DIA. PIPE Do (In/mm)	DESIGN DISCH. Qo (CFS/CMS)	LENGTH PIPE Lo (Ft/M)	FRICTION SLOPE, Sfo (FT/FT) (M/M)	FRICTION LOSS Hf (Ft/M)	JUNCTION LOSS Vo	Contr. Ho (Ft/M)	Vi	Vi*2/2g	Hi (Expn) 0.35*MAX. (Vi2/2g)	SKEW Angle	K	Bend H (Ft/M)	Sum HL (Ft/M)	SURFACE FLOW	Adj. Ht 1.3 Ht (Ft/M)	Inlet Shaping? Y/N	0.5 Ht (Ft/M)	FINAL H (Ft/M)	Inlet Water Surface Elevation	Top of MH Top of Inlet Elev. APPROX.	Adjustment?
(1)	(2)			(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)		(12)	(13)		(14)	(15)		(16)		(16)	(17)	(18)	(19)	
12-09																								-19.230		
12-08	129+18.00	-20.830	2.00	-19.230	24	10.156	46.00	0.00180	0.083	4.439	0.076	12.988	2.619	0.917	0.0	0.00	0.000	0.993	0.238	0.993	YES	0.497	0.579	-18.651	-17.040	O.K.
12-22	129+56.77	-19.710	1.25	-18.651	15	9.915	36.00	0.02098	0.755	12.988	0.655	11.134	1.925	0.674	0.0	0.00	0.000	1.329	0.230	1.329	YES	0.664	1.420	-17.231	-15.410	O.K.
12-21	129+99.31	-18.080	1.25	-17.080	15	9.688	40.00	0.02351	0.940	11.134	0.481	10.126	1.592	0.557	0.0	0.00	0.000	1.038	0.305	1.038	YES	0.519	1.460	-15.620	-13.950	O.K.
12-07	130+50.97	-16.620	1.25	-15.620	15	9.388	49.00	0.02208	1.082	10.126	0.398	10.838	1.824	0.638	4.0	0.06	0.105	1.142	0.554	1.142	YES	0.571	1.653	-13.967	-12.510	O.K.
12-06	131+50.07	-15.180	1.25	-13.967	15	8.840	96.00	0.01668	1.601	10.838	0.456	10.571	1.735	0.607	0.0	0.00	0.000	1.063	0.591	1.063	YES	0.532	2.133	-11.834	-9.590	O.K.
12-05	132+38.16	-12.260	1.25	-11.260	15	8.241	86.00	0.01450	1.247	10.571	0.434	10.389	1.676	0.587	96.0	0.67	1.130	2.150	0.737	2.150	YES	1.075	2.322	-8.938	-7.040	O.K.
13-18	133+10.40	-9.710	1.25	-8.710	15	7.471	70.00	0.01191	0.834	10.389	0.419	7.619	0.901	0.315	119.8	0.67	0.602	1.337	0.640	1.337	YES	0.668	1.502	-7.208	-4.940	O.K.
13-17	133+95.64	-7.610	1.25	-6.610	15	3.005	83.00	0.00193	0.160	8.167	0.259	7.690	0.918	0.321	0.0	0.00	0.000	0.580	0.653	0.754	YES	0.377	0.537	-6.073	-2.470	O.K.
13-16	134+96.32	-5.140	1.25	-4.140	15	2.310	98.00	0.00114	0.112	7.690	0.230	7.437	0.859	0.301	0.0	0.00	0.000	0.530	0.660	0.689	YES	0.345	0.456	-3.684	0.560	O.K.
13-15	135+44.45	-2.110	1.00	-1.310	12	1.592	45.00	0.00178	0.080	7.437	0.215	4.600	0.329	0.115	0.0	0.00	0.000	0.330	0.706	0.429	YES	0.214	0.294	-1.016	2.000	O.K.
13-26	136+12.78	-0.500	1.00	0.300	12	0.824	65.00	0.00056	0.036	4.600	0.082	0.000	0.000	0.000	0.0	0.00	0.000	0.082	0.749	0.107	NO	0.107	0.143	0.443	3.700	O.K.
13-19	11+64.30	-7.610	1.00	-6.810	12	3.812	42.00	0.01197	0.503	7.619	0.225	6.571	0.670	0.235	139.6	0.61	0.410	0.870	0.491	0.870	YES	0.435	0.938	-5.872	-4.090	O.K.
13-27	12+42.62	-6.590	1.00	-5.790	12	3.302	76.00	0.00898	0.682	6.571	0.168	3.506	0.191	0.067	6.1	0.08	0.016	0.250	1.095	0.325	YES	0.163	0.845	-4.945	-2.720	O.K.
13-23	134+73.00	-5.220	1.00	-4.420	12	2.138	80.00	0.00321	0.257	3.506	0.048	0.000	0.000	0.000	0.0	0.00	0.000	0.048	1.943	0.062	NO	0.062	0.319	-5.101	7.580	O.K.

PROJECT	**Elizabeth River Tunnels Project**		
ROAD		**COUNTY**	Norfolk (city)
CULVERT	12-18		VA

SHEET OF

UNITS **ENGLISH**

CULVERT DESIGN FORM LD-269

DESIGNER:	AMO	DATE:	2/18/2013
REVIEWER:	MJP	DATE:	2/25/2013

HYDROLOGICAL DATA

Method: RATIONAL

Drainage Area: 0.121 Acres

Time of Concentration 13.862 Minutes

DESIGN FLOWS

R.I. (years)	FLOW (cfs)	
5	Design	0.20
2	Check	0.17
10	Max.	0.23

CULVERT DESCRIPTION:

TYPE: **Single/Multiple Conforming**

Roadway Width 10 ft ROADWAY ELEVATION 5.66 ft Road Length 152 Suface Type PAVED

Freeboard= 4.83 ft

Shldr. Elev. Rt.= 5.66 ft

Shldr. Elev. Lt. = 5.66 ft

ELHWd= 0.83 ft

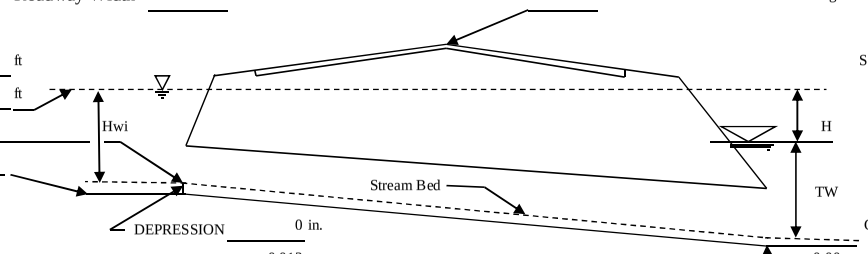
Elsf= 0.00 ft

Eli= 0.00 ft

L= 0 ft

S=

SKEW= 0 O



TW DEPTH 0.32 ft

TW VEL. 0.66 ft

Channel Inv.El.. 3.26 ft

Inlet Edge Description:

Square edge w/headwall

Single / Multiple Conforming / Broken Back Culverts

MATERIAL	SHAPE	Size (in)	N	Mannings n	TOTAL FLOW Q cfs	FLOW PER BARREL Q/N cfs	HEADWATER CALCULATIONS INLET CONTROL HWi/D	HWi ft	FALL ft	ELHWi ft	OUTLET CONTROL TW ft	dc ft	(dc+D)/2 ft	ho ft	ke	H ft	ELHWo ft	CONTROL HEADWATER ELEV ft	OUTLET VEL fps	MINIMUM SHOULDER ELEV. ft	COMMENTS
Concrete	Circular	18	1	0.01	0.20	0.2	0.55	0.17	0.00	0.17	0.32	0.16	0.83	0.83	0.50	0.00	0.83	0.83	0.52		
					0.17	0.2	0.55	0.16	0.00	0.16	0.30	0.15	0.83	0.83	0.50	0.00	0.83	0.83	0.52		
					0.23	0.2	0.56	0.18	0.00	0.18	0.34	0.18	0.84	0.84	0.50	0.00	0.84	0.84	0.52		

Broken Back Culvert

LENGTH	Elev.	SKEW O

TAILWATER DATA:

Channel Shape	Triangular		
Bottom Width, ft	0.00	"n" =	0.035
Side Slope Lt: (H:1V)	3.00		
Side Slope Rt: (H:1V)	3.00		
Channel Slope, ft/ft	0.0030		

Distance					
Elevation					
"n" =					

TAILWATER RESULTS:

	Discharge cfs	Elevation ft	Flow depth ft	Velocity fps	Shear force PSF
Design	3.58	0.32	0.66	0.06	
Check	3.56	0.30	0.63	0.06	
Max.	3.60	0.34	0.68	0.06	

ROADWAY DATA:

Roadway Width, ft	10
Surface Type	PAVED
Top of Road Elevation, ft	5.66
Length of Road, ft	152

ROADWAY OVERTOPPING:

	Discharge cfs	Overtopping Discharge cfs	Overtopping Elevation ft
Design	0		0.00
Check	0		0.00
Max.	0		0.00

TECHNICAL FOOTNOTES:

(1) USE Q/NB FOR BOX CULVERTS

(2) HWi/D = HW/D OR HWi/D FROM DESIGN CHARTS

(3) FALL = HWI - (ELHWd - ELsf); FALL IS ZERO FOR CULVERTS ON GRADE

(4) ELhi = HWi + ELi (INVERT OF INLET CONTROL SECTION)

(5) TW BASED ON DOWNSTREAM CONTROL OR FLOW DEPTH IN CHANNEL

(6) ho = TW or (dc + D/2) (WHICHEVER IS GREATER)

(7) $H = [1 + ke + (29n^2L)/R^{1.33}]v^2/2g$

SUBSCRIPT DEFINITIONS:

HWd	DESIGN HEADWATER	i	INLET
HWi	HW IN INLET CONTROL	o	OUTLET
HWo	HW IN OUTLET CONTROL	sf	Streambed @ culvert face

COMMENTS / DISCUSSION:

CULVERT BARREL SELECTED

SIZE: n:

SHAPE: MATERIAL:

ENTRANCE:

9.7. APPENDIX G – MLK Drainage Calculations

ROUTE Ramp EN, C, Frederick Blvd. **PROJECT DESCRIPTION** Elizabeth River Tunnels Project, Ramp EN, C, Frederick Blvd. **DESIGNER:** AMO **CHECKED:** MJP **DATE** 6/6/2013 **UNITS** ENGLISH

INLET																												Sag Inlets Only				
NUMBER	TYPE	LENGTH (FT; M)	STATION	DRAINAGE AREA (AC; HA)	C	CA	ΣCA	I (IN/HR; mm/HR)	Q INCR. (CFS; CMS)	Qc-CARRYOVER (CFS; CMS)	QT GUTTER FLOW (CFS; CMS)	S GUTTER SLOPE (FT/FT; M/M)	Sx CROSS SLOPE (FT/FT; M/M)	T (SPREAD) (FT; M)	W (GUTTER WIDTH) (FT; M)	W/T	Sw (GUTTER SLOPE) (FT/FT; M/M)	Sw/Sx	Eo (App. 9C-8)	a	S'w	Se	COMPUTED LENGTH L_T (FT; M)	INLET / GRATE LENGTH (FT; M)	L/LT	E (App. 9C-18)	Q INTERCEPTED (CFS; CMS) or d/h	Qb CARRYOVER (CFS; CMS)	d (FT; M)	h (FT; M)	d/h	T SPREAD @ SAG (FT; M)	REMARKS
3-01	DI-13	20.000	301+50	0.267	0.90	0.2403																										
							0.24	7.67	2.025	0	2.025	0.014	0.0200	8.023	2.000	0.249	0.0500	2.5	0.617	2.72	0.1133	0.0899	11.826	20.000	1.691	1.000	2.025	0.000					
3-03	DI-13	20.000	303+25	0.285	0.90	0.2565																										
							0.257	7.67	2.168	0	2.168	0.015	0.0200	8.141	2.000	0.246	0.0500	2.5	0.610	2.72	0.1133	0.0891	12.489	20.000	1.601	1.000	2.168	0.000					
4-01	DI-13	20.000	305+75	0.395	0.90	0.3555																										
							0.356	7.67	2.731	0	2.731	0.014	0.0390	6.213	2.000	0.322	0.0500	1.2821	0.666	2.26	0.0943	0.1018	12.440	20.000	1.608	1.000	2.731	0.000					
4-06	DI-10L	16.000	307+90	0.406	0.90	0.3654																										Back/Lt.
							0.365	9.55	4.183	0		0.003	0.0390	9.855	2.000	0.203	0.0500	1.2821		2.26												Back/Lt.
				0.098	0.90	0.0882																										Ahead/Rt.
							0.088	9.55	1.008	0																						Ahead/Rt.
											5.191	0.003			2.000									16			5.191		0.5288	0.3333	1.58859	13.558	Orifice Flow
4-07	DI-10K	14	308+10.73	0.486	0.90	0.4374																										
							0.437	9.55	5.008	0	5.008	0.004	0.0500	8.631	2.000	0.232	0.0500	1	0.505	2.00	0.0833	0.0921	11.705	2.000	1.196	1.000	5.008	0.000					
5-01	DI-10K	12	311+00.00	0.298	0.90	0.2682																										
							0.268	7.67	2.261	0	2.261	0.017	0.0500	4.887	2.000	0.409	0.0500	1	0.755	2.00	0.0833	0.1129	11.451	2.000	1.048	1.000	2.261	0.000					
5-03	DI-10K	14	312+50.00	0.381	0.90	0.3429																										
							0.343	7.67	2.894	0	2.894	0.017	0.0501	5.353	2.000	0.374	0.0501	1	0.713	2.00	0.0833	0.1095	12.934	2.000	1.082	1.000	2.894	0.000					
5-05	DI-10K	12	314+50.00	0.360	0.90	0.324																										
							0.324	7.67	2.734	0	2.734	0.020	0.0510	5.027	2.000	0.398	0.0510	1	0.742	2.00	0.0833	0.1128	13.026	2.000	0.921	0.990	2.706	0.028					
6-01	DI-7	3.000	320+95.00	0.083	0.90	0.0747																										Back/Lt.
				0.531	0.35	0.1859																										Back/Lt.
				0.720	0.35	0.252																										Back/Lt.
							0.513	8.71	4.915	0																						Back/Lt.
				0.152	0.90	0.1368																										Ahead/Rt.
				0.088	0.35	0.0308																										Ahead/Rt.
				0.800	0.35	0.28																										Ahead/Rt.
							0.448	8.71	4.292	0																						Ahead/Rt.
											9.207	0.0100			3.000									3			9.207						
6-02	DI-7	3.000	320+69.89	0.064	0.90	0.0576																										
				0.144	0.35	0.0504																										
							0.108	7.67	0.828	0	0.828	0.0100			3.000									3.000		1.000	0.828	0.000	0.1423				BHt.=0.080'
6-04	DI-10K	10	801+69.90	0.095	0.90	0.0855																										
							0.086	7.67	0.726	0	0.726	0.017	0.0510	3.154	2.000	0.634	0.0510	1	0.932	2.00	0.0833	0.1286	6.570	2.000	1.522	1.000	0.726	0.000					
6-05	DI-10L	16.000	802+24.38	0.048	0.90	0.0432																										Back/Lt.

ROUTE Ramp EN, C, Frederick Blvd. **PROJECT DESCRIPTION** Elizabeth River Tunnels Project, Ramp EN, C, Frederick Blvd. **DESIGNER:** AMO **CHECKED:** MJP **DATE** 6/6/2013 **UNITS** ENGLISH

INLET																													Sag Inlets Only				
NUMBER	TYPE	LENGTH (FT; M)	STATION	DRAINAGE AREA (AC; HA)	C	CA	ΣCA	I (IN/HR; mm/HR)	Q INCR. (CFS; CMS)	Qc CARRYOVER (CFS; CMS)	QT GUTTER FLOW (CFS; CMS)	S GUTTER SLOPE (FT/FT; M/M)	Sx CROSS SLOPE (FT/FT; M/M)	T (SPREAD) (FT; M)	W (GUTTER WIDTH) (FT; M)	W/T	Sw (GUTTER SLOPE) (FT/FT; M/M)	Sw/Sx	Eo (App. 9C-8)	a	S'w	Se	COMPUTED LENGTH L_T (FT; M)	INLET / GRATE LENGTH (FT; M)	L/LT	E (App. 9C-18)	Q INTERCEPTED (CFS; CMS) or d/h	Qb CARRYOVER (CFS; CMS)	d (FT; M)	h (FT; M)	d/h	T SPREAD @ SAG (FT; M)	REMARKS
							0.043	7.67	0.363	0		0.002	0.0498	3.687	2.000	0.542	0.0498	1		2.00													Back/Lt.
				0.018	0.90	0.0162																											Ahead/Rt.
							0.016	7.67	0.135	0																							Ahead/Rt.
											0.498	0.002			2.167									16			0.498		0.1108	0.3333	0.33333	2.225	Weir Flow
6-07	DI-10K	8	317+25	0.050	0.90	0.045																											
							0.045	7.67	0.345	0	0.345	0.006	0.0510	2.901	0.000	0.000	0.0510	1	0.975	2.00	0.0833	0.1322	3.460	2.000	2.312	1.000	0.345	0.000					
7-02	DI-10K	14	322+66.75	0.109	0.90	0.0981																											
							0.098	7.67	0.827	0.038	0.865	0.008	0.0253	5.466	2.000	0.366	0.0500	1.9763	0.770	2.59	0.1080	0.1085	6.247	2.167	2.241	1.000	0.865	0.000					
7-04	DI-10K	14	323+25	0.096	0.90	0.0864																											
							0.086	7.67	0.726	0	0.726	0.022	0.0220	5.085	2.000	0.393	0.0220	1	0.737	2.00	0.0833	0.0834	9.208	2.000	1.520	1.000	0.726	0.000					
7-05	DI-10K	12	324+25	0.176	0.90	0.1584																											
							0.158	7.67	1.333	0	1.333	0.037	0.0600	3.092	2.000	0.647	0.0600	1	0.938	2.00	0.0833	0.1382	10.260	2.000	1.170	1.000	1.333	0.000					
7-07	DI-10K	10	803+15.23	0.073	0.90	0.0657																											
							0.066	7.67	0.557	0	0.557	0.012	0.0480	3.167	2.000	0.632	0.0480	1	0.930	2.00	0.0833	0.1255	5.373	2.000	1.861	1.000	0.557	0.000					
7-10	DI-10K	10	326+50	0.149	0.90	0.1341																											
							0.134	7.67	1.028	0	1.050	0.060	0.0600	2.583	0.000	0.000	0.0600	1	0.992	2.00	0.0833	0.1427	10.526	2.000	0.950	0.995	1.045	0.005					
8-05	DI-3C	10.000	810+87.41	0.096	0.90	0.0864																											Back/Lt.
				0.006	0.35	0.0021																											Back/Lt.
							0.089	4	0.356	0																							Back/Lt.
				0.528	0.90	0.4752																											Ahead/Rt.
				0.139	0.35	0.0487																											Ahead/Rt.
							0.524	4	2.096	0		0.004	0.0142	13.687	0.000	0.000	0.0142	1		2.00													Ahead/Rt.
											2.452	0.004												10			2.452		0.183	0.3333	0.54955	12.888	Weir Flow
8-09	DI-3B	8.000	3000+71.64	0.104	0.95	0.0988																											
				0.123	0.35	0.0431																											
							0.142	4	0.568	0	0.568	0.001	0.0140	10.978	0.000	0.000	0.0140	1	0.415	2.00	0.0833	0.0486	4.542	8.000	1.761	1.000	0.568	0.000					T > 6.0 ft
8-14	DI-3B	8.000	3002+01.49	0.045	0.90	0.0405																											
				0.028	0.35	0.0098																											
							0.05	4	0.2	0	0.200	0.001	0.0159	6.858	0.000	0.000	0.0159	1	0.602	2.00	0.0833	0.0660	2.438	8.000	3.281	1.000	0.200	0.000					T > 6.0 ft
9-2	DI-7	3.000	3004+80.68	0.538	0.90	0.4842																											
				0.348	0.35	0.1218																											
							0.606	6	4	0	4.000	0.015			3.000									3.000		1.000	4.000	0.000	0.3895				BHt.=0.229'
EX	DI-1	2.000	303+80	0.513	0.90	0.4617																											
							0.462	7.67	3.898	0	3.898	0.011	0.0208	10.275	2.000	0.195	0.0833	4.0048	0.560	3.50	0.1458	0.1025	13.389	2.000	0.149	0.594	2.317	1.581					T > 8.0 ft

STORMWATER INLET COMPUTATIONS

ROUTE Ramp EN, C, Frederick Blvd.

PROJECT DESCRIPTION Elizabeth River Tunnels Project
Ramp EN, C, Frederick Blvd.

DESIGNER: AMO
CHECKED: MJP

DATE 6/6/2013
UNITS ENGLISH

INLET																													Sag Inlets Only				
NUMBER	TYPE	LENGTH (FT; M)	STATION	DRAINAGE AREA (AC; HA)	C	CA	ΣCA	I (IN/HR; mm/HR)	Q INCR. (CFS; CMS)	Qc CARRYOVER (CFS; CMS)	QT GUTTER FLOW (CFS; CMS)	S GUTTER SLOPE (FT/FT; M/M)	Sx CROSS SLOPE (FT/FT; M/M)	T (SPREAD) (FT; M)	W (GUTTER WIDTH) (FT; M)	W/T	Sw (GUTTER SLOPE) (FT/FT; M/M)	Sw/Sx	Eo (App. 9C-8)	a	S'w	Se	COMPUTED LENGTH L_T (FT; M)	INLET / GRATE LENGTH (FT; M)	L/LT	E (App. 9C-18)	Q INTERCEPTED (CFS; CMS) or d/h	Qb CARRYOVER (CFS; CMS)	d (FT; M)	h (FT; M)	d/h	T SPREAD @ SAG (FT; M)	REMARKS
EX2	DI-1	2.000	306+25	0.275	0.90	0.2475																											
							0.248	7.67	2.092	0	2.092	0.012	0.0235	6.959	2.000	0.287	0.0833	3.5447	0.732	3.44	0.1431	0.1283	9.245	2.000	0.216	0.758	1.585	0.507					
EX3	DI-1	2.000	311+85.67	0.513	0.90	0.4617																											
							0.462	7.67	3.544	0	3.544	0.021	0.0208	8.453	2.000	0.237	0.0833	4.0048	0.656	3.50	0.1458	0.1164	14.466	2.000	0.138	0.673	2.386	1.158					T > 8.0 ft
	Denotes existing pipes or structures to remain in place																																

LD-229
STORM SEWER DESIGN COMPUTATIONS

STORM FREQUENCY **25**

PROJECT: Elizabeth River Tunnels Project
LOCATION: Portsmouth
COUNTY: Norfolk (city)

Designed by: AMO
Checked by: MJP

UNITS **ENGLISH**

PIPE NO.	FROM POINT REFERENCE (1)	FROM POINT STA.	TO POINT REFERENCE (2)	TO POINT STA.	DRAIN. AREA "A" Acre (3)	RUNOFF COEFF. "C" (4)	CA INCRE-MENT (5)	CA ACCUM-ULATED (6)	TOTAL INLET TIME Minutes (7)	RAIN FALL In/Hr (8)	RUNOFF Lateral CFS	RUNOFF Total Q CFS (9)	INVERT ELEVATIONS UPPER END (10)	INVERT ELEVATIONS LOWER END (11)	LENGTH of Pipe Ft. (12)	SLOPE Ft./Ft. (13)	SIZE (Dia. Or Span/Rise) In. (14)	SHAPE	Number of Pipes	Capacity CFS (15)	Friction Slope Ft./Ft.	NORMAL FLOW Depth of Flow, dn Ft.	NORMAL FLOW Area of Flow, An SqFt	NORMAL FLOW Hrn Ft.	NORMAL FLOW Vn Ft/Sec (16)	NORMAL FLOW En Ft.	FLOW TIME Sec. (17)	REMARKS (18)
3-01/3-02	3-01	301+50	3-02	301+50	0.27	0.90	0.24	0.24	5.00	8.71	0.00	2.30	17.27	17.24	4.00	0.00750	15	Circular	1	2.69	0.00570	0.89	0.93	0.37	2.47	0.98	1.62	
3-03/3-04	3-03	303+25	3-04	303+25	0.29	0.90	0.26	0.26	5.00	8.71	0.00	2.46	14.47	14.43	4.00	0.01000	15	Circular	1	3.11	0.00650	0.84	0.88	0.37	2.81	0.96	1.42	
EX/3-08	EX	303+80	3-08	303+80	0.51	0.90	0.46	0.46	5.00	8.71	0.00	4.43	14.27	13.92	73.40	0.00477	15	Circular	1	4.46	0.00490	1.02	1.07	0.38	4.15	1.28	17.71	
4-01/4-02	4-01	305+75	4-02	305+75	0.40	0.90	0.36	0.36	5.00	8.71	0.00	3.41	10.50	10.45	4.00	0.01250	15	Circular	1	3.48	0.01260	1.00	1.06	0.38	3.23	1.17	1.24	
EX2/4-04	EX2	306+25	4-04	306+25	0.28	0.90	0.25	0.25	5.00	8.71	0.00	2.38	9.40	9.17	80.00	0.00288	15	Circular	1	3.47	0.00140	0.76	0.78	0.35	3.04	0.90	26.28	
4-06/4-07	4-06	307+90	4-07	308+10.73	0.50	0.90	0.45	0.45	5.00	9.55	0.00	5.19	7.57	7.50	18.00	0.00389	18	Circular	1	6.55	0.00250	1.01	1.26	0.44	4.11	1.27	4.38	
4-07/4-08	4-07	308+10.73	4-08	308+10.79	0.49	0.90	0.44	0.89	5.07	9.51	0.00	10.16	7.50	7.44	15.00	0.00400	24	Circular	1	14.31	0.00210	1.25	2.06	0.57	4.94	1.62	3.04	
4-09/4-08	4-09	307+88.45	4-08	308+10.79	2.35	0.78	1.84	1.84	5.00	8.71	0.00	17.64	7.63	7.44	30.00	0.00633	24	Circular	1	18.00	0.00630	1.60	2.70	0.61	6.53	2.27	4.59	
4-08/4-11	4-08	308+10.79	4-11	309+23.92	0.00		0.00	2.73	5.12	8.66	0.00	26.01	7.44	7.22	107.00	0.00206	36	Circular	1	30.27	0.00160	2.14	5.40	0.89	4.82	2.50	22.22	
5-01/5-02	5-01	311+00.00	5-02	311+00.00	0.30	0.90	0.27	0.27	5.00	8.71	0.00	2.57	6.95	6.92	15.00	0.00200	15	Circular	1	2.89	0.00170	0.92	0.97	0.38	2.66	1.03	5.64	
EX3/5-13	EX3	311+85.67	5-13	311+85.67	0.51	0.90	0.46	0.46	5.00	7.67	0.00	3.54	13.00	12.56	84.00	0.00524	15	Circular	1	4.68	0.00310	0.81	0.85	0.36	4.19	1.09	20.05	
5-03/5-04	5-03	312+50.00	5-04	312+50.00	0.38	0.90	0.34	0.34	5.00	8.71	0.00	3.29	10.55	10.50	18.00	0.00278	15	Circular	1	3.41	0.00270	0.99	1.04	0.38	3.16	1.14	5.69	
5-05/5-06	5-05	314+50.00	5-06	314+50.09	0.36	0.90	0.32	0.32	5.00	8.71	0.00	3.11	8.27	8.19	26.00	0.00308	15	Circular	1	3.59	0.00240	0.90	0.94	0.37	3.29	1.07	7.90	
5-07/5-09	5-07	315+67	5-09	315+92.5	0.00		0.00	0.00	5.00	0.00		11.53	7.30	7.25	21.00	0.00238	30	Circular	1	20.01	0.00080	1.36	2.73	0.66	4.22	1.64	4.98	
5-08/5-09	5-08	316+32.03	5-09	315+92.50	0.00		0.00	0.00	5.00	0.00		11.57	7.30	7.25	35.00	0.00143	30	Circular	1	15.51	0.00080	1.61	3.34	0.72	3.46	1.80	10.10	
EX15-16/23	EX15-16		EX15-23		0.00		0.00	0.00	5.00	0.00		103.76	7.30	7.11	63.80	0.00298	36	Circular	1	36.41	0.02510	3.00	7.07	0.75	14.68	6.35	4.35	Pressure Flow
6-07/6-08	6-07	317+25	6-08	317+25	0.05	0.90	0.05	0.05	5.00	8.71	0.00	0.43	7.77	7.51	35.00	0.00743	15	Circular	1	5.57	0.00000	0.24	0.16	0.14	2.70	0.35	12.99	
6-01/6-02	6-01	320+95.00	6-02	320+69.89	2.37	0.41	0.96	0.96	5.00	8.71	0.00	9.21	8.05	7.91	71.00	0.00197	24	Circular	1	10.04	0.00170	1.51	2.54	0.60	3.63	1.71	19.58	
6-02/6-03	6-02	320+69.89	6-03	319+00	0.21	0.52	0.11	1.07	5.33	8.58	0.00	10.08	7.91	7.65	166.00	0.00157	30	Circular	1	16.25	0.00060	1.43	2.89	0.68	3.49	1.61	47.59	
6-04/6-05	6-04	801+69.90	6-05	802+24.38	0.10	0.91	0.09	0.09	5.00	8.71	0.00	0.82	10.50	10.35	52.00	0.00288	15	Circular	1	3.47	0.00020	0.42	0.36	0.23	2.32	0.50	22.44	
6-05/7-07	6-05	802+24.38	7-07	803+15.23	0.07	0.89	0.06	0.15	5.37	8.56	0.00	1.37	10.35	10.00	89.00	0.00393	15	Circular	1	4.05	0.00050	0.50	0.46	0.27	2.98	0.64	29.88	
7-07/7-02	7-07	803+15.23	7-02	322+66.75	0.07	0.90	0.07	0.21	5.87	8.36	0.00	1.94	10.00	9.70	57.00	0.00526	15	Circular	1	4.69	0.00090	0.56	0.53	0.29	3.64	0.77	15.67	
7-05/7-04	7-05	324+25	7-04	323+25	0.18	0.90	0.16	0.16	5.00	8.71	0.00	1.51	10.85	10.35	74.00	0.00676	15	Circular	1	5.31	0.00060	0.46	0.41	0.25	3.73	0.67	19.83	
7-04/7-02	7-04	323+25	7-02	322+66.75	0.10	0.90	0.09	0.24	5.33	8.57	0.00	2.30	10.25	9.70	80.00	0.00688	15	Circular	1	5.36	0.00130	0.57	0.55	0.30	4.20	0.85	19.04	
7-02/7-08	7-02	322+66.75	7-08	322+67.21	0.11	0.90	0.10	0.55	6.13	8.26	0.00	5.02	8.65	8.50	53.00	0.00283	18	Circular	1	5.59	0.00240	1.11	1.40	0.45	3.58	1.31	14.81	
7-08/7-09	7-08	322+67.21	7-09	323+64.49	0.00		0.00	0.55	6.38	8.16	0.00	4.97	8.50	8.30	92.00	0.00217	24	Circular	1	10.54	0.00050	0.97	1.50	0.49	3.31	1.14	27.84	
7-09/7-12	7-09	323+64.49	7-12	323+64.59	0.00		0.00	0.55	6.84	8.00	0.00	4.86	8.30	8.28	8.00	0.00250	24	Circular	1	11.31	0.00050	0.92	1.40	0.47	3.47	1.10	2.31	
7-10/7-11	7-10	326+50	7-11	326+50	0.15	0.90	0.13	0.13	5.00	8.71	0.00	1.28	20.10	20.06	10.00	0.00400	15	Circular	1	4.09	0.00040	0.48	0.44	0.26	2.95	0.62	3.39	

LD-229
STORM SEWER DESIGN COMPUTATIONS

STORM FREQUENCY **25**

PROJECT: Elizabeth River Tunnels Project
LOCATION: Portsmouth
COUNTY: Norfolk (city)

Designed by: AMO
Checked by: MJP

UNITS **ENGLISH**

PIPE NO.	FROM POINT REFERENCE (1)	FROM POINT STA.	TO POINT REFERENCE (2)	TO POINT STA.	DRAIN. AREA "A" Acre (3)	RUNOFF COEFF. "C" (4)	CA INCRE-MENT (5)	CA ACCUM-ULATED (6)	TOTAL INLET TIME Minutes (7)	RAIN FALL In/Hr (8)	RUNOFF Lateral CFS	RUNOFF Total Q CFS (9)	INVERT ELEVATIONS UPPER END (10)	INVERT ELEVATIONS LOWER END (11)	LENGTH of Pipe Ft. (12)	SLOPE Ft./Ft. (13)	SIZE (Dia. Or Span/Rise) In. (14)	SHAPE	Number of Pipes	Capacity CFS (15)	Friction Slope Ft./Ft.	NORMAL FLOW Depth of Flow, dn Ft.	NORMAL FLOW Area of Flow, An SqFt	NORMAL FLOW Hrn Ft.	NORMAL FLOW Vn Ft/Sec (16)	NORMAL FLOW En Ft.	FLOW TIME Sec. (17)	REMARKS (18)
8-05/8-19	8-05	810+87.41	8-19	810+92.94	0.77	0.80	0.61	0.61	5.00	7.67	0.00	4.70	6.50	6.45	11.00	0.00455	18	Circular	1	7.09	0.00210	0.89	1.10	0.42	4.29	1.18	2.57	
8-08	BR.SCPR	328+90	8-08	3000+65.40	0.00		0.00	0.00	5.00	0.00	0.00	0.97	8.30	8.26	8.00	0.00500	15	Circular	1	4.57	0.00020	0.39	0.33	0.22	2.95	0.53	2.71	
8-09/8-14	8-09	3000+71.64	8-14	3002+01.49	0.23	0.63	0.14	0.14	5.00	7.67	0.00	1.09	6.95	6.70	125.00	0.00200	18	Circular	1	4.70	0.00010	0.49	0.50	0.28	2.17	0.56	57.75	
8-14/8-20	8-14	3002+01.49	8-20	3002+56.37	0.07	0.69	0.05	0.19	5.96	7.31	0.00	1.40	6.27	6.10	85.00	0.00200	24	Circular	1	10.12	0.00000	0.50	0.62	0.30	2.27	0.58	37.52	
9-1/9-2	9-1	3004+64.97	9-2	3004+80.68	1.32	0.90	1.19	1.19	5.00	8.71	0.00	11.41	6.10	6.00	51.00	0.00196	30	Circular	1	18.16	0.00080	1.44	2.92	0.68	3.91	1.67	13.05	
9-2/9-3	9-2	3004+80.68	9-3	3005+06.63	0.89	0.68	0.61	1.80	5.22	8.67	0.00	17.13	5.23	5.13	49.00	0.00204	30	Circular	1	18.53	0.00180	1.90	4.00	0.76	4.28	2.18	11.44	

Denotes existing pipes or structures to remain in place

LD-347
HYDRAULIC GRADE LINE ANALYSIS

PROJECT: Elizabeth River Tunnels Project

DESIGNED BY: AMO

Checked: MJP

INCIDENCE PROBABILITY **25** **Year**

INLET OR JUNCTION	STA.	INVERT EL. OUTFLOW PIPE	DEPTH OF FLOW OUTFLOW PIPE	OUTLET WATER SURFACE ELEV.	DIA. PIPE Do (In/mm)	DESIGN DISCH. Qo (CFS/CMS)	LENGTH PIPE Lo (Ft/M)	FRICTION SLOPE, Sfo (FT/FT) (M/M)	FRICTION LOSS Hf (Ft/M)	JUNCTION LOSS Vo	Contr. Ho (Ft/M)	Vi	Vi*2/2g	Hi (Expn) 0.35*MAX. (Vi2/2g)	SKEW Angle	K	Bend H (Ft/M)	Sum HL (Ft/M)	SURFACE FLOW	Adj. Ht 1.3 Ht (Ft/M)	Inlet Shaping? Y/N	0.5 Ht (Ft/M)	FINAL H (Ft/M)	Inlet Water Surface Elevation	Top of MH Top of Inlet Elev. APPROX.	Adjustment?
(1)	(2)			(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)		(12)	(13)		(14)	(15)		(16)		(16)	(17)	(18)	(19)	
3-02																								18.240		
3-01	301+50	17.240	1.25	18.240	15	2.300	4.00	0.00572	0.023	2.466	0.024	0.000	0.000	0.000	0.0	0.00	0.000	0.024	2.091	0.031	NO	0.031	0.054	18.294	19.770	O.K.
3-04																								15.430		
3-03	303+25	14.430	1.25	15.430	15	2.463	4.00	0.00656	0.026	2.811	0.031	0.000	0.000	0.000	0.0	0.00	0.000	0.031	2.239	0.040	NO	0.040	0.066	15.496	16.970	O.K.
3-08																								14.920		
EX	303+80	13.920	1.25	14.936	15	4.428	73.40	0.00491	0.361	4.145	0.067	0.000	0.000	0.000	0.0	0.00	0.000	0.067	4.026	0.087	NO	0.087	0.447	15.383	17.800	O.K.
4-02																								11.450		
4-01	305+75	10.450	1.25	11.454	15	3.412	4.00	0.01258	0.050	3.231	0.041	0.000	0.000	0.000	0.0	0.00	0.000	0.041	3.102	0.053	NO	0.053	0.103	11.557	13.000	O.K.
4-04																								10.170		
EX2	306+25	9.170	1.25	10.170	15	2.377	80.00	0.00142	0.113	3.044	0.036	0.000	0.000	0.000	0.0	0.00	0.000	0.036	2.161	0.047	NO	0.047	0.160	10.330	14.800	O.K.
4-11																								9.620		
4-08	308+10.79	7.220	3.00	9.620	36	26.009	107.00	0.00159	0.170	4.815	0.090	6.531	0.662	0.232	90.0	0.70	0.265	0.587	0.000	0.587	YES	0.294	0.464	10.084	10.920	O.K.
4-07	308+10.73	7.440	2.00	10.084	24	10.157	15.00	0.00211	0.032	4.942	0.095	4.112	0.263	0.092	0.0	0.00	0.000	0.187	4.156	0.243	YES	0.121	0.153	10.237	11.500	O.K.
4-06	307+90	7.500	1.50	10.237	18	5.190	18.00	0.00255	0.046	4.112	0.066	0.000	0.000	0.000	0.0	0.00	0.000	0.066	4.325	0.085	NO	0.085	0.131	10.368	11.390	O.K.
4-09	307+88.45	7.440	2.00	10.084	24	17.637	30.00	0.00635	0.191	6.531	0.166	0.000	0.000	0.000	0.0	0.00	0.000	0.166	0.000	0.166	YES	0.083	0.273	10.357	11.040	O.K.
5-02																								7.920		
5-01	311+00.00	6.920	1.25	7.920	15	2.569	15.00	0.00165	0.025	2.661	0.027	0.000	0.000	0.000	0.0	0.00	0.000	0.027	2.335	0.036	NO	0.036	0.061	7.981	14.550	O.K.
5-13																								13.560		
EX3	311+85.67	12.560	1.25	13.560	15	3.542	84.00	0.00314	0.264	4.191	0.068	0.000	0.000	0.000	0.0	0.00	0.000	0.068	3.542	0.089	NO	0.089	0.353	13.913	18.700	O.K.
5-04																								11.500		
5-03	312+50.00	10.500	1.25	11.500	15	3.288	18.00	0.00271	0.049	3.162	0.039	0.000	0.000	0.000	0.0	0.00	0.000	0.039	2.989	0.050	NO	0.050	0.099	11.599	17.390	O.K.
5-06																								9.190		

LD-347
HYDRAULIC GRADE LINE ANALYSIS

PROJECT: Elizabeth River Tunnels Project

DESIGNED BY: AMO

Checked: MJP

INCIDENCE PROBABILITY **25** **Year**

INLET OR JUNCTION	STA.	INVERT EL. OUTFLOW PIPE	DEPTH OF FLOW OUTFLOW PIPE	OUTLET WATER SURFACE ELEV.	DIA. PIPE Do (In/mm)	DESIGN DISCH. Qo (CFS/CMS)	LENGTH PIPE Lo (Ft/M)	FRICTION SLOPE, Sfo (FT/FT) (M/M)	FRICTION LOSS Hf (Ft/M)	JUNCTION LOSS Vo	Contr. Ho (Ft/M)	Vi	Vi^2/2g	Hi (Expn) 0.35*MAX. (Vi2/2g)	SKEW Angle	K	Bend H (Ft/M)	Sum HL (Ft/M)	SURFACE FLOW	Adj. Ht 1.3 Ht (Ft/M)	Inlet Shaping? Y/N	0.5 Ht (Ft/M)	FINAL H (Ft/M)	Inlet Water Surface Elevation	Top of MH Top of Inlet Elev. APPROX.	Adjustment?
(1)	(2)			(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)		(12)	(13)		(14)	(15)		(16)		(16)	(17)	(18)	(19)	
5-05	314+50.00	8.190	1.25	9.190	15	3.106	26.00	0.00242	0.063	3.289	0.042	0.000	0.000	0.000	0.0	0.00	0.000	0.042	2.823	0.055	NO	0.055	0.117	9.307	20.920	O.K.
EX15-23																								9.510		
EX15-16		7.110	3.00	10.110	36	103.760	63.80	0.02530	1.614	14.679	0.836	0.000	0.000	0.000	0.0	0.00	0.000	0.836	0.000	0.836	NO	0.836	2.450	12.560	12.670	O.K.
5-09																								9.650		
5-07	315+67	7.250	2.50	9.650	30	11.530	21.00	0.00083	0.017	4.220	0.069	0.000	0.000	0.000	0.0	0.00	0.000	0.069	0.000	0.069	NO	0.069	0.086	9.736	10.110	O.K.
5-08	316+32.03	7.250	2.50	9.650	30	11.570	35.00	0.00083	0.029	3.464	0.047	0.000	0.000	0.000	0.0	0.00	0.000	0.047	0.000	0.047	NO	0.047	0.076	9.726	10.110	O.K.
6-08																								8.510		
6-07	317+25	7.510	1.25	8.510	15	0.431	35.00	0.00005	0.002	2.695	0.028	0.000	0.000	0.000	0.0	0.00	0.000	0.028	0.392	0.037	NO	0.037	0.038	8.548	23.390	O.K.
6-03																								9.650		
6-02	320+69.89	7.650	2.50	9.650	30	10.083	166.00	0.00063	0.105	3.488	0.047	3.626	0.204	0.071	0.0	0.00	0.000	0.119	0.926	0.119	YES	0.059	0.164	9.814	12.060	O.K.
6-01	320+95.00	7.910	2.00	9.814	24	9.212	71.00	0.00173	0.123	3.626	0.051	0.000	0.000	0.000	0.0	0.00	0.000	0.051	8.374	0.066	NO	0.066	0.189	10.004	11.000	O.K.
7-12																								9.650		
7-09	323+64.49	8.280	2.00	9.880	24	4.864	8.00	0.00048	0.004	3.465	0.047	3.305	0.170	0.059	0.0	0.00	0.000	0.106	0.000	0.106	YES	0.053	0.057	9.937	11.880	O.K.
7-08	322+67.21	8.300	2.00	9.937	24	4.965	92.00	0.00050	0.046	3.305	0.042	3.579	0.199	0.070	0.0	0.00	0.000	0.112	0.000	0.112	YES	0.056	0.102	10.039	12.000	O.K.
7-02	322+66.75	8.500	1.50	10.039	18	5.022	53.00	0.00239	0.127	3.579	0.050	4.201	0.274	0.096	81.0	0.64	0.176	0.322	0.809	0.322	YES	0.161	0.288	10.327	12.950	O.K.
7-07	803+15.23	9.700	1.25	10.700	15	1.939	57.00	0.00094	0.054	3.638	0.051	2.979	0.138	0.048	0.0	0.00	0.000	0.100	0.551	0.129	YES	0.065	0.118	10.818	14.130	O.K.
6-05	802+24.38	10.000	1.25	11.000	15	1.365	89.00	0.00047	0.042	2.979	0.034	2.317	0.083	0.029	0.0	0.00	0.000	0.064	0.505	0.083	YES	0.041	0.083	11.083	13.600	O.K.
6-04	801+69.90	10.350	1.25	11.350	15	0.824	52.00	0.00017	0.009	2.317	0.021	0.000	0.000	0.000	0.0	0.00	0.000	0.021	0.749	0.027	NO	0.027	0.036	11.386	13.910	O.K.
7-04	323+25	9.700	1.25	10.700	15	2.301	80.00	0.00133	0.106	4.201	0.069	3.732	0.216	0.076	0.0	0.00	0.000	0.144	0.737	0.187	YES	0.094	0.200	10.900	13.610	O.K.
7-05	324+25	10.350	1.25	11.350	15	1.514	74.00	0.00057	0.042	3.732	0.054	0.000	0.000	0.000	0.0	0.00	0.000	0.054	1.377	0.070	NO	0.070	0.113	11.463	15.240	O.K.
8-20																								7.700		
8-14	3002+01.49	6.100	2.00	7.700	24	4.669	85.00	0.00045	0.038	3.156	0.039	2.055	0.066	0.023	0.0	0.00	0.000	0.062	3.809	0.080	YES	0.040	0.078	7.778	10.820	O.K.
8-09	3000+71.64	6.700	1.50	7.900	18	0.905	125.00	0.00008	0.010	2.055	0.016	0.000	0.000	0.000	0.0	0.00	0.000	0.016	0.905	0.021	YES	0.011	0.020	7.920	10.500	O.K.

LD-347
HYDRAULIC GRADE LINE ANALYSIS

PROJECT: Elizabeth River Tunnels Project

DESIGNED BY: AMO

Checked: MJP

INCIDENCE PROBABILITY **25** **Year**

INLET OR JUNCTION	STA.	INVERT EL. OUTFLOW PIPE	DEPTH OF FLOW OUTFLOW PIPE	OUTLET WATER SURFACE ELEV.	DIA. PIPE Do (In/mm)	DESIGN DISCH. Qo (CFS/CMS)	LENGTH PIPE Lo (Ft/M)	FRICTION SLOPE, Sfo (FT/FT) (M/M)	FRICTION LOSS Hf (Ft/M)	JUNCTION LOSS Vo	Contr. Ho (Ft/M)	Vi	Vi*2/2g	Hi (Expn) 0.35*MAX. (Vi2/2g)	SKEW Angle	K	Bend H (Ft/M)	Sum HL (Ft/M)	SURFACE FLOW	Adj. Ht 1.3 Ht (Ft/M)	Inlet Shaping? Y/N	0.5 Ht (Ft/M)	FINAL H (Ft/M)	Inlet Water Surface Elevation	Top of MH Top of Inlet Elev. APPROX.	Adjustment?
(1)	(2)			(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)		(12)	(13)		(14)	(15)		(16)		(16)	(17)	(18)	(19)	
8-19																								7.650		
8-05	810+87.41	6.450	1.50	7.650	18	4.699	11.00	0.00209	0.023	4.288	0.071	0.000	0.000	0.000	0.0	0.00	0.000	0.071	4.699	0.093	YES	0.046	0.069	7.719	9.890	O.K.
9-3																								7.630		
9-2	3004+80.68	5.130	2.50	7.630	30	17.13	49.00	0.00182	0.089	4.284	0.071	4.398	0.300	0.105	0.0	0.00	0.000	0.176	5.251	0.229	YES	0.115	0.204	7.834	9.700	O.K.
9-1	3004+64.97	5.330	2.50	7.834	30	11.41	30.00	0.00081	0.024	4.398	0.075	0.000	0.000	0.000	0.0	0.00	0.000	0.075	0.000	0.075	YES	0.038	0.062	7.896	11.000	O.K.

Denotes existing pipes or structures to remain in place

Parsons Brinckerhoff
Project: Elizabeth River Tunnels Project
Location: Portsmouth, VA
Design Phase: RFC Design
Description: Bridge Scupper Design

Designed By: CC
Date: 12/13/2012
Checked By: MJP

MLK Expressway - Ramp 'EN' Bridge over Frederick Blvd
VDOT

Begin Bridge @ Sta 328+80.00
End Bridge @ Sta 335+51.75

Total Bridge Length (ft) = 671.75

Ht Point @ Sta 331+75.00 F.G. Elev (ft) = 51.05

From the Plan Grade Distance to Lt Side D/S Shoulder (ft) = 22

Def Angle (Deg) @ Abutment A = 45.00
Def Angle (Deg) @ Pier 1 = 41.48
Def Angle (Deg) @ Pier 2 = 20.00

	Station PGL	Station D/S Shoulder	Bent No.	Span Length (ft)	F.G. Elev (ft)	Longitudinal Slope (ft/ft)	Cross Slope (ft/ft)	Remark
	328+80.00	328+58.00	Begin Bridge / Abutment A		40.8600			
Span 1				83.00		0.05723	0.06	
	329+63.00	329+43.55	Pier 1		45.6100			
Span 2				85.75		0.04245		- Full Super Elevation @ 0.06 ft/ft (Lt Side Shoulder) to Sta 329+91
	330+48.75	330+40.74	Pier 2		49.2500			
Span 3				83.00		0.01831		- Transition 0.06 ft/ft (Lt Side Shoulder) to 0.02 ft/ft (Rt Side shoulder) from Sta Sta
	331+31.75	331+31.75	Pier 3		50.7700			- Transition 0.06 ft/ft (Lt Side Shoulder) to 0.00 ft/ft fom Sta Sta 329+91 to Sta 331+37.25
Span 4				140.00		0.00647		- Transition 0.00 ft/ft to 0.02 ft/ft (Rt Side Shoulder) fom Sta 331+37.25 to Sta 331+86
						0.00930	0.02	Ht Point @ Sta 331+75.00
	332+71.75	332+71.75	Pier 4		50.1500			
Span 5				140.00		0.03421	0.02	
	334+11.75	334+11.75	Pier 5		45.3600			
Span 6				140.00		0.02800	0.02	
	335+51.75	335+51.75	End Bridge / Abutment B		41.4400			
Total Length of Bridge =				671.75				

Design Storm Event (year) = 10
Check Storm Event (year) = 25
Minimum Time of Concentration (minutes) = 5

Rainfall Intensity Rate (in/hr)
- 10 Yr = 7.67
- 25 Yr = 8.71

Width of bridge deck pavement contributing to gutter flow [Wp (ft)] = 30

Runoff Coefficients:
Pavement / Bridge Deck = 0.9
Paved Shoulder = 0.9

- 4" Dia Drain Hole

Manning's n for pavement gutter = 0.015 (for rough concrete gutter - asphalt pavement)

Inside Dia. of Drain Hole (ft) = 0.333

Width of Gutter Suppression
LT Side Shoulder (ft) = 6
RT Side Shoulder (ft) = 8

- 54" ACO Bridge Drain - Scupper Grate
Effective Length of Scupper Grating (ft) = 0.656
Effective Width of Scupper Grating (ft) = 1.982

Note: the side flow interception efficiency, Rs, is assumed "0" since a side inflow to small rectangular inets is negligible (Chart 10 of the HEC-21, Page 113)

Location				Hydrology				Gutter Spread						Inlet Efficiency - Q10						Efficiency - Q25						Remark
	Station	Grade/Sag	Outlet Location (Rt/Lt)	Drainage Area (sq. ft)	Drainage Area (ac)	Q10 (cfs)	Q25 (cfs)	Average Profile Grade (ft/ft)	Cross Slope (ft/ft)	Gutter Spread - Q10 (ft)	Gutter Spread - Q25 (ft)	Flow Depth - Q10 (in)	Flow Depth - Q25 (in)	Frontal Flow Ratio, Eo	Gutter Velocity (ft/s)	Frontal Flow Intercept Efficiency, Rf	Inlet Efficiency, E	Q Entering Structure (cfs)	Q Passing Structure (cfs)	Frontal Flow Ratio, Eo	Gutter Velocity (ft/s)	Frontal Flow Intercept Efficiency, Rf	Inlet Efficiency, E	Q Entering Structure (cfs)	Q Passing Structure (cfs)	
	331+75.00	Ht Pt																								
Between High Pt & Pier 4	332+60.00	Grade	Rt	2550.00	0.0585	0.404	0.459	0.00930	0.02	5.080	5.328	1.22	1.28	0.733	1.556	1	0.733	0.296	0.108	0.711	1.607	1	0.711	0.326	0.133	- 54" ACO Bridge Drain - Scupper Grate
Between Pier 4 & Pier 5	334+00.00	Grade	Rt	4200.00	0.0964	0.773	0.888	0.03421	0.02	5.076	5.347	1.22	1.28	0.733	2.983	1	0.733	0.567	0.206	0.710	3.088	1	0.710	0.630	0.258	- 54" ACO Bridge Drain - Scupper Grate
Between Pier 4 & End	335+20.00	Grade	Rt	3600.00	0.0826	0.777	0.906	0.02800	0.02	5.279	5.592	1.27	1.34	0.715	2.770	1	0.715	0.556	0.221	0.689	2.879	1	0.689	0.624	0.282	- 54" ACO Bridge Drain - Scupper Grate
	335+40.00	Grade	Rt	600.00	0.0138	0.316	0.390	0.02800	0.02	3.768	4.075	0.90	0.98	0.864	2.210	1	0.864	0.273	0.043	0.831	2.329	1	0.831	0.324	0.066	
	331+75.000	Ht Pt																								
Between High Pt & Pier 3	331+55.000	Grade	Rt	600.00	0.0138	0.095	0.108	0.00647	0.007	5.943	6.233	0.52	0.54	0.662	0.733	1	0.662	0.063	0.032	0.640	0.757	1	0.640	0.069	0.039	- 54" ACO Bridge Drain - Scupper Grate
	331+45.000	Grade	Rt	300.00	0.0069	0.080	0.093	0.00647	0.003	9.339	9.889	0.36	0.38	0.471	0.569	1	0.471	0.038	0.042	0.450	0.592	1	0.450	0.042	0.051	
Between Pier 3 & Pier 2	330+50.000	Grade	Lt	3135.00	0.0720	0.539	0.615	0.01831	0.048	2.887	3.034	1.66	1.74	0.955	2.684	1	0.955	0.515	0.024	0.941	2.775	1	0.941	0.579	0.036	- 54" ACO Bridge Drain - Scupper Grate
Between Pier 1 & Begin Bridge	328+90.000	Grade	Lt	5280.00	0.1212	0.861	0.987	0.04984	0.060	2.478	2.608	1.78	1.88	0.986	4.649	1	0.986	0.849	0.012	0.978	4.810	1	0.978	0.965	0.022	- 54" ACO Bridge Drain - Scupper Grate

Parsons Brinckerhoff			
Project:	**Elizabeth River Tunnels Project**	***Designed By:***	**AMO**
Location:	**Portsmouth, VA**	***Date:***	**6/6/2013**
Design Phase:	**RFC Design**	***Checked By:***	**MJP**
Description:	**Roadside Ditch Analysis**	***Date:***	**6/6/2013**
Design Year:	**25 Year for Capacity Design**		
	50 Year for Capacity Design for D10-08		

Trapezoidal Channels

Ditch	Baseline	From Station	To Station	Invert In	Invert Out	Solve For	Friction Method	Roughness Coefficient	Channel Slope (ft/ft)	Normal Depth (ft)	Left Side Slope (ft/ft (H:V))	Right Side Slope (ft/ft (H:V))	Bottom Width (ft)	Discharge (ft^3/s)	Flow Area (ft^2)	Wetted Perimeter (ft)	Hydraulic Radius (ft)	Top Width (ft)	Critical Depth (ft) Design	Critical Slope (ft/ft)	Velocity (ft/s)	Velocity Head (ft)	Specific Energy (ft)	Froude Number	Flow Type	Material	Width Erosion Control Lining
D4-09	Ramp EN	301+45.92	307+88.45	9.90	7.63	Normal Depth	Manning Formula	0.05	0.0035	1.79	2	2	2	17.49	9.97	9.99	1	9.15	0.97	0.0465	1.75	0.05	1.84	0.3	Subcritical	EC-2	13
D5-10(2)	Ramp EN	309+23.92	312+20.40	7.22	6.64	Normal Depth	Manning Formula	0.05	0.002	2.3	2	2	2	23.22	15.18	12.28	1.24	11.2	1.12	0.0448	1.53	0.04	2.34	0.23	Subcritical	EC-2	22
D5-07	Ramp EN	313+78.96	315+62.44	8.85	7.30	Normal Depth	Manning Formula	0.05	0.00814	1.21	2	2	2	11.52	5.34	7.41	0.72	6.84	0.78	0.0491	2.16	0.07	1.28	0.43	Subcritical	EC-2	15
D5-08	Ramp EN	316+36.60	318+94.03	7.30	7.65	Normal Depth	Manning Formula	0.03	0.0014	1.5	2	2	2	12.65	7.53	8.72	0.86	8.02	0.82	0.0175	1.68	0.04	1.55	0.31	Subcritical	N/A	N/A
D10-08	Ramp EN	340+31.19	335+70.37	13.00	9.45	Normal Depth	Manning Formula	0.05	0.00793	1.20	2	2	2	11.14	5.26	7.35	0.72	6.79	0.76	0.0493	2.12	0.07	1.27	0.42	Subcritical	EC-2	15

Triangular Channels

Ditch	Baseline	From Station	To Station	Invert In	Invert Out	Solve For	Friction Method	Roughness Coefficient	Channel Slope (ft/ft)	Normal Depth (ft)	Left Side Slope (ft/ft (H:V))	Right Side Slope (ft/ft (H:V))	Discharge (ft^3/s)	Flow Area (ft^2)	Wetted Perimeter (ft)	Hydraulic Radius (ft)	Top Width (ft)	Critical Depth (ft) Design	Critical Slope (ft/ft)	Velocity (ft/s)	Velocity Head (ft)	Specific Energy (ft)	Froude Number	Flow Type	Material	Width Erosion Control Lining
D5-10(1)	Ramp EN	308+07.78	309+51.58	10.78	7.3	Normal Depth	Manning Formula	0.05	0.02697	0.42	2	2	0.58	0.36	1.9	0.19	1.7	0.35	0.0756	1.61	0.04	0.47	0.62	Subcritical	EC-2	27
D6-01(1)	Ramp EN	317+09.34	320+92.36	24.00	11.00	Normal Depth	Manning Formula	0.05	0.033	0.71	2	2	2.5	1	3.16	0.32	2.82	0.63	0.0622	2.5	0.1	0.8	0.74	Subcritical	EC-2	2
D6-01(2)	Ramp EN	320+96.71	322+01.24	13.50	11.00	Normal Depth	Manning Formula	0.05	0.02383	0.64	2	2	1.6	0.81	2.84	0.28	2.54	0.53	0.066	1.98	0.06	0.7	0.62	Subcritical	EC-2	3
D 8-08	Frederick Blvd.	3000+46.80	3000+63.16	8.26	8.20	Normal Depth	Manning Formula	0.03	0.0036	0.17	2	2	0.03	0.06	0.76	0.08	0.68	0.11	0.0402	0.53	0.000	0.17	0.32	Subcritical	N/A	N/A
D10-04	Ramp EN	332+89.02	333+40.12	10.36	14.00	Normal Depth	Manning Formula	0.05	0.03204	0.54	2	2	1.2	0.58	2.41	0.24	2.16	0.47	0.0686	2.06	0.07	0.6	0.7	Subcritical	EC-3B	10
	Ramp EN	333+40.12	335+00.00	14.00	22.00	Normal Depth	Manning Formula	0.05	0.05	0.41	2	2	0.71	0.33	1.82	0.18	1.63	0.38	0.0736	2.14	0.07	0.48	0.83	Subcritical	EC-2	8
	Ramp EN	335+00.00	340+65.38	22.00	39.96	Normal Depth	Manning Formula	0.05	0.0421	0.41	2	2	0.67	0.34	1.85	0.18	1.65	0.37	0.0741	1.98	0.06	0.47	0.77	Subcritical	EC-2	5

Temporary Triangular Channel

Ditch	Baseline	From Station	To Station	Invert In	Invert Out	Solve For	Friction Method	Roughness Coefficient	Channel Slope (ft/ft)	Normal Depth (ft)	Left Side Slope (ft/ft (H:V))	Right Side Slope (ft/ft (H:V))	Discharge (ft^3/s)	Flow Area (ft^2)	Wetted Perimeter (ft)	Hydraulic Radius (ft)	Top Width (ft)	Critical Depth (ft) Design	Critical Slope (ft/ft)	Velocity (ft/s)	Velocity Head (ft)	Specific Energy (ft)	Froude Number	Flow Type	Material	Width Erosion Control Lining
Temporary Ditch	Ramp EN	307+45	308+16.21	10.96	10.78	Normal Depth	Manning Formula	0.03	0.00204	0.44	2	2	0.29	0.39	1.97	0.2	1.76	0.27	0.0298	0.76	0.01	0.45	0.28	Subcritical	N/A	N/A
	Ramp EN	308+16.21	309+70.00	10.78	7.48	Normal Depth	Manning Formula	0.05	0.02062	0.41	2	2	0.47	0.34	1.85	0.18	1.65	0.32	0.0777	1.38	0.03	0.44	0.54	Subcritical	EC-2	29

Closed System Analysis
Nodes 27-04 to 30-04
Martin Luther King Expressway

Drainage Area Summary						
Identification	Runoff C	Drainage Area	Time of Conc.	Time Used	Intensity	Discharge
30-04	0.9	0.10	5.00	5.00	8.71	0.8
30-01	0.4	0.59	5.00	5.00	8.71	2.3
28-05	0.5	0.70	5.00	5.00	8.71	3.5
28-07	0.9	0.03	5.00	5.00	8.71	0.3
28-09	0.9	0.46	5.00	5.00	8.71	4.0
28-01	0.5	1.31	11.26	11.26	6.75	5.0
28-04	0.9	0.03	5.00	5.00	8.71	0.3
28-06	0.8	0.11	5.00	5.00	8.71	0.8
28-08	0.9	0.42	5.00	5.00	8.71	3.6
28-11	0.5	2.40	5.00	5.00	8.71	11
27-05	0.9	0.23	5.00	5.00	8.71	1.9
28-03	0.9	0.03	5.00	5.00	8.71	0.3
27-04	0.8	1.33	7.14	7.14	7.90	9.2

Closed System Analysis
Nodes 27-04 to 30-04
Martin Luther King Expressway

Inlet on Grade Summary

ID	Type	Discharge	Width	Depth	Slope	Length	Depr.	Capacity	By Pass
28-05	Curb	3.522	10.36	0.24	1.00	8	0.17	2.37	1.15
28-07	Curb	0.282	1.90	0.16	0.74	4	0.17	0.28	
28-09	Curb	4.003	4.29	0.29	4.00	20	0.08	4.00	0.00
28-01	Curb	4.98	7.77	0.29	1.90	8	0.17	3.01	1.97
28-04	Curb	0.25	1.53	0.13	1.90	4	0.17	0.25	
28-06	Curb	0.815	5.06	0.23	0.74	4	0.17	0.77	0.05
28-08	Curb	3.632	4.14	0.28	4.00	20	0.08	3.63	
28-03	Curb	0.261	1.63	0.14	1.44	4	0.17	0.26	
27-04	Curb	9.218	15.08	0.36	0.80	20	0.17	8.45	0.77

Closed System Analysis
Nodes 27-04 to 30-04
Martin Luther King Expressway

Link Summary

ID	Upstream ID	Downstream ID	Discharge	Length	Shape	Rise	Span	n	Slope	Upstream Invert	Downstream Invert
Pipe-20	30-04	29-02	42	38.26	Circular	3.00	n/a	0.013	0.200	1.79	1.71
Pipe-19	30-01	30-04	42	69.54	Circular	3.00	n/a	0.013	0.192	1.93	1.79
Pipe-18	28-10	30-01	40	171.18	Circular	3.00	n/a	0.013	0.194	2.27	1.93
Pipe-13	28-05	28-10	17	254.25	Circular	3.00	n/a	0.013	0.197	2.78	2.27
Pipe-15	28-07	28-10	1.1	62.06	Circular	1.25	n/a	0.013	0.567	6.37	6.00
Pipe-17	28-09	28-10	19	6.66	Circular	2.00	n/a	0.013	0.296	5.10	5.07
Pipe-9	28-01	28-05	14	37.51	Circular	2.50	n/a	0.013	0.195	2.86	2.78
Pipe-12	28-04	28-05	0.5	37.79	Circular	1.25	n/a	0.013	0.586	5.54	5.30
Pipe-14	28-06	28-07	0.8	16.92	Circular	1.25	n/a	0.013	0.156	6.40	6.37
Pipe-16	28-08	28-09	3.6	41.98	Circular	1.25	n/a	0.013	9.455	19.80	15.55
Pipe-44	28-11	28-09	11	104.98	Circular	2.00	n/a	0.013	0.48	5.62	5.10
Pipe-8	27-05	28-01	11	193.24	Circular	2.50	n/a	0.013	0.194	3.24	2.86
Pipe-11	28-03	28-04	0.3	16.72	Circular	1.25	n/a	0.013	0.158	5.57	5.54
Pipe-7	27-04	27-05	9.2	22.24	Circular	2.50	n/a	0.013	0.359	3.33	3.24

Closed System Analysis
Nodes 27-04 to 30-04
Martin Luther King Expressway

HGL Summary Summary												
	Upstream	Downstream	Upstream	Downstream					Uniform		Actual	
ID	ID	ID	HGL	HGL	Discharge	Capacity	Slope	Loss	Velocity	Depth	Velocity	Depth
Pipe-20	30-04	29-02	6.262	5.94	42.0	32.1	0.343	0.163	6.10	3.00	5.95	3.00
Pipe-19	30-01	30-04	6.813	6.26	41.7	31.4	0.337	0.266	6.05	3.00	5.89	3.00
Pipe-18	28-10	30-01	7.782	6.81	40.0	31.6	0.311	0.339	5.81	3.00	5.66	3.00
Pipe-13	28-05	28-10	8.001	7.78	17.3	31.9	0.189	0.044	4.28	1.67	2.45	3.00
Pipe-15	28-07	28-10	7.806	7.78	1.1	5.2	0.558	0.005	3.18	0.40	0.89	1.25
Pipe-17	28-09	28-10	7.977	7.78	18.6	13.2	0.582	0.126	6.06	2.00	5.91	2.00
Pipe-9	28-01	28-05	8.083	8.00	14.3	19.5	0.192	0.031	4.06	1.69	2.92	2.50
Pipe-12	28-04	28-05	8.005	8.00	0.5	5.3	0.582	0.001	2.59	0.27	0.41	1.25
Pipe-14	28-06	28-07	7.812	7.81	0.8	2.7	0.156	0.002	1.85	0.49	0.66	1.25
Pipe-16	28-08	28-09	20.984	15.92	3.6	21.4	9.457	0.098	12.32	0.36	11.94	0.37
Pipe-44	28-11	28-09	8.303	7.98	11.2	16.9	0.487	0.06	5.46	1.25	3.58	2.00
Pipe-8	27-05	28-01	8.24	8.08	10.9	19.4	0.196	0.019	3.87	1.39	2.22	2.50
Pipe-11	28-03	28-04	8.006	8.01	0.3	2.8	0.167	0	1.37	0.27	0.21	1.25
Pipe-7	27-04	27-05	8.27	8.24	9.2	26.4	0.356	0.016	4.63	1.06	1.88	2.50

Closed System Analysis
Nodes 27-04 to 30-04
Martin Luther King Expressway

Drainage Area Summary						
Identification	Runoff C	Drainage Area	Time of Conc.	Time Used	Intensity	Discharge
25-20	0.8	0.16	5.00	5.00	8.71	1.2
25-19	0.8	0.12	5.00	5.00	8.71	0.9
27-11	0.8	0.37	5.00	5.00	8.71	2.9
27-10	0.8	0.14	5.00	5.00	8.71	1.1
27-07	0.9	0.23	9.00	9.00	7.32	1.6
27-09	0.9	0.05	5.00	5.00	8.71	0.4
27-06	0.8	1.87	9.50	9.50	7.19	12.1
27-03	0.9	0.30	5.00	5.00	8.71	2.6
27-08	0.9	0.43	5.00	5.00	8.71	3.7
27-02	0.9	0.07	5.00	5.00	8.71	0.6
27-01	0.9	0.07	5.00	5.00	8.71	0.6
27-32	0.9	0.49	6.99	6.99	7.94	3.8

Closed System Analysis
Nodes 27-04 to 30-04
Martin Luther King Expressway

Inlet on Grade Summary									
ID	Type	Discharge	Width	Depth	Slope	Length	Depr.	Capacity	By Pass
27-11	Curb	2.9	6.83	0.26	3.415	6	0.17	1.8	1.1
27-09	Curb	0.5	2.51	0.13	3.415	12	0.08	0.5	
27-06	Curb	12.1	16.91	0.41	0.75	20	0.17	10.4	1.8
27-03	Curb	2.6	4.65	0.30	1.82	14	0.17	2.6	
27-08	Curb	3.7	4.85	0.24	4.652	20	0.08	3.6	0.1
27-02	Curb	0.6	8.03	0.41	1.4	8	0.17	0.6	
27-01	Curb	0.6	2.33	0.18	1.4	14	0.17	0.6	
27-32	Curb	3.8	5.83	0.36	1.4	20	0.17	3.8	

Closed System Analysis
Nodes 27-04 to 30-04
Martin Luther King Expressway

Sag Inlet Summary Summary															
			Discharge		Ponded Width		Slope								Ponded
ID	Type	Discharge	Left	Right	Left	Right	Left	Right	Length	Width	Depr.	Area	Perim.	Capacity	Depth
25-20	Curb	1.2	0.6	0.6	7.63	7.63	0.1	0.1	20	n/a	0.167	n/a	n/a	19.2	0.08
25-19	Curb	0.9	0.4	0.4	6.46	6.46	0.1	0.1	6	n/a	0.167	n/a	n/a	7.8	0.12

Closed System Analysis
Nodes 27-04 to 30-04
Martin Luther King Expressway

Link Summary											
	Upstream	Downstream								Upstream	Downstream
ID	ID	ID	Discharge	Length	Shape	Rise	Span	n	Slope	Invert	Invert
Pipe-29	25-22	25-23	34.0	14.73	Ellipse	2.42	3.75	0.012	0.179	2.97	2.94
Pipe-28	25-21	25-22	34.0	184.00	Ellipse	2.42	3.75	0.012	0.197	3.34	2.97
PIPE 32	25-20	25-21	2.1	3.90	Circular	1.25	n/a	0.013	0.276	3.45	3.43
Pipe-59	27-13	25-21	32.6	68.00	Ellipse	2.42	3.75	0.012	0.208	3.49	3.34
Pipe-26	25-19	25-20	0.9	20.62	Circular	1.25	n/a	0.013	0.172	4.29	4.25
Pipe-27	27-12	27-13	27.3	56.73	Ellipse	2.42	3.75	0.012	0.181	3.60	3.49
Pipe-24	27-11	27-12	2.9	42.79	Circular	1.25	n/a	0.013	0.195	4.60	4.51
Pipe-25	27-10	27-12	25.2	68.52	Ellipse	2.42	3.75	0.012	0.194	3.74	3.60
Pipe-4	27-07	27-10	21.4	138.50	Ellipse	2.42	3.75	0.012	0.19	4.01	3.74
Pipe-23	27-09	27-10	4.1	6.16	Circular	1.25	n/a	0.013	5.886	5.50	5.00
Pipe-3	27-06	27-07	12.1	39.41	Circular	2.00	n/a	0.013	1.894	6.00	5.20
Pipe-6	27-03	27-07	8.2	35.59	Ellipse	2.00	3.17	0.012	0.235	4.10	4.01
Pipe-31	27-08	27-09	3.7	80.84	Circular	1.25	n/a	0.013	4.03	12.28	8.93
Pipe-58	27-35	27-03	5.9	34.08	Ellipse	1.58	2.5	0.012	0.339	4.23	4.10
Pipe-2	27-02	27-35	4.8	54.01	Ellipse	1.58	2.5	0.012	0.305	4.40	4.23
Pipe-1	27-01	27-02	4.3	40.51	Ellipse	1.17	1.92	0.012	0.187	4.48	4.40
Pipe-30	27-32	27-01	3.8	76.50	Circular	1.25	n/a	0.013	1.734	5.85	4.48

Closed System Analysis
Nodes 27-04 to 30-04
Martin Luther King Expressway

HGL Summary Summary												
	Upstream	Downstream	Upstream	Downstream					Uniform		Actual	
ID	ID	ID	HGL	HGL	Discharge	Capacity	Slope	Loss	Velocity	Depth	Velocity	Depth
Pipe-29	25-22	25-23	6.213	6	33.99	30.213	0.227	0.175	4.769	2.42	4.769	2.42
Pipe-28	25-21	25-22	6.741	6.213	33.99	31.657	0.227	0.101	4.769	2.42	4.769	2.42
PIPE 32	25-20	25-21	6.767	6.741	2.071	3.652	0.275	0.018	2.898	0.706	1.687	1.25
Pipe-59	27-13	25-21	6.972	6.741	32.579	32.57	0.208	0.081	4.571	2.42	4.571	2.42
Pipe-26	25-19	25-20	6.774	6.767	0.887	2.879	0.172	0.002	1.96	0.495	0.722	1.25
Pipe-27	27-12	27-13	7.123	6.972	27.266	30.37	0.18	0.063	4.972	1.739	3.826	2.42
Pipe-24	27-11	27-12	7.239	7.123	2.856	3.072	0.195	0.025	2.648	1.027	2.328	1.25
Pipe-25	27-10	27-12	7.263	7.123	25.181	31.406	0.2	0.049	5.079	1.588	3.533	2.42
Pipe-4	27-07	27-10	7.496	7.263	21.374	31.116	0.197	0.105	4.847	1.437	2.999	2.42
Pipe-23	27-09	27-10	7.42	7.263	4.063	16.858	5.882	0.122	10.721	0.434	3.311	1.25
Pipe-3	27-06	27-07	7.934	7.496	12.135	33.486	1.892	0.111	9.292	0.867	3.863	2
Pipe-6	27-03	27-07	7.565	7.496	8.195	21.412	0.226	0.055	3.913	0.875	1.646	2
Pipe-31	27-08	27-09	13.467	9.387	3.668	13.95	4.028	0.099	9.087	0.455	9.037	0.457
Pipe-58	27-35	27-03	7.603	7.565	5.943	13.667	0.347	0.014	4.254	0.728	1.916	1.58
Pipe-2	27-02	27-35	7.657	7.603	4.792	12.96	0.314	0.03	3.853	0.667	1.545	1.58
Pipe-1	27-01	27-02	7.811	7.657	4.329	4.766	0.191	0.088	3.189	0.841	2.453	1.17
Pipe-30	27-32	27-01	8.138	7.811	3.846	9.151	1.739	0.046	6.764	0.589	3.134	1.25

Closed System Analysis
Nodes 14-08 to 13-06
Martin Luther King Expressway

Drainage Area Summary						
Identification	Runoff C	Drainage Area	Time of Conc.	Time Used	Intensity	Discharge
13-05	0.9	0.07	5.00	5.00	8.714	0.62
14-08	0.4	0.34	5.00	5.00	8.714	1.41

Closed System Analysis
Nodes 14-08 to 13-06
Martin Luther King Expressway

Inlet on Grade Summary									
ID	Type	Discharge	Width	Depth	Slope	Length	Depr.	Capacity	By Pass
13-05	Curb	0.62	2.82	0.14	2.8	10.00	0.083	0.624	
14-08	Curb	1.41	2.97	0.21	2.8	16.00	0.083	1.406	

Closed System Analysis
Nodes 14-08 to 13-06
Martin Luther King Expressway

Link Summary											
	Upstream	Downstream								Upstream	Downstream
ID	ID	ID	Discharge	Length	Shape	Rise	Span	n	Slope	Invert	Invert
Pipe-33	13-05	13-06	2.00	54.61	Circular	1.25	n/a	0.013	1.783	13	12
Pipe-32	14-08	13-05	1.406	91.942	Circular	1.25	n/a	0.013	2.802	25.85	23.19

Closed System Analysis
Nodes 14-08 to 13-06
Martin Luther King Expressway

HGL Summary Summary												
	Upstream	Downstream	Upstream	Downstream					Uniform		Actual	
ID	ID	ID	HGL	HGL	Discharge	Capacity	Slope	Loss	Velocity	Depth	Velocity	Depth
Pipe-33	13-05	13-06	13.78	12.41	2.004	9.28	1.778	0.215	5.718	0.41	5.698	0.411
Pipe-32	14-08	13-05	26.505	23.495	1.406	11.632	2.809	0.052	6.087	0.304	6.07	0.305

Closed System Analysis
Nodes 20-13 to 20-15
Martin Luther King Expressway

Drainage Area Summary						
Identification	Runoff C	Drainage Area	Time of Conc.	Time Used	Intensity	Discharge
20-14	0.505	0.255	5	5	8.714	1.234
20-13	0.114	1.127	5	5	8.714	1.234

Closed System Analysis
Nodes 20-13 to 20-15
Martin Luther King Expressway

Inlet on Grade Summary									
ID	Type	Discharge	Width	Depth	Slope	Length	Depr.	Capacity	By Pass
20-13	Curb	1.234	4.416	0.221	0.869	20	0.083	1.234	

Closed System Analysis
Nodes 20-13 to 20-15
Martin Luther King Expressway

Sag Inlet Summary Summary															
			Discharge		Ponded Width			Slope							Ponded
ID	Type	Discharge	Left	Right	Left	Right	Left	Right	Length	Width	Depr.	Area	Perim.	Capacity	Depth
20-14	Curb	1.234	0.617	0.617	5.107	5.107	0.1	0.1	10	n/a	0.167	n/a	n/a	5.14	0.116

Closed System Analysis
Nodes 20-13 to 20-15
Martin Luther King Expressway

Link Summary											
	Upstream	Downstream								Upstream	Downstream
ID	ID	ID	Discharge	Length	Shape	Rise	Span	n	Slope	Invert	Invert
Pipe-35	20-14	20-15	3.654	24.077	Circular	1.25	n/a	0.013	20.866	11.26	6
Pipe-34	20-13	20-14	2.467	51.272	Circular	1.25	n/a	0.013	0.474	11.63	11.36

Closed System Analysis
Nodes 20-13 to 20-15
Martin Luther King Expressway

HGL Summary Summary												
	Upstream	Downstream	Upstream	Downstream					Uniform		Actual	
ID	ID	ID	HGL	HGL	Discharge	Capacity	Slope	Loss	Velocity	Depth	Velocity	Depth
Pipe-35	20-14	20-15	9.704	6.384	3.658	21.974	10.004	0.31	12.597	0.358	11.45	0.384
Pipe-34	20-13	20-14	12.349	11.99	2.467	4.913	0.509	0.068	3.82	0.651	3.983	0.63

Closed System Analysis
Nodes 30-03 to 30-06
Martin Luther King Expressway

Drainage Area Summary						
Identification	Runoff C	Drainage Area	Time of Conc.	Time Used	Intensity	Discharge
30-02	0.9	0.05	5	5	8.714	0.4
30-03	0.9	0.18	5	5	8.714	1.6

Closed System Analysis
Nodes 30-03 to 30-06
Martin Luther King Expressway

Inlet on Grade Summary									
ID	Type	Discharge	Width	Depth	Slope	Length	Depr.	Capacity	By Pass
30-02	Curb	0.5	7.34	0.07	2.468	10	0.08	0.5	0.1
30-03	Curb	1.6	5.29	0.15	3.283	14	0.08	1.5	0.1

Closed System Analysis
Nodes 30-03 to 30-06
Martin Luther King Expressway

Link Summary											
	Upstream	Downstream								Upstream	Downstream
ID	ID	ID	Discharge	Length	Shape	Rise	Span	n	Slope	Invert	Invert
Pipe-38	30-02	30-06	2.0	65.08	Circular	1.25	n/a	0.013	2.419	7.96	6.35
Pipe-37	30-03	30-02	1.6	80.01	Circular	1.25	n/a	0.013	2.867	10.34	7.96

Closed System Analysis
Nodes 30-03 to 30-06
Martin Luther King Expressway

HGL Summary Summary												
	Upstream	Downstream	Upstream	Downstream					Uniform		Actual	
ID	ID	ID	HGL	HGL	Discharge	Capacity	Slope	Loss	Velocity	Depth	Velocity	Depth
Pipe-38	30-02	30-06	8.62	6.73	2.0	10.8	2.409	0.098	6.37	0.38	6.35	0.38
Pipe-37	30-03	30-02	11.04	8.28	1.6	11.8	2.873	0.055	6.34	0.32	6.32	0.32

Closed System Analysis
Nodes 25-38 to 27-33
Martin Luther King Expressway

Drainage Area Summary						
Identification	Runoff C	Drainage Area	Time of Conc.	Time Used	Intensity	Discharge
25-38	0.8	0.84	5	5	8.714	6.51
27-33	0.9	0.45	5	5	8.714	3.85

Closed System Analysis
Nodes 25-38 to 27-33
Martin Luther King Expressway

Sag Inlet Summary Summary															
			Discharge		Ponded Width			Slope							Ponded
ID	Type	Discharge	Left	Right	Left	Right	Left	Right	Length	Width	Depr.	Area	Perim.	Capacity	Depth
25-38	Curb	6.5	3.3	3.3	11.78	11.78	0.1	0.1	8	n/a	0.17	n/a	n/a	9.4	0.39
27-33	Curb	3.9	1.9	1.9	10.96	10.96	0.1	0.1	8	n/a	0.17	n/a	n/a	9.4	0.28

Closed System Analysis
Nodes 25-38 to 27-33
Martin Luther King Expressway

Link Summary											
	Upstream	Downstream								Upstream	Downstream
ID	ID	ID	Discharge	Length	Shape	Rise	Span	n	Slope	Invert	Invert
Existing	27-34	Exist Outle	34.8	32.17	Circular	3.50	n/a	0.013	0.029	-0.78	-0.79
Pipe-42	25-38	27-34	31.5	217.44	Circular	3.50	n/a	0.013	0.027	-0.72	-0.78
Pipe-43	27-33	27-34	3.9	14.60	Circular	1.25	n/a	0.013	0.39	2.21	2.14
Pipe-40	25-36	25-38	20.0	152.55	Circular	3.50	n/a	0.013	0.571	0.29	-0.6
Pipe-41	25-37	25-38	5.0	128.11	Circular	2.00	n/a	0.013	0.046	-0.66	-0.72
Pipe-39	25-34	25-36	20.0	254.02	Circular	3.50	n/a	0.013	0.283	1.02	0.29

Closed System Analysis
Nodes 25-38 to 27-33
Martin Luther King Expressway

HGL Summary Summary												
	Upstream	Downstream	Upstream	Downstream					Uniform		Actual	
ID	ID	ID	HGL	HGL	Discharge	Capacity	Slope	Loss	Velocity	Depth	Velocity	Depth
Exist	27-34	Exist Outle	2.86	2.71	34.8	18.5	0.104	0.11	3.71	3.50	3.62	3.50
Pipe-42	25-38	27-34	3.11	2.86	31.5	17.8	0.085	0.03	3.36	3.50	3.28	3.50
Pipe-43	27-33	27-34	3.44	2.93	3.9	4.3	0.395	0.08	3.76	0.97	4.69	0.79
Pipe-40	25-36	25-38	3.21	3.11	20.0	81.8	0.57	0.06	6.66	1.23	2.08	3.50
Pipe-41	25-37	25-38	3.19	3.11	5.0	5.2	0.042	0.01	1.63	1.88	1.59	2.00
Pipe-39	25-34	25-36	3.32	3.21	20.0	57.6	0.278	0.04	5.13	1.49	2.33	2.92

Closed System Analysis
Nodes 30-12 to 30-09
Martin Luther King Expressway

Drainage Area Summary						
Identification	Runoff C	Drainage Area	Time of Conc.	Time Used	Intensity	Discharge
30-12	0.9	0.084	5	5	8.714	0.7
30-10	0.9	0.066	5	5	8.714	0.6

Closed System Analysis
Nodes 30-12 to 30-09
Martin Luther King Expressway

Inlet on Grade Summary									
ID	Type	Discharge	Width	Depth	Slope	Length	Depr.	Capacity	By Pass
30-10	Curb	0.6	4.93	0.17	0.367	20	0.083	0.6	
30-11	Curb	0.7	4.35	0.21	0.359	20	0.083	0.7	
30-09	Curb	1.0	6.46	0.14	1.055	10	0.083	0.9	0.0

Closed System Analysis
Nodes 30-12 to 30-09
Martin Luther King Expressway

Sag Inlet Summary Summary															
			Discharge		Ponded Width			Slope							Ponded
ID	Type	Discharge	Left	Right	Left	Right	Left	Right	Length	Width	Depr.	Area	Perim.	Capacity	Depth
25-38	Curb	6.5	3.3	3.3	11.78	11.78	0.1	0.1	8	n/a	0.17	n/a	n/a	9.4	0.39
27-33	Curb	3.9	1.9	1.9	10.96	10.96	0.1	0.1	8	n/a	0.17	n/a	n/a	9.4	0.28

Closed System Analysis
Nodes 30-12 to 30-09
Martin Luther King Expressway

Link Summary											
	Upstream	Downstream								Upstream	Downstream
ID	ID	ID	Discharge	Length	Shape	Rise	Span	n	Slope	Invert	Invert
Pipe-48	30-12	out	2.9	31.291	Circular	1.25	n/a	0.013	11.751	4.85	1.00
Pipe-46	30-10	30-12	1.5	34.417	Circular	1.25	n/a	0.013	0.187	4.92	4.85
Pipe-47	30-11	30-12	0.7	33.622	Circular	1.25	n/a	0.013	0.191	4.92	4.85
Pipe-45	30-09	30-10	1.0	67.007	Circular	1.25	n/a	0.013	0.714	5.42	4.92

Closed System Analysis
Nodes 30-12 to 30-09
Martin Luther King Expressway

HGL Summary Summary												
	Upstream	Downstream	Upstream	Downstream					Uniform		Actual	
ID	ID	ID	HGL	HGL	Discharge	Capacity	Slope	Loss	Velocity	Depth	Velocity	Depth
Pipe-48	30-12	out	6.09	6.00	2.9	23.8	11.75	0.02	12.48	0.31	2.36	1.25
Pipe-46	30-10	30-12	6.11	6.09	1.5	3.0	0.181	0.01	2.29	0.66	1.23	1.24
Pipe-47	30-11	30-12	6.09	6.09	0.7	3.0	0.196	0.00	1.95	0.43	0.60	1.24
Pipe-45	30-09	30-10	6.12	6.11	1.0	5.9	0.708	0.01	3.34	0.36	0.79	1.19

INLET																														SAG INLETS ONLY				
NUMBER	INLET TYPE	LENGTH (FT)	STATION	DRAINAGE AREA (AC)	C	CA	sum CA	I (IN/HR)	Q INCR (CFS)	Q CARRYOVER (CFS)	QT, GUTTER FLOW (CFS)	SHOULDER WIDTH (FT)	S GUTTER SLOPE (FT/FT)	S_x CROSS SLOPE (FT/FT)	T (SPREAD)	W (FT)	W/T	S_w (FT/FT)	S_w/S_x	Eo	a=12W(Sw-Sx)+Loc Dep	S'w=a/(12W)	Se(FT/FT)=Sx+S'wEo	COMPUTED LENGTH, L_T (FT)	L, SPECIFIED LENGTH (FT)	L/LT	E	Qi INTERCEPTED CFS	Qb CARRYOVER CFS	d (FT)	h (FT)	d/h	T SPREAD @ SAG (FT)	**Remarks**
			Ramp SE																															
21-17	Slotted Barrier Rail	2	Ramp SE 228+90.00 RT	0.293	0.9	0.264	0.264	7.67	2.02	0.00	2.02	14	0.0093	0.0500	5.24	0.67	0.13	0.08	1.66	0.30	0.35	0.04	0.06	12.90	2	0.16	0.26	0.53	1.49					
21-16	Slotted Barrier Rail	2	Ramp SE 228+78.00 RT	0.015	0.9	0.014	0.014	7.67	0.10	1.49	1.60	14	0.0102	0.0500	4.71	0.67	0.14	0.08	1.66	0.33	0.35	0.04	0.06	11.88	2	0.17	0.28	0.45	1.15					
21-15	Slotted Barrier Rail	2	Ramp SE 228+66.00 RT	0.015	0.9	0.014	0.014	7.67	0.10	1.15	1.25	14	0.0112	0.0500	4.23	0.67	0.16	0.08	1.66	0.37	0.35	0.04	0.07	10.87	2	0.18	0.31	0.38	0.87					
21-04	D1I3TY2	20	RAMP SE 226+39, 12.00 RT	0.26	0.9	0.234	0.234	7.67	1.79	0.87	2.66	12	0.0157	0.0500	5.26	2.33	0.44	0.08	1.66	0.79	1.01	0.04	0.08	14.90	20	1.34	1.00	2.66	0.00					
21-01	D1I3TY2	20	RAMP SE 223+75, 12.00 RT	0.31	0.9	0.279	0.279	7.67	2.14	0.00	2.14	12	0.0110	0.0500	5.19	2.33	0.45	0.08	1.66	0.80	1.01	0.04	0.08	12.20	20	1.64	1.00	2.14	0.00					
20-10	D1I3TY1	10	RAMP SE 222+54, 12.00 RT	0.14	0.9	0.126	0.126	7.67	0.97	0.00	0.97	12	0.0110	0.0500	3.85	2.33	0.61	0.08	1.66	0.92	1.01	0.04	0.08	8.46	10	1.18	1.00	0.97	0.00					
20-08	D1I3TY1	10	RAMP SE 221+00, 12.00 RT	0.19	0.9	0.171	0.171	7.67	1.31	0.00	1.31	12	0.0110	0.0500	4.32	2.33	0.54	0.08	1.66	0.87	1.01	0.04	0.08	9.72	10	1.03	1.00	1.31	0.00					
20-03	DI2C	10	RAMP SE 219+00, 12.00 RT	0.26	0.9	0.234	0.234	7.67	1.79	0.00	1.79	12	0.0066	0.0500	5.34	2.33	0.44	0.08	1.66	0.78	1.01	0.04	0.08	9.75	10	1.03	1.00	1.79	0.00					
20-01	DI2C	10	RAMP SE 217+35, 12.00 RT	0.26	0.9	0.234	0.234	7.67	1.80	0.00	1.80	12	0.0066	0.0500	5.34	2.33	0.44	0.08	1.66	0.78	1.01	0.04	0.08	9.76	10	1.02	1.00	1.80	0.00					
18-08	Trench Drain	108	RAMP SE 216+09, 12.00 RT	0.37	0.9	0.332	0.332	7.67	2.55	0.00	2.55	12	0.0066	0.0500	6.09	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A					
18-04	Trench Drain	68	RAMP SE 215+15, 12.00 RT	0.26	0.9	0.234	0.234	7.67	1.79	0.00	1.79	12	0.0020	0.0500	6.68	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A					
18-06	D1I3TY1	10	RAMP SE 213+50, 12.00 RT	0.20	0.9	0.180	0.180	7.67	1.38	0.00	1.38	12	0.0105	0.0500	4.44	2.33	0.52	0.08	1.66	0.86	1.01	0.04	0.08	9.83	10	1.02	1.00	1.38	0.00					
18-01	D1I3TY2	20	RAMP SE 212+25, 12.00 RT	0.29	0.9	0.261	0.261	7.67	2.00	0.00	2.00	12	0.0139	0.0500	4.84	2.33	0.48	0.08	1.66	0.83	1.01	0.04	0.08	12.62	20	1.59	1.00	2.00	0.00					
15-21	D1I3TY2	20	RAMP SE 210+40, 12.00 RT	0.44	0.9	0.396	0.396	7.67	3.04	0.00	3.04	12	0.0139	0.0500	5.66	2.33	0.41	0.08	1.66	0.76	1.01	0.04	0.08	15.32	20	1.31	1.00	3.04	0.00					
15-04	D1I3TY2	20	RAMP SE 207+75, 12.00 RT	0.45	0.9	0.401	0.401	7.67	3.08	0.00	3.08	12	0.0156	0.0578	5.08	2.33	0.46	0.08	1.44	0.81	0.79	0.03	0.08	15.56	20	1.29	1.00	3.08	0.00					
13-14	Slotted Barrier Rail	2	RAMP SE 202+24, RT	0.29	0.9	0.257	0.257	7.67	1.97	0.00	1.97	8	0.0025	0.0790	4.99	2.33	0.47	0.08	1.05	0.81	0.20	0.01	0.08	7.23	2	0.28	0.44	0.87	1.10					
13-15	Slotted Barrier Rail	2	RAMP SE 202+12, RT	0.01	0.9	0.009	0.009	7.67	0.07	1.10	1.17	8	0.0019	0.0790	4.32	2.33	0.54	0.08	1.05	0.87	0.20	0.01	0.09	5.33	2	0.37	0.57	0.67	0.50					
13-16	Slotted Barrier Rail	2	RAMP SE 202+00, RT	0.02	0.9	0.017	0.017	7.67	0.13	0.50	0.63	8	0.0010	0.0790	3.87	2.33	0.60	0.08	1.05	0.91	0.20	0.01	0.09	3.39	2	0.59	0.80	0.63	0.00	0.31	0.50	0.6	3.87	
13-17	Slotted Barrier Rail	2	RAMP SE 201+88, RT	0.01	0.9	0.009	0.009	7.67	0.07	1.88	1.95	8	0.0019	0.0790	5.23	2.33	0.45	0.08	1.05	0.79	0.20	0.01	0.08	6.63	2	0.30	0.48	0.93	1.02					
13-18	Slotted Barrier Rail	2	RAMP SE 201+76, RT	0.44	0.9	0.393	0.393	7.67	3.02	0.00	3.02	8	0.0025	0.0790	5.85	2.33	0.40	0.08	1.05	0.74	0.20	0.01	0.08	8.67	2	0.23	0.38	1.13	1.88					
			Martin Luther King Expressway																															
14-08	DI10H	20	MLK 1001+00.00, 1.00 RT	0.340	0.9	0.306	0.306	7.67	2.35	0.72	3.07	6.375	0.0280	0.0720	3.97	2.33	0.59	0.08	1.15	0.91	0.39	0.01	0.08	17.98	20	1.11	1.00	3.07	0.00					
13-05	DI10H	10	MLK 1000+05.00, 1.00 RT	0.072	0.9	0.065	0.065	7.67	0.50	0.00	0.50	6.375	0.0280	0.0480	2.58	2.33	0.90	0.08	1.73	1.00	1.06	0.04	0.09	8.29	10	1.21	1.00	0.50	0.00					
30-02	DI10H	10	MLK 1048+56.00, 1.00 RT	0.051	0.9	0.046	0.046	7.67	0.35	0.00	0.35	6.375	0.0247	0.0100	6.21	2.33	0.38	0.08	8.30	0.72	2.12	0.08	0.06	8.23	10	1.21	1.00	0.35	0.00					
30-03	DI10H	14	MLK 1047+73.00, 1.00 RT	0.183	0.9	0.164	0.164	7.67	1.26	0.00	1.26	6.375	0.0328	0.0291	4.86	2.33	0.48	0.08	2.86	0.82	1.59	0.06	0.08	13.84	14	1.01	1.00	1.26	0.00					
28-08	DI10H	20	MLK 1045+30.00, 1.00 RT	0.420	0.9	0.378	0.378	7.67	2.90	0.00	2.90	6.375	0.0400	0.0670	3.80	2.33	0.61	0.08	1.24	0.92	0.53	0.02	0.08	19.55	20	1.02	1.00	2.90	0.00					
28-09	DI10H	20	MLK 1045+30.00, 46.7 LT	0.464	0.9	0.418	0.418	7.67	3.20	0.00	3.20	12	0.0400	0.0670	3.94	2.33	0.59	0.08	1.24	0.91	0.53	0.02	0.08	20.42	20	0.98	1.00	3.20	0.00					
30-09	DI10H	10	MLK 1050+00.00, 1.00 LT	0.111	0.9	0.100	0.100	7.67	0.77	0.00	0.77	4.3	0.0105	0.0221	5.93	2.33	0.39	0.08	3.76	0.74	1.79	0.06	0.07	8.47	10	1.18	1.00	0.77	0.00					
30-10	DI10H	20	MLK 1050+70.00, 1.00 LT	0.066	0.9	0.059	0.059	7.67	0.46	0.00	0.46	3	0.0036	0.0354	4.44	2.33	0.52	0.08	2.34	0.86	1.41	0.05	0.08	4.54	20	4.40	1.00	0.46	0.00					
30-12	DI10H	20	MLK 1051+07.41, 1.00 LT	0.043	0.9	0.038	0.038	7.67	0.29	0.00	0.29	2	0.0010	0.0362	4.73	2.33	0.49	0.08	2.29	0.84	1.39	0.05	0.08	2.60	20	7.69	1.00	0.29	0.00	0.17	0.38	0.4	5.00	
30-12	DI10H	20	MLK 1051+07.41, 1.00 LT	0.042	0.9	0.038	0.038	7.67	0.29	0.00	0.29	2	0.0010	0.0362	4.69	2.33	0.50	0.08	2.29	0.84	1.39	0.05	0.08	2.57	20	7.78	1.00	0.29	0.00	0.17	0.38	0.4	5.00	
30-11	DI10H	20	MLK 1051+44.00, 1.00 LT	0.085	0.9	0.077	0.077	7.67	0.59	0.00	0.59	2	0.0036	0.0487	4.00	2.33	0.58	0.08	1.70	0.90	1.04	0.04	0.08	4.93	20	4.06	1.00	0.59	0.00					
30-19	DI10H	10	MLK 1052+40, 1.00 LT	0.112	0.9	0.101	0.101	7.67	0.77	0.00	0.77	2	0.0140	0.0580	3.08	2.33	0.76	0.08	1.43	0.98	0.78	0.03	0.09	8.14	10	1.23	1.00	0.77	0.00					
31-01	DI10H	10	MLK 1053+63, 1.00 LT	0.122	0.9	0.110	0.110	7.67	0.84	0.21	1.05	2	0.0085	0.0580	3.80	2.33	0.61	0.08	1.43	0.92	0.78	0.03	0.08	8.04	10	1.24	1.00	1.05	0.00					
50-17	EX-DI10H	4 EXIST	MLK 1054+90, 1.00 LT	0.122	0.9	0.109	0.109	7.67	0.84	0.14	0.98	5	0.0052	0.0500	4.45	2.33	0.52	0.08	1.66	0.86	1.01	0.04	0.08	6.89	4	0.58	0.79	0.77	0.21					Exist Grate eliminates bypass
50-22	EX-DI10H	4 EXIST	MLK 1056+16, 1.00 LT	0.120	0.9	0.108	0.108	7.67	0.83	0.00	0.83	5	0.0052	0.0500	4.18	2.33	0.56	0.08	1.66	0.89	1.01	0.04	0.08	6.38	4	0.63	0.83	0.69	0.14					Exist Grate eliminates bypass
30-18	DI10H	20	MLK 1050+69.00, 1.00 LT	0.210	0.9	0.189	0.189	7.67	1.45	0.00	1.45	2	0.0700	0.0500	3.17	2.33	0.74	0.08	1.66	0.97	1.01	0.04	0.08	17.23	20	1.16	1.00	1.45	0.00					
30-13	DI10H	8	MLK 1051+07.00, 1.00 LT	0.040	0.9	0.036	0.036	7.67	0.28	0.00	0.28	2	0.0600	0.0500	1.75	2.33	1.33	0.08	1.66	0.95	1.01	0.04	0.08	8.24	8	0.97	1.00	0.28	0.00					
			RAMP N																															
27-01	DI2B	14	RAMP N 614+79.00, 22 RT	0.070	0.9	0.063	0.063	7.67	0.48	0.78	1.26	10	0.0140	0.0500	4.06	2.33	0.57	0.08	1.66	0.90	1.01	0.04	0.08	10.21	14	1.37	1.00	1.26	0.00					
27-32	DI2B	20	RAMP N 614+00.00, 22 RT	0.489	0.9	0.440	0.440	7.67	3.38	4.65	8.03	10	0.0222	0.0500	7.46	2.33	0.31	0.08	1.66	0.63	1.01	0.04	0.07	27.51	20	0.73	0.90	7.25	0.78					
27-02	DI2B	8	RAMP N 614+88.00, 16.00 LT	0.065	0.9	0.059	0.059	7.67	0.45	0.00	0.45	6	0.0140	0.0500	2.76	2.33	0.84	0.08	1.66	0.99	1.01	0.04	0.09	6.46	8	1.24	1.00	0.45	0.00					
			RAMP S																															
27-09	DI10KTY3	12	RAMP S 502+00.00, 8.00' RT	0.049	0.9	0.044	0.044	7.67	0.34	0.60	0.94	8	0.0331	0.0500	3.10	2.33	0.75	0.08	1.66	0.98	1.01	0.04	0.09	11.48	12	1.05	1.00	0.94	0.00					
27-08	DI10KTY3	20	RAMP S 502+90.00, 8.00' RT	0.426	0.9	0.383	0.383	7.67	2.94	2.58	5.51	8	0.0465	0.0500	5.64	2.33	0.41	0.08	1.66	0.76	1.01	0.04	0.08	28.27	20	0.71	0.89	4.91	0.60					
27-03	DI2B		RAMP S 500+55.00,20.00' LT	0.300	0.9	0.270	0.270	7.67	2.07	0.00	2.07	6	0.0182	0.0500	4.66	2.33	0.50	0.08	1.66	0.84	1.01	0.04	0.08	13.82	14	1.01	1.00	2.07	0.00					
			Ramp WN																															
20-19	DI10KTY3	20	Ramp WN 407+60.00, 8.00 RT	0.492	0.9	0.443	0.443	7.67	3.40	1.94	5.34	8	0.0350	0.0700	4.76	2.33	0.49	0.08	1.19	0.83	0.45	0.02	0.08	24.48	20	0.82	0.95	5.09	0.25					
20-16	DI3B	10	Ramp WN 405+93.00, 8.00 RT	0.130	0.9	0.117	0.117	7.67	0.90	0.25	1.15	8	0.0091	0.0500	4.25	2.33	0.55	0.08	1.66	0.88	1.01	0.04	0.08	8.67	10	1.15	1.00	1.15	0.00					

INLET																														SAG INLETS ONLY				
NUMBER	INLET TYPE	LENGTH (FT)	STATION	DRAINAGE AREA (AC)	C	CA	sum CA	I (IN/HR)	Q INCR (CFS)	Q CARRYOVER (CFS)	QT, GUTTER FLOW (CFS)	SHOULDER WIDTH (FT)	S GUTTER SLOPE (FT/FT)	S_x CROSS SLOPE (FT/FT)	T (SPREAD)	W (FT)	W/T	S_W (FT/FT)	S_W/S_X	Eo	a=12W(Sw-Sx)+Loc Dep	S'w=a/(12W)	Se(FT/FT)=Sx+S'wEo	COMPUTED LENGTH, L_T (FT)	L, SPECIFIED LENGTH (FT)	L/LT	E	Qi INTERCEPTED CFS	Qb CARRYOVER CFS	d (FT)	h (FT)	d/h	T SPREAD @ SAG (FT)	Remarks
20-14	DI2C	6	Ramp WN 405+36.00, 8.00 RT	0.250	0.9	0.225	0.225	7.67	1.73	0.03	1.76	8	0.0010	0.0500	7.55	2.33	0.31	0.08	1.66	0.63	1.01	0.04	0.07	5.74	6	1.05	1.00	1.76	0.00	0.25	0.1	3.1	5.1	
20-13	DI10KTY3	20	Ramp WN 404+79.00, 8.00 RT	1.130	0.9	1.017	1.017	7.67	7.80	0.00	7.80	8	0.0087	0.0500	8.80	2.33	0.26	0.08	1.66	0.56	1.01	0.04	0.07	20.96	20	0.95	1.00	7.77	0.03					
			I-264																															
18-10	D1I3TY1	20	I-264 1441+00, 58.00 LT	0.282	0.9	0.254	0.254	7.67	1.95	0.00	1.95	12	0.0187	0.0200	8.04	2.33	0.29	0.08	4.15	0.60	1.84	0.07	0.06	16.25	20	1.23	1.00	1.95	0.00					
18-11	D1I3TY1	20	I-264 1444+50, 58.00 LT	0.139	0.9	0.125	0.125	7.67	0.96	0.00	0.96	12	0.0564	0.0200	5.01	2.33	0.46	0.08	4.15	0.81	1.84	0.07	0.07	14.81	20	1.35	1.00	0.96	0.00					
			RAMP SW																															
15-37	Slotted Barrier Rail	2	Ramp SW 107+20.00 RT	0.670	0.9	0.603	0.603	7.67	4.63	0.00	4.63	8	0.0276	0.0500	5.83	2.33	0.40	0.08	1.66	0.74	1.01	0.04	0.08	22.54	2	0.09	0.15	0.71	3.91					
15-36	Slotted Barrier Rail	2	Ramp SW 107+58.00 RT	0.030	0.9	0.027	0.027	7.67	0.21	3.91	4.12	8	0.0271	0.0500	5.60	2.33	0.42	0.08	1.66	0.76	1.01	0.04	0.08	21.25	2	0.09	0.16	0.67	3.45					
15-34	Slotted Barrier Rail	2	Ramp SW 107+97.00 RT	0.035	0.9	0.032	0.032	7.67	0.24	3.45	3.69	8	0.0197	0.0500	5.70	2.33	0.41	0.08	1.66	0.75	1.01	0.04	0.08	18.48	2	0.11	0.19	0.69	3.00					
15-33	Slotted Barrier Rail	2	Ramp SW 108+34.00 RT	0.044	0.9	0.040	0.040	7.67	0.30	3.00	3.31	8	0.0122	0.0500	5.99	2.33	0.39	0.08	1.66	0.73	1.01	0.04	0.08	15.38	2	0.13	0.22	0.73	2.57					
15-33	Slotted Barrier Rail	2	Ramp SW 108+64.00 RT	0.032	0.9	0.029	0.029	7.67	0.22	2.57	2.79	8	0.0075	0.0500	6.16	2.33	0.38	0.08	1.66	0.72	1.01	0.04	0.08	12.43	2	0.16	0.27	0.76	2.04					
15-32	Slotted Barrier Rail	2	Ramp SW 108+76.00 RT	0.013	0.9	0.012	0.012	7.67	0.09	2.04	2.13	8	0.0057	0.0500	5.86	2.33	0.40	0.08	1.66	0.74	1.01	0.04	0.08	10.12	2	0.20	0.33	0.70	1.43					
15-31	Slotted Barrier Rail	2	Ramp SW 108+88.00 RT	0.012	0.9	0.011	0.011	7.67	0.08	1.43	1.51	8	0.0047	0.0500	5.35	2.33	0.44	0.08	1.66	0.78	1.01	0.04	0.08	8.18	2	0.24	0.40	0.60	0.91					
15-30	Slotted Barrier Rail	2	Ramp SW 109+00.00 RT	0.013	0.9	0.012	0.012	7.67	0.09	0.91	1.00	12	0.0015	0.0500	5.67	2.33	0.41	0.08	1.66	0.76	1.01	0.04	0.08	4.93	2	0.41	0.61	0.61	0.39					
15-29	Slotted Barrier Rail	2	Ramp SW 109+12.00 RT	0.039	0.9	0.035	0.035	7.67	0.27	0.57	0.84	12.8	0.0010	0.0500	5.72	2.33	0.41	0.08	1.66	0.75	1.01	0.04	0.08	4.06	2	0.49	0.71	0.84	0.00	0.64	0.5	1.3	7.4	
15-28	Slotted Barrier Rail	2	Ramp SW 109+24.00 RT	0.017	0.9	0.015	0.015	7.67	0.12	0.51	0.63	13	0.0015	0.0500	4.75	2.33	0.49	0.08	1.66	0.83	1.01	0.04	0.08	3.96	2	0.51	0.72	0.45	0.18					
15-27	Slotted Barrier Rail	2	Ramp SW 109+36.00 RT	0.012	0.9	0.011	0.011	7.67	0.08	0.92	1.01	13	0.0037	0.0500	4.81	2.33	0.48	0.08	1.66	0.83	1.01	0.04	0.08	6.32	2	0.32	0.50	0.50	0.51					
15-26	Slotted Barrier Rail	2	Ramp SW 109+48.00 RT	0.013	0.9	0.012	0.012	7.67	0.09	1.41	1.49	13	0.0055	0.0500	5.16	2.33	0.45	0.08	1.66	0.80	1.01	0.04	0.08	8.52	2	0.23	0.38	0.57	0.92					
15-25	Slotted Barrier Rail	2	Ramp SW 109+60.00 RT	0.011	0.9	0.010	0.010	7.67	0.08	1.96	2.04	13	0.0074	0.0500	5.49	2.33	0.42	0.08	1.66	0.77	1.01	0.04	0.08	10.68	2	0.19	0.31	0.64	1.41					
15-24	Slotted Barrier Rail	2	Ramp SW 109+72.00 RT	0.010	0.9	0.009	0.009	7.67	0.07	2.44	2.51	14	0.0136	0.0500	5.29	0.67	0.13	0.08	1.66	0.30	0.35	0.04	0.06	15.85	2	0.13	0.22	0.54	1.96					
12-08	Slotted Barrier Rail	2	Ramp SW 109+84.00 RT	0.010	0.9	0.009	0.009	7.67	0.07	2.97	3.04	14	0.0136	0.0500	5.68	0.67	0.12	0.08	1.66	0.28	0.35	0.04	0.06	17.32	2	0.12	0.20	0.60	2.44					
12-07	Slotted Barrier Rail	2	Ramp SW 109+96.00 RT	0.012	0.9	0.011	0.011	7.67	0.08	3.55	3.63	14	0.0136	0.0500	6.08	0.67	0.11	0.08	1.66	0.27	0.35	0.04	0.06	18.80	2	0.11	0.18	0.67	2.97					
12-06	Slotted Barrier Rail	2	Ramp SW 110+08.00 RT	0.011	0.9	0.010	0.010	7.67	0.08	4.21	4.28	14	0.0136	0.0500	6.46	0.67	0.10	0.08	1.66	0.25	0.35	0.04	0.06	20.27	2	0.10	0.17	0.73	3.55					
12-05	Slotted Barrier Rail	2	Ramp SW 110+20.00 RT	0.011	0.9	0.010	0.010	7.67	0.08	4.93	5.00	14	0.0136	0.0500	6.85	0.67	0.10	0.08	1.66	0.24	0.35	0.04	0.06	21.76	2	0.09	0.16	0.80	4.21					
12-04	Slotted Barrier Rail	2	Ramp SW 110+32.00 RT	0.021	0.9	0.019	0.019	7.67	0.14	5.65	5.79	14	0.0136	0.0500	7.24	0.67	0.09	0.08	1.66	0.23	0.35	0.04	0.06	23.26	2	0.09	0.15	0.87	4.93					
12-02	Slotted Barrier Rail	2	Ramp SW 114+40.00 RT	0.951	0.9	0.856	0.856	7.67	6.56	0.00	6.56	14	0.0142	0.0500	7.53	0.67	0.09	0.08	1.66	0.22	0.35	0.04	0.06	24.92	2	0.08	0.14	0.92	5.65					
			RAMP EN																															
N/A	Spread Check		Ramp EN 347+00.00 RT	0.334	0.9	0.301	0.301	7.67	2.31	0.00	2.31	8	0.0508	0.0720	3.19																			
13-07	Slotted Barrier Rail	2	Ramp EN 349+35.00 RT	0.498	0.9	0.448	0.448	7.67	3.44	0.00	3.44	8	0.0045	0.0500	7.32	0.67	0.09	0.08	1.66	0.22	0.35	0.04	0.06	13.42	2	0.15	0.25	0.87	2.57					
13-08, 13-09 & 13-10	Slotted Barrier Rail	2	Ramp EN 349+57.00 RT (SAG)	0.027	0.9	0.024	0.024	7.67	0.18	0.00	0.18	8	0.0010	0.0500	3.23	0.67	0.21	0.08	1.66	0.46	0.35	0.04	0.07	2.27	2	0.88	0.98	0.18	0.00	0.40	0.50	0.80	3.6	
13-11	Slotted Barrier Rail	2	Ramp EN 349+80.00 RT	0.038	0.9	0.034	0.034	7.67	0.26	0.00	0.26	8	0.0044	0.0500	2.80	0.67	0.24	0.08	1.66	0.52	0.35	0.04	0.07	4.03	2	0.50	0.71	0.19	0.08					
12-12 & 13-13	Slotted Barrier Rail	2	Ramp EN 349+90.00 LT	0.097	0.9	0.087	0.087	7.67	0.67	0.00	0.67	6	0.0010	0.0500	5.26	0.67	0.13	0.08	1.66	0.30	0.35	0.04	0.06	4.16	2	0.48	0.69	0.46	0.21					
			High Street																															
27-06	DI3B	20	17+34.00, 30' RT	1.866	0.8	1.536	1.536	4	6.14	0.00	6.14	8	0.0075	0.0240	13.09	0.67	0.05	0.08	3.46	0.13	0.56	0.07	0.03	28.49	20	0.70	0.89	5.45	0.69					Exceeds Allowable Spread Width
27-04	DI3B	10	17+92.00, 30' LT	1.372	0.8	1.098	1.098	4	4.39	0.00	4.39	8	0.0080	0.0240	11.40	0.67	0.06	0.08	3.46	0.15	0.56	0.07	0.03	24.66	20	0.81	0.95	4.17	0.22	0.19	0.50	0.38	11.57	Exceeds Allowable Spread Width

INLET																													
NUMBER	INLET TYPE	SIZE (INxIN)	STATION	DRAINAGE AREA (AC)	C	CA	SUM CA	I (IN/HR)	Q INCR (CFS)	Q CARRYOVER (CFS)	Q_T GUTTER FLOW (CFS)	SHOULDER WIDTH (FT)	S GUTTER SLOPE (FT/FT)	S_X CROSS SLOPE (FT/FT)	T (SPREAD)	CLOGGING FACTOR (%)	Q10 DEPTH OF FLOW (FT)	Q10 AREA SF	Q10 VELOCITY FT/SEC	GUTTER DEPRESSION @ INLET (IN)	Ljump	Intercept factor	Frontal Flow Eo	Q channel	Q weir	Q orifice	Q intercepted	E_U (#10)	Q by-pass	REMARKS
			Martin Luther King Expressway																										
15-07	Scupper	8"X54"	MLK 1010+37, 33.00 LT	0.31	0.90	0.28	0.28	7.67	2.1	0.0	2.1	8.0	0.005	0.054	5.7	0	0.31	0.89	2.39	0.50	0.71	0.05	0.95	1.88	1.19	0.95	0.95	0.4	1.17	
15-15	Scupper	8"X54"	MLK 1009+16, 31.40 LT	0.09	0.90	0.08	0.08	7.67	0.6	1.2	1.8	8.0	0.015	0.023	7.5	0	0.17	0.64	2.82	0.50	0.65	-0.03	1.00	1.50	0.49	0.71	0.49	1.9	1.32	
15-16	Scupper	8"X54"	MLK 1008+46,31.40 LT	0.05	0.90	0.05	0.05	7.67	0.4	1.3	1.7	8.0	0.021	0.020	7.5	0	0.15	0.56	2.99	0.50	0.66	-0.02	1.00	1.40	0.40	0.66	0.40	2.4	1.29	
15-19	Scupper	8"X54"	MLK 1007+29,31.40 LT	0.09	0.90	0.08	0.08	7.67	0.6	1.3	1.9	8.0	0.028	0.020	7.4	0	0.15	0.55	3.46	0.50	0.75	0.11	0.89	1.41	0.40	0.66	0.40	1.9	1.50	
15-20	Scupper	8"X54"	MLK 1006+84,31.40 LT	0.03	0.90	0.03	0.03	7.67	0.2	1.5	1.7	8.0	0.028	0.020	7.2	0	0.14	0.51	3.38	0.50	0.73	0.08	0.92	1.36	0.38	0.65	0.38	3.1	1.36	
14-04	Scupper	8"X54"	MLK 1006+29,31.40 LT	0.04	0.90	0.04	0.04	7.67	0.3	1.4	1.6	8.0	0.028	0.020	7.0	0	0.14	0.49	3.33	0.50	0.71	0.06	0.94	1.33	0.36	0.64	0.36	2.7	1.28	
14-05	Scupper	8"X54"	MLK 1005+75,31.40 LT	0.04	0.90	0.04	0.04	7.67	0.3	1.3	1.6	8.0	0.028	0.020	6.9	0	0.14	0.48	3.30	0.50	0.70	0.04	0.96	1.31	0.35	0.64	0.35	2.5	1.22	
14-06	Scupper	8"X54"	MLK 1005+22,31.40 LT	0.04	0.90	0.04	0.04	7.67	0.3	1.2	1.5	8.0	0.028	0.020	6.8	0	0.14	0.46	3.26	0.50	0.69	0.02	0.98	1.28	0.35	0.63	0.35	2.4	1.15	
16-01	Scupper	8"X54"	MLK 1013+95, 31.40 RT	0.11	0.90	0.10	0.10	7.67	0.8	0.0	0.8	8.0	0.005	0.020	7.4	0	0.15	0.54	1.45	0.50	0.31	-1.13	1.00	0.65	0.39	0.66	0.39	0.5	0.39	
16-02	Scupper	8"X54"	MLK 1013+85, 31.40 RT	0.01	0.90	0.01	0.01	7.67	0.1	0.4	0.4	8.0	0.005	0.017	6.7	0	0.11	0.37	1.20	0.50	0.24	-1.85	1.00	0.39	0.26	0.57	0.26	5.0	0.19	
16-03	Scupper	8"X54"	MLK 1013+75, 31.40 RT	0.01	0.90	0.01	0.01	7.67	0.1	0.2	0.2	8.0	0.005	0.013	6.2	0	0.08	0.25	0.98	0.50	0.17	-2.89	1.00	0.23	0.16	0.49	0.16	3.1	0.09	
16-04	Scupper	8"X54"	MLK 1013+64, 31.40 RT	0.01	0.90	0.01	0.01	7.67	0.1	0.1	0.1	8.0	0.005	0.010	6.1	0	0.06	0.18	0.80	0.50	0.13	-4.22	1.00	0.14	0.10	0.42	0.10	1.7	0.04	
16-05	Scupper	8"X54"	MLK 1012+17, 1.00 RT	0.11	0.90	0.10	0.10	7.67	0.8	0.0	0.8	6.4	0.005	0.038	5.1	0	0.19	0.48	1.73	0.50	0.42	-0.61	1.00	0.80	0.57	0.75	0.57	0.8	0.26	
15-06	Scupper	8"X54"	MLK 1010+54, 1.00 RT	0.13	0.90	0.11	0.11	7.67	0.9	0.3	1.1	6.4	0.005	0.051	4.7	0	0.24	0.56	2.01	0.50	0.53	-0.26	1.00	1.10	0.80	0.84	0.80	1.2	0.33	
15-09	Scupper	8"X54"	MLK 1009+50, 1.00 RT	0.08	0.90	0.07	0.07	7.67	0.5	0.3	0.9	6.4	0.013	0.027	5.3	0	0.14	0.38	2.26	0.50	0.49	-0.38	1.00	0.82	0.37	0.65	0.37	1.0	0.48	
15-10	Scupper	8"X54"	MLK 1009+00, 1.00 RT	0.04	0.90	0.03	0.03	7.67	0.3	0.5	0.7	6.4	0.015	0.020	5.9	0	0.12	0.34	2.16	0.50	0.43	-0.56	1.00	0.69	0.28	0.59	0.28	1.5	0.47	
15-11	Scupper	8"X54"	MLK 1008+50, 1.00 RT	0.04	0.90	0.04	0.04	7.67	0.3	0.5	0.7	6.4	0.021	0.020	5.5	0	0.11	0.30	2.46	0.50	0.48	-0.40	1.00	0.70	0.25	0.57	0.25	1.4	0.49	
15-12	Scupper	8"X54"	MLK 1008+00, 1.00 RT	0.04	0.90	0.03	0.03	7.67	0.3	0.5	0.8	6.4	0.024	0.020	5.4	0	0.11	0.29	2.59	0.50	0.50	-0.34	1.00	0.72	0.24	0.56	0.24	1.4	0.51	
15-13	Scupper	8"X54"	MLK 1007+50, 1.00 RT	0.04	0.90	0.04	0.04	7.67	0.3	0.5	0.8	6.4	0.028	0.020	5.3	0	0.11	0.28	2.76	0.50	0.53	-0.26	1.00	0.75	0.24	0.56	0.24	1.4	0.54	
15-14	Scupper	8"X54"	MLK 1007+00, 1.00 RT	0.04	0.90	0.03	0.03	7.67	0.3	0.5	0.8	6.4	0.028	0.020	5.4	0	0.11	0.29	2.79	0.50	0.54	-0.25	1.00	0.77	0.24	0.56	0.24	1.5	0.56	
14-01	Scupper	8"X54"	MLK 1006+50, 1.00 RT	0.04	0.90	0.03	0.03	7.67	0.3	0.6	0.8	6.4	0.028	0.020	5.4	0	0.11	0.29	2.80	0.50	0.54	-0.23	1.00	0.78	0.25	0.56	0.25	1.5	0.58	
14-02	Scupper	8"X54"	MLK 1006+00, 1.00 RT	0.04	0.90	0.03	0.03	7.67	0.3	0.6	0.8	6.4	0.028	0.020	5.5	0	0.11	0.30	2.82	0.50	0.55	-0.22	1.00	0.80	0.25	0.57	0.25	1.5	0.59	
14-03	Scupper	8"X54"	MLK 1005+22, 1.00 RT	0.06	0.90	0.05	0.05	7.67	0.4	0.6	1.0	6.4	0.028	0.020	5.8	0	0.12	0.34	2.94	0.50	0.58	-0.15	1.00	0.93	0.27	0.58	0.27	1.3	0.72	
24-01	Scupper	8"X54"	MLK 1026+41, 64' RT	0.86	0.90	0.78	0.78	7.67	6.0	0.0	6.0	12.0	0.010	0.041	8.8	0	0.36	1.59	3.75	0.50	1.19	0.44	0.56	2.53	1.51	1.03	1.03	0.2	4.93	
27-31	Scupper	8"X54"	MLK SB 1038+00.00, 43.38' LT	0.24	0.90	0.22	0.22	7.67	1.7	0.0	1.7	12.0	0.016	0.020	7.8	0	0.16	0.62	2.71	0.50	0.60	-0.11	1.00	1.35	0.43	0.68	0.43	0.3	1.24	
27-18	Scupper	8"X54"	MLK SB 1036+75.00, 43.38' LT	0.13	0.90	0.12	0.12	7.67	0.9	0.0	0.9	12.0	0.003	0.020	8.5	0	0.17	0.73	1.24	0.50	0.29	-1.34	1.00	0.70	0.49	0.71	0.49	0.5	0.42	
27-15, 16, 17	Scupper	8"X54"	Sag (Multiple Inlets)	0.08	0.90	0.07	0.07	7.67	0.5	0.8	1.3	12.0	0.001	0.020	12.0	0	0.24	1.44	0.90	0.50	0.24	-1.81	1.00	N/A	0.82	0.84	0.82	N/A	N/A	Per Chapter 22 of Bridge Drainage Manual 2 inlets are required.
27-14	Scupper	8"X54"	MLK SB 1036+15.00, 43.38' LT	0.12	0.90	0.10	0.10	7.67	0.8	0.0	0.8	12.0	0.003	0.020	8.1	0	0.16	0.66	1.20	0.50	0.27	-1.47	1.00	0.63	0.45	0.69	0.45	0.6	0.34	
25-06	Scupper	8"X54"	MLK SB 1035+00.00, 43.38' LT	0.40	0.90	0.36	0.36	7.67	2.8	0.1	2.8	12.0	0.015	0.020	9.7	0	0.19	0.94	3.02	0.50	0.73	0.09	0.91	1.83	0.59	0.76	0.59	0.3	2.25	
24-18	Scupper	8"X54"	MLK SB 1028+15.00, 1.00' LT	0.01	0.90	0.01	0.01	7.67	0.1	0.1	0.1	6.0	0.015	0.010	4.9	0	0.05	0.11	1.16	0.50	0.17	-2.89	1.00	0.13	0.07	0.37	0.07	1.2	0.06	
24-17	Scupper	8"X54"	MLK SB 1028+10.00, 1.00' LT	0.01	0.90	0.01	0.01	7.67	0.1	0.1	0.1	6.0	0.015	0.010	4.8	0	0.05	0.12	1.22	0.50	0.18	-2.63	1.00	0.14	0.08	0.38	0.08	1.3	0.07	
24-16	Scupper	8"X54"	MLK SB 1028+05.00, 1.00' LT	0.01	0.90	0.01	0.01	7.67	0.1	0.1	0.2	6.0	0.015	0.011	4.8	0	0.05	0.13	1.30	0.50	0.20	-2.33	1.00	0.17	0.09	0.40	0.09	1.5	0.08	
24-15	Scupper	8"X54"	MLK SB 1028+00.00, 1.00' LT	0.01	0.90	0.01	0.01	7.67	0.1	0.2	0.2	6.0	0.015	0.012	5.0	0	0.06	0.15	1.40	0.50	0.22	-2.00	1.00	0.21	0.10	0.42	0.10	1.8	0.11	
24-14	Scupper	8"X54"	MLK SB 1027+95.00, 1.00' LT	0.02	0.90	0.01	0.01	7.67	0.1	0.2	0.3	6.0	0.015	0.013	5.3	0	0.07	0.18	1.52	0.50	0.25	-1.66	1.00	0.26	0.12	0.45	0.12	1.3	0.15	
24-13	Scupper	8"X54"	MLK SB 1027+85.00, 1.00' LT	0.02	0.90	0.01	0.01	7.67	0.1	0.2	0.3	6.0	0.015	0.015	5.1	0	0.08	0.19	1.61	0.50	0.28	-1.43	1.00	0.30	0.14	0.47	0.14	1.5	0.16	
24-12	Scupper	8"X54"	MLK SB 1027+75.00, 1.00' LT	0.02	0.90	0.02	0.02	7.67	0.1	0.2	0.4	6.0	0.015	0.017	5.0	0	0.08	0.21	1.73	0.50	0.31	-1.19	1.00	0.35	0.17	0.49	0.17	1.7	0.20	
24-11	Scupper	8"X54"	MLK SB 1027+65.00, 1.00' LT	0.02	0.90	0.02	0.02	7.67	0.1	0.3	0.4	6.0	0.015	0.019	5.1	0	0.09	0.24	1.86	0.50	0.34	-0.95	1.00	0.43	0.20	0.52	0.20	2.0	0.25	
24-10	Scupper	8"X54"	MLK SB 1027+55.00, 1.00' LT	0.02	0.90	0.02	0.02	7.67	0.1	0.4	0.6	6.0	0.015	0.020	5.2	0	0.11	0.28	2.03	0.50	0.39	-0.72	1.00	0.54	0.24	0.56	0.24	2.5	0.33	
24-09	Scupper	8"X54"	MLK SB 1027+45.00, 1.00' LT	0.02	0.90	0.02	0.02	7.67	0.1	0.6	0.7	6.0	0.015	0.022	5.5	0	0.12	0.33	2.21	0.50	0.45	-0.50	1.00	0.70	0.29	0.60	0.29	2.7	0.45	
24-08	Scupper	8"X54"	MLK SB 1027+35.00, 1.00' LT	0.02	0.90	0.02	0.02	7.67	0.2	0.8	1.0	6.0	0.015	0.024	5.8	0	0.14	0.40	2.41	0.50	0.51	-0.31	1.00	0.89	0.35	0.63	0.35	3.0	0.60	
24-07	Scupper	8"X54"	MLK SB 1027+20.00, 1.00' LT	0.03	0.90	0.03	0.03	7.67	0.2	1.0	1.2	6.0	0.015	0.027	5.9	0	0.16	0.47	2.63	0.50	0.59	-0.14	1.00	1.14	0.43	0.68	0.43	3.1	0.79	
24-06	Scupper	8"X54"	MLK SB 1027+00.00, 1.00' LT	0.04	0.90	0.04	0.04	7.67	0.3	1.3	1.5	6.0	0.015	0.030	6.0	0	0.18	0.54	2.88	0.50	0.68	0.01	0.99	1.41	0.53	0.73	0.53	3.2	1.02	
24-05	Scupper	8"X54"	MLK SB 1026+75.00, 1.00' LT	0.09	0.90	0.08	0.08	7.67	0.6	1.3	1.9	6.0	0.015	0.035	5.9	0	0.21	0.61	3.15	0.50	0.78	0.14	0.86	1.52	0.64	0.78	0.64	2.4	1.27	
24-04	Scupper	8"X54"	MLK SB 1026+10.00, 1.00' LT	0.09	0.90	0.08	0.08	7.67	0.6	1.5	2.1	6.0	0.015	0.046	5.1	0	0.24	0.61	3.47	0.50	0.92	0.27	0.73	1.48	0.80	0.83	0.80	2.9	1.31	
24-03	Scupper	8"X54"	MLK SB 1025+50.00, 1.00' LT	0.18	0.90	0.16	0.16	7.67	1.2	1.2	2.4	6.0	0.015	0.053	4.9	0	0.26	0.65	3.70	0.50	1.02	0.34	0.66	1.52	0.92	0.87	0.87	1.9	1.52	
23-15	Scupper	8"X54"	MLK SB 1024+14.00, 1.00' LT	0.18	0.90	0.16	0.16	7.67	1.2	0.8	2.0	6.0	0.015	0.053	4.6	0	0.24	0.57	3.54	0.50	0.95	0.29	0.71	1.38	0.83	0.85	0.83	1.5	1.17	
23-14	Scupper	8"X54"	MLK SB 1022+80.00, 1.00' LT	0.19	0.90	0.17	0.17	7.67	1.3	0.2	1.6	6.0	0.012	0.053	4.4	0	0.23	0.52	3.01	0.50	0.79	0.15	0.85	1.28	0.78	0.83	0.78	0.8	0.78	
23-13	Scupper	8"X54"	MLK SB 1021+35.00, 1.00' LT	0.06	0.90	0.05	0.05	7.67	0.4	0.2	0.6	6.0	0.005	0.025	5.8	0	0.15	0.42	1.44	0.50	0.31	-1.14	1.00	0.57	0.38	0.65	0.38	1.1	0.23	
23-12	Scupper	8"X54"	MLK SB 1020+90.00, 1.00' LT	0.06	0.90	0.05	0.05	7.67	0.4	0.2	0.6	6.0	0.005	0.025	5.7	0	0.14	0.41	1.42	0.50	0.30	-1.20	1.00	0.54	0.37	0.65	0.37	1.1	0.21	
23-11	Scupper	8"X54"	MLK SB 1020+50.00, 1.00' LT	0.06	0.90	0.05	0.05	7.67	0.4	0.1	0.5	6.0	0.005	0.025	5.6	0	0.14	0.38	1.39	0.50	0.29	-1.28	1.00	0.50	0.35	0.63	0.35	0.9	0.18	

NUMBER	INLET TYPE	SIZE (INxIN)	STATION	DRAINAGE AREA (AC)	C	CA	SUM CA	I (IN/HR)	Q INCR (CFS)	Q CARRYOVER (CFS)	Q_T GUTTER FLOW (CFS	SHOULDER WIDTH (FT	S GUTTER SLOPE (FT/F	S_X CROSS SLOPE (FT/F	T (SPREAD)	CLOGGING FACTOR (%	Q10 DEPTH OF FLOW (F	Q10 AREA SF	Q10 VELOCITY FT/SEC	GUTTER DEPRESSION (INLET (IN)	Ljump	Intercept factor	Frontal Flow Eo	Q channel	Q weir	Q orifice	Q intercepted	E_0 (#10)	Q by-pass	REMARKS
23-10	Scupper	8"X54"	MLK 1020+0.000, 55.40' LT	0.01	0.90	0.01	0.01	7.67	0.1	0.1	0.2	12.0	0.005	0.004	11.2	0	0.05	0.27	0.69	0.50	0.10	-5.52	1.00	0.12	0.07	0.38	0.07	0.9	0.11	
23-09	Scupper	8"X54"	MLK 1019+90.00, 55.40' LT	0.01	0.90	0.01	0.01	7.67	0.1	0.1	0.2	12.0	0.005	0.006	9.0	0	0.05	0.25	0.75	0.50	0.12	-4.76	1.00	0.14	0.09	0.40	0.09	1.1	0.10	
23-08	Scupper	8"X54"	MLK 1019+80.00, 55.40' LT	0.01	0.90	0.01	0.01	7.67	0.1	0.1	0.2	12.0	0.005	0.008	7.9	0	0.06	0.25	0.82	0.50	0.13	-4.07	1.00	0.16	0.11	0.43	0.11	1.3	0.09	
23-07	Scupper	8"X54"	MLK 1019+70.00, 55.40' LT	0.01	0.90	0.01	0.01	7.67	0.1	0.2	0.2	12.0	0.005	0.010	7.5	0	0.07	0.27	0.91	0.50	0.15	-3.35	1.00	0.21	0.14	0.46	0.14	1.7	0.11	
23-06	Scupper	8"X54"	MLK 1019+60.00, 55.40' LT	0.01	0.90	0.01	0.01	7.67	0.1	0.3	0.3	12.0	0.005	0.012	7.3	0	0.09	0.33	1.05	0.50	0.19	-2.50	1.00	0.29	0.19	0.52	0.19	2.4	0.16	
23-05	Scupper	8"X54"	MLK 1019+50.00, 55.40' LT	0.01	0.90	0.01	0.01	7.67	0.1	0.4	0.5	12.0	0.005	0.013	8.0	0	0.11	0.43	1.17	0.50	0.23	-1.97	1.00	0.40	0.24	0.56	0.24	3.1	0.26	
23-04	Scupper	8"X54"	MLK 1019+40.00, 55.40' LT	0.01	0.90	0.01	0.01	7.67	0.1	0.6	0.7	12.0	0.005	0.015	8.5	0	0.13	0.55	1.33	0.50	0.27	-1.44	1.00	0.56	0.32	0.62	0.32	4.2	0.41	
23-03	Scupper	8"X54"	MLK 1019+30.00, 55.40' LT	0.01	0.90	0.01	0.01	7.67	0.1	1.0	1.1	12.0	0.005	0.017	9.2	0	0.15	0.71	1.50	0.50	0.33	-1.02	1.00	0.78	0.42	0.67	0.42	5.7	0.64	
23-02	Scupper	8"X54"	MLK 1019+20.00, 55.40' LT	0.03	0.90	0.02	0.02	7.67	0.2	1.3	1.5	12.0	0.005	0.019	9.9	0	0.18	0.90	1.68	0.50	0.40	-0.68	1.00	1.06	0.54	0.73	0.54	4.4	0.97	
23-01	Scupper	8"X54"	MLK 1019+00.00, 55.40' LT	0.13	0.90	0.12	0.12	7.67	0.9	1.1	2.0	12.0	0.005	0.020	10.4	0	0.21	1.09	1.84	0.50	0.46	-0.46	1.00	1.34	0.66	0.78	0.66	1.8	1.34	
17-01	Scupper	8"X54"	MLK 1017+97.00, 55.40' LT	0.13	0.90	0.12	0.12	7.67	0.9	0.8	1.7	12.0	0.005	0.020	9.8	0	0.20	0.96	1.76	0.50	0.43	-0.57	1.00	1.18	0.60	0.76	0.60	1.5	1.08	
17-08	Scupper	8"X54"	MLK 1017+00.00, 55.38' LT	0.19	0.90	0.17	0.17	7.67	1.3	0.0	1.3	12.0	0.005	0.020	8.9	0	0.18	0.80	1.65	0.50	0.39	-0.73	1.00	0.98	0.52	0.72	0.52	0.4	0.79	
17-05	Scupper	8"X54"	MLK 1017+30.00, 31.00' RT	0.14	0.90	0.12	0.12	7.67	0.9	0.0	0.9	8.0	0.005	0.020	7.8	0	0.16	0.61	1.52	0.50	0.34	-0.98	1.00	0.75	0.43	0.68	0.43	0.5	0.50	
17-04	Scupper	8"X54"	MLK 1018+04.00, 31.00' RT	0.06	0.90	0.05	0.05	7.67	0.4	0.5	0.9	8.0	0.005	0.020	7.7	0	0.15	0.60	1.50	0.50	0.33	-1.02	1.00	0.73	0.42	0.67	0.42	1.6	0.47	
17-03	Scupper	8"X54"	MLK 1018+14.00, 31.00' RT	0.01	0.90	0.01	0.01	7.67	0.1	0.5	0.5	8.0	0.005	0.020	6.3	0	0.13	0.40	1.32	0.50	0.27	-1.48	1.00	0.48	0.31	0.61	0.31	6.1	0.22	
17-02	Scupper	8"X54"	MLK 1018+24.00, 31.00' RT	0.01	0.90	0.01	0.01	7.67	0.1	0.2	0.3	8.0	0.005	0.020	4.9	0	0.10	0.24	1.11	0.50	0.21	-2.20	1.00	0.26	0.21	0.54	0.21	4.1	0.06	
27-25	Scupper	8"X54"	MLK 1039+25.00, 1.00' RT	0.11	0.90	0.10	0.10	7.67	0.7	0.0	0.7	6.4	0.013	0.020	6.0	0	0.12	0.36	2.06	0.50	0.41	-0.61	1.00	0.69	0.29	0.59	0.29	0.4	0.46	
27-24	Scupper	8"X54"	MLK 1039+05.00, 1.00' RT	0.02	0.90	0.02	0.02	7.67	0.1	0.5	0.6	6.4	0.016	0.020	5.3	0	0.11	0.28	2.08	0.50	0.40	-0.68	1.00	0.55	0.24	0.55	0.24	2.5	0.34	
27-23	Scupper	8"X54"	MLK 1038+85.00, 1.00' RT	0.02	0.90	0.02	0.02	7.67	0.1	0.3	0.5	6.4	0.016	0.020	4.8	0	0.10	0.23	1.96	0.50	0.36	-0.84	1.00	0.44	0.21	0.53	0.21	2.1	0.25	
27-22	Scupper	8"X54"	MLK 1038+75.00, 1.00' RT	0.01	0.90	0.01	0.01	7.67	0.1	0.3	0.3	6.4	0.016	0.018	4.6	0	0.08	0.19	1.75	0.50	0.31	-1.18	1.00	0.32	0.16	0.49	0.16	2.3	0.17	
27-21	Scupper	8"X54"	MLK 1038+62.00, 1.00' RT	0.01	0.90	0.01	0.01	7.67	0.1	0.2	0.2	6.4	0.016	0.015	4.6	0	0.07	0.16	1.55	0.50	0.26	-1.61	1.00	0.24	0.12	0.45	0.12	1.8	0.12	
27-20	Scupper	8"X54"	MLK 1038+50.00, 1.00' RT	0.01	0.90	0.01	0.01	7.67	0.1	0.1	0.2	6.4	0.016	0.012	4.8	0	0.06	0.14	1.41	0.50	0.22	-2.00	1.00	0.19	0.10	0.41	0.10	1.4	0.10	
27-19	Scupper	8"X54"	MLK 1038+41.00, 1.00' RT	0.01	0.90	0.01	0.01	7.67	0.1	0.1	0.2	6.4	0.016	0.010	5.1	0	0.05	0.13	1.28	0.50	0.20	-2.42	1.00	0.16	0.08	0.39	0.08	1.3	0.09	
27-30	Scupper	8"X54"	MLK 1036+75, 43.38' RT	0.18	0.90	0.17	0.17	7.67	1.3	0.1	1.4	12.0	0.003	0.020	9.9	0	0.20	0.99	1.38	0.50	0.34	-0.99	1.00	0.94	0.62	0.76	0.62	0.6	0.74	
27-27, 28, 29	Scupper	8"X54"	Sag (Multiple Inlets)	0.08	0.90	0.07	0.07	7.67	0.5	2.1	2.7	12.0	0.001	0.020	12.0	0	0.24	1.44	1.86	0.50	0.49	-0.36	1.00	N/A	0.82	0.84	0.82	N/A	N/A	Per Chapter 22 of Bridge Drainage Manual 3 inlets are required.
27-26	Scupper	8"X54"	MLK 1036+15, 43.38' RT	0.12	0.90	0.11	0.11	7.67	0.8	1.4	2.2	12.0	0.003	0.020	11.9	0	0.24	1.42	1.55	0.50	0.41	-0.63	1.00	1.34	0.81	0.84	0.81	2.4	1.40	
25-05	Scupper	8"X54"	MLK 1035+00, 43.38' RT	0.27	0.90	0.24	0.24	7.67	1.9	0.0	1.9	12.0	0.015	0.020	8.3	0	0.17	0.68	2.72	0.50	0.62	-0.09	1.00	1.45	0.46	0.70	0.46	0.3	1.39	
			RAMP N																											
24-02	Scupper	8"X54"	Ramp N 604+50.00, 24.00 RT	0.31	0.90	0.28	0.28	7.67	2.1	0.0	2.1	12.0	0.016	0.020	8.7	0	0.17	0.75	2.86	0.50	0.66	-0.01	1.00	1.63	0.50	0.71	0.50	0.2	1.65	
25-01	Scupper	8"X54"	Ramp N 606+27.00, 24.00 RT	0.33	0.90	0.29	0.29	7.67	2.2	1.6	3.9	12.0	0.016	0.020	10.8	0	0.22	1.17	3.32	0.50	0.84	0.21	0.79	2.02	0.70	0.80	0.70	2.0	3.20	
25-02	Scupper	8"X54"	Ramp N 607+47.00, 24.00 RT	0.24	0.90	0.22	0.22	7.67	1.7	3.2	4.9	12.0	0.016	0.020	11.8	0	0.24	1.39	3.51	0.50	0.93	0.28	0.72	2.17	0.80	0.83	0.80	3.7	4.09	
25-03	Scupper	8"X54"	Ramp N 608+14.00, 24.00 RT	0.14	0.90	0.12	0.12	7.67	1.0	4.1	5.0	12.0	0.018	0.020	11.6	0	0.23	1.34	3.77	0.50	0.98	0.32	0.68	2.14	0.77	0.83	0.77	4.9	4.27	
25-04	Scupper	8"X54"	Ramp N 608+90.00, 24.00 RT	0.15	0.90	0.14	0.14	7.67	1.0	4.3	5.3	12.0	0.033	0.020	10.6	0	0.21	1.11	4.78	0.50	1.20	0.44	0.56	1035.64	0.67	0.79	0.67	4.9	4.65	
			RAMP S																											
25-07	Scupper	8"X54"	Ramp S 508+50, 8.00' RT	0.46	0.90	0.42	0.42	7.67	3.2	0.1	3.3	8.0	0.012	0.020	10.6	0	0.21	1.13	2.88	0.50	0.73	0.08	0.92	1.99	0.68	0.79	0.68	0.3	2.58	
			RAMP NW																											
17-06	Scupper	8"X54"	Ramp NW 415+00.00, 8' RT	0.42	0.90	0.38	0.38	7.67	2.9	0.1	3.0	8.0	0.009	0.035	7.7	0	0.27	1.03	2.88	0.50	0.80	0.16	0.84	2.03	0.96	0.89	0.89	0.4	2.07	
17-07	Scupper	8"X54"	Ramp NW 414+00.00, 8' RT	0.08	0.90	0.07	0.07	7.67	0.5	2.1	2.6	8.0	0.009	0.020	10.4	0	0.21	1.07	2.42	0.50	0.60	-0.11	1.00	1.75	0.65	0.78	0.65	3.3	1.94	

9.8. APPENDIX H – Existing Culvert Analysis

CULVERT SUMMARY SHEET
EXISTING 30"/PROPOSED 30" CULVERT UNDER I-264 (Potters Field)

I. DRAINAGE AREAS PRE/POST

PRE-DEVELOPMENT

Area	Soil Type	Type	Area (acres)	CN	CR	CRA	Isite
30" Culvert	D	Pavement	4.68	98	0.9	4.21	
		Industrial	1.75	93	0.85	1.49	
		Grass	28.34	80	0.3	8.50	
		Residential	1.40	92	0.45	0.63	
			36.15	**83**	**CR**	**0.41**	**30**

Weighted "C" (existing) 0.41
% impervious (existing) 30

Time of Concentration (Tc) = 40 minutes (See TOC calculation sheet)

POST-DEVELOPMENT

Area	Soil Type	Type	Area (acres)	CN	CR	CRA	Isite
30" Culvert	D	Pavement	7.31	98	0.9	6.58	
		Industrial	1.82	93	0.85	1.55	
		Grass	24.25	80	0.3	7.28	
		Residential	1.40	92	0.45	0.63	
		Water	1.37	100	1	1.37	
			36.15	**86**	**CR**	**0.48**	**40**

Weighted "C" (proposed) 0.48
% impervious (proposed) 40

Time of Concentration (Tc) = 53 minutes (See TOC calculation sheet)

PARSONS BRINCKERHOFF COMPUTATION SHEET

Page 1 of 1

Made by Melissa Pritchard

Checked by Lewis White

PB PROJECT NO. 173513A

Subject Elixabeth River Tunnels Project

Norfolk/Portsmouth, VA

Post Development Tc Calculations

TIME OF CONCENTRATION (Tc) OR TRAVEL TIME (Tt)

Drainage Basin: 30" CULVERT UNDER 264 (Potters Field)

SHEET FLOW

1	Surface Description			Grass
2	Mannings Roughness Coefficient, n			0.06
3	Flow Length, L (total L , 300')		ft	219
4	Two-year, 24hr. Rainfall, P_2		in	3.61
5	Land Slope, s		ft/ft	0.010
6	$Tt = 0.007(nL)^{0.8}/P_2^{0.5}s^{0.4}$)	Compute Tt	hr	0.18

SHALLOW CONCENTRATED FLOW

7	Surface Description (paved or unpaved)			Grass
8	Flow Length, L		ft	100
9	Watercourse Slope, s		ft/ft	0.001
10	Average Velocity, V		ft/s	1.15
11	Tt=L/(3600*V)	Compute Tt	hr	0.024

CHANNEL FLOW

				Ditch	Pipes
12	Cross Sectional Area		ft^2	10.00	5.1
13	Wetted Permiter, Pw		ft	13.30	7.85
14	Hydraulic Radius, R_h=a/Pw		ft	0.75	0.65
15	Channel Slope, s		ft/ft	0.003	0.001
16	Mannings Open Channel Flow Coefficient, n			0.060	0.060
17	$V=(1.486/n)*R_h^{2/3}*s^{1/2}$		ft/s	1.06	0.59
18	Flow Length, L		ft	779	52
19	Tt=L/(3600*V)		hr	0.20	0.02
20	**Watershed or subarea Tc or Tt (add Tt in steps 6, 11, and 19)**		hr	0.43	
			min	26.07	

	27	Minutes
POND 14	26	Minutes
TOTAL	53	Minutes

PROJECT	**Elizabeth River Tunnels Project**		
ROAD	**I-264**	**COUNTY**	Portsmouth (city)
CULVERT	Existing 30" RCP Culvert		VA

SHEET OF

UNITS **ENGLISH**

CULVERT DESIGN FORM LD-269

DESIGNER: MJP DATE: 11/8/2012

REVIEWER: LRW DATE: 11/13/2012

HYDROLOGICAL DATA

Method: RATIONAL

Drainage Area: 36.15 Acres

Time of Concentration 53 Minutes

DESIGN FLOWS

R.I. (years)	FLOW (cfs)	
50	Design	73.34
2	Check	31.77
50	Max.	73.34

CULVERT DESCRIPTION:

TYPE: **Single/Multiple Conforming**

Roadway Width 162 ft ROADWAY ELEVATION 15.50 ft Road Length 1000 Suface Type PAVED

Freeboard= -0.50 ft

Shldr. Elev. Rt.= 15.00 ft

Shldr. Elev. Lt. = 15.00 ft

ELHWd= 15.50 ft

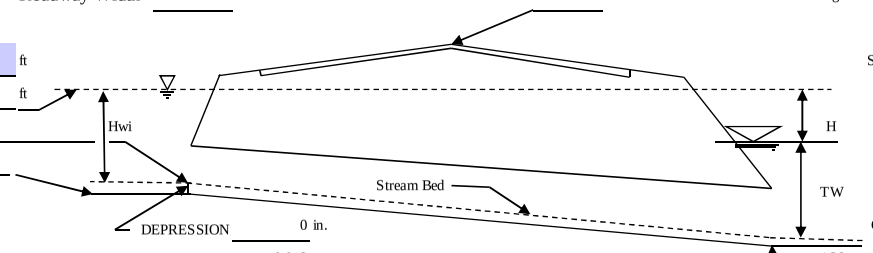
Elsf= 0.00 ft

Eli= 4.59 ft

L= 201.29 ft

S= 0.11%

SKEW= 0 O



TW DEPTH 2.32 ft

TW VEL. 4.53 ft

Channel Inv.El.. 4.36 ft

Inlet Edge Description:

Square edge w/headwall

Single / Multiple Conforming / Broken Back Culverts

MATERIAL	SHAPE	Size (in)	N	Mannings n	TOTAL FLOW Q cfs	FLOW PER BARREL Q/N cfs	INLET CONTROL HWi/D	HWi ft	FALL ft	ELHWi ft	OUTLET CONTROL TW ft	dc ft	(dc+D)/2 ft	ho ft	ke	H ft	ELHWo ft	CONTROL HEADWATER ELEV ft	OUTLET VEL fps	MINIMUM SHOULDER ELEV. ft	COMMENTS
Concrete	Circular	30	1	0.01	73.34	73.3	4.36	10.56	0.00	15.15	2.32	2.45	2.48	2.48	0.50	11.60	18.43	15.50	14.91		
					31.77	31.8	1.66	3.34	0.00	7.93	1.70	1.92	2.21	2.21	0.50	2.18	8.75	8.75	6.47		
					73.34	73.3	4.36	10.56	0.00	15.15	2.32	2.45	2.48	2.48	0.50	11.60	18.43	15.50	14.91		

Broken Back Culvert

LENGTH	Elev.	SKEW O

TAILWATER DATA:

Channel Shape	Triangular	
Bottom Width, ft	0.00	"n" = 0.035
Side Slope Lt: (H:1V)	3.00	
Side Slope Rt: (H:1V)	3.00	
Channel Slope, ft/ft	0.0100	

Distance					
Elevation					
"n" =					

TAILWATER RESULTS:

	Discharge cfs	Elevation ft	Flow depth ft	Velocity fps	Shear force PSF
Design	6.68	2.32	4.53	1.45	
Check	6.06	1.70	3.68	1.06	
Max.	6.68	2.32	4.53	1.45	

ROADWAY DATA:

Roadway Width, ft	162
Surface Type	PAVED
Top of Road Elevation, ft	15.5
Length of Road, ft	1000

ROADWAY OVERTOPPING:

	Discharge cfs	Overtopping Discharge cfs	Overtopping Elevation ft
Design	0		15.50
Check	0		0.00
Max.	0		15.50

TECHNICAL FOOTNOTES:

(1) USE Q/NB FOR BOX CULVERTS

(2) HWi/D = HW/D OR HWi/D FROM DESIGN CHARTS

(3) FALL = HWI - (ELHWd - ELsf); FALL IS ZERO FOR CULVERTS ON GRADE

(4) ELhi = HWi + ELi (INVERT OF INLET CONTROL SECTION)

(5) TW BASED ON DOWNSTREAM CONTROL OR FLOW DEPTH IN CHANNEL

(6) ho = TW or (dc + D/2) (WHICHEVER IS GREATER)

(7) $H = [1 + ke + (29n^2L)/R^{1.33}]v^2/2g$

SUBSCRIPT DEFINITIONS:

HWd	DESIGN HEADWATER	i	INLET
HWi	HW IN INLET CONTROL	o	OUTLET
HWo	HW IN OUTLET CONTROL	sf	Streambed @ culvert face

COMMENTS / DISCUSSION:

CULVERT BARREL SELECTED

SIZE: n:

SHAPE: MATERIAL:

ENTRANCE:

PROJECT	**Elizabeth River Tunnels Project**		
ROAD	**I-264**	**COUNTY**	Portsmouth (city)
CULVERT	Proposed Double 30" RCP Culvert		VA

SHEET 1 OF 1

UNITS **ENGLISH**

CULVERT DESIGN FORM LD-269

DESIGNER: MJP DATE: 11/8/2012

REVIEWER: LRW DATE: 11/13/2012

HYDROLOGICAL DATA

Method: RATIONAL

Drainage Area: 36.15 Acres

Time of Concentration 53 Minutes

DESIGN FLOWS

R.I. (years)	FLOW (cfs)	
50	Design	73.34
2	Check	31.77
50	Max.	73.34

CULVERT DESCRIPTION:

TYPE: **Single/Multiple Conforming**

Roadway Width 162 ft ROADWAY ELEVATION 15.50 ft Road Length 1000 Suface Type PAVED

Freeboard= 5.42 ft

Shldr. Elev. Rt.= 15.00 ft

Shldr. Elev. Lt. = 15.00 ft

ELHWd= 9.58 ft

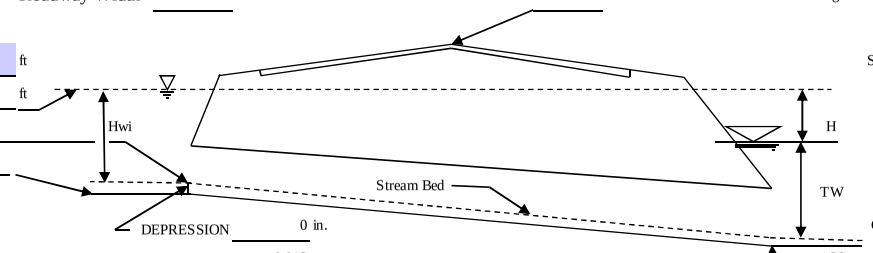
Elsf= 0.00 ft

Eli= 4.59 ft

L= 201.29 ft

S= 0.11%

SKEW= 0 O



TW DEPTH 2.32 ft

TW VEL. 4.53 ft

Channel Inv.El.. 4.36 ft

Inlet Edge Description:

Square edge w/headwall

Single / Multiple Conforming / Broken Back Culverts

MATERIAL	SHAPE	Size (in)	N	Mannings n	TOTAL FLOW Q cfs	FLOW PER BARREL Q/N cfs	INLET CONTROL HWi/D	HWi ft	FALL ft	ELHWi ft	OUTLET CONTROL TW ft	dc ft	(dc+D)/2 ft	ho ft	ke	H ft	ELHWo ft	CONTROL HEADWATER ELEV ft	OUTLET VEL fps	MINIMUM SHOULDER ELEV. ft	COMMENTS
Concrete	Circular	30	2	0.01	73.34	36.7	2.00	3.89	0.00	8.48	2.32	2.05	2.28	2.32	0.50	2.90	9.58	9.58	7.47		
					31.77	15.9	0.90	1.64	0.00	6.23	1.70	1.35	1.93	1.92	0.50	0.54	6.83	6.83	3.50		
					73.34	36.7	2.00	3.89	0.00	8.48	2.32	2.05	2.28	2.32	0.50	2.90	9.58	9.58	7.47		

Broken Back Culvert

LENGTH	Elev.	SKEW O

TAILWATER DATA:

Channel Shape	Triangular	
Bottom Width, ft	0.00	"n" = 0.035
Side Slope Lt: (H:1V)	3.00	
Side Slope Rt: (H:1V)	3.00	
Channel Slope, ft/ft	0.0100	

Distance					
Elevation					
"n" =					

TAILWATER RESULTS:

	Discharge cfs	Elevation ft	Flow depth ft	Velocity fps	Shear force PSF
Design	6.68	2.32	4.53	1.45	
Check	6.06	1.70	3.68	1.06	
Max.	6.68	2.32	4.53	1.45	

ROADWAY DATA:

Roadway Width, ft	162
Surface Type	PAVED
Top of Road Elevation, ft	15.5
Length of Road, ft	1000

ROADWAY OVERTOPPING:

	Discharge cfs	Overtopping Discharge cfs	Overtopping Elevation ft
Design	0		0.00
Check	0		0.00
Max.	0		0.00

TECHNICAL FOOTNOTES:

(1) USE Q/NB FOR BOX CULVERTS

(2) HWi/D = HW/D OR HWi/D FROM DESIGN CHARTS

(3) FALL = HWI - (ELHWd - ELsf); FALL IS ZERO FOR CULVERTS ON GRADE

(4) ELhi = HWi + ELi (INVERT OF INLET CONTROL SECTION)

(5) TW BASED ON DOWNSTREAM CONTROL OR FLOW DEPTH IN CHANNEL

(6) ho = TW or (dc + D/2) (WHICHEVER IS GREATER)

(7) $H = [1 + ke + (29n^2L)/R^{1.33}]v^2/2g$

SUBSCRIPT DEFINITIONS:

HWd	DESIGN HEADWATER	i	INLET
HWi	HW IN INLET CONTROL	o	OUTLET
HWo	HW IN OUTLET CONTROL	sf	Streambed @ culvert face

COMMENTS / DISCUSSION:

CULVERT BARREL SELECTED

SIZE: n:

SHAPE: MATERIAL:

ENTRANCE:

9.9. APPENDIX I – Existing CSX Outfall Analysis

CULVERT SUMMARY SHEET
36" CULVERT UNDER I-264

I. DRAINAGE AREAS PRE/POST

PRE-DEVELOPMENT

Area	Soil Type	Type	Area (acres)	CN	CR	CRA	Isite
36" Culvert	D	Pavement	23.26	98	0.9	20.93	
		Industrial	0.12	93	0.85	0.10	
		Grass	1.52	80	0.3	0.46	
		Residential	149.24	92	0.45	67.16	
			174.14	**93**	**CR**	**0.51**	**44**

Weighted "C" (existing) 0.51
% impervious (existing) 44

Time of Concentration (Tc) = 108 minutes (See TOC calculation sheet)

POST-DEVELOPMENT

Area	Soil Type	Type	Area (acres)	CN	CR	CRA	Isite
36" Culvert	D	Pavement	23.00	98	0.9	20.70	
		Industrial	0.12	93	0.85	0.10	
		Grass	1.78	80	0.3	0.53	
		Residential	149.24	92	0.45	67.16	
		Water	0.00	100	1	0.00	
			174.14	**93**	**CR**	**0.51**	**44**

Weighted "C" (proposed) 0.51
% impervious (proposed) 44

Time of Concentration (Tc) = 108 minutes (See TOC calculation sheet)

PARSONS BRINCKERHOFF
COMPUTATION SHEET

Page 1 of 1
Made by Melissa Pritchard
Date
Checked by Lewis White
Date
PB PROJECT NO. 173513A

Subject **Downtown Tunnel-Midtown Tunnel-MLK Expressway Extension**
Norfolk/Portsmouth, VA
Post Development Tc Calculations

TIME OF CONCENTRATION (Tc) OR TRAVEL TIME (Tt)

Drainage Basin: 36" Culvert (Storm Sewer) under 264

SHEET FLOW

1	Surface Description			Grass
2	Mannings Roughness Coefficient, n			0.05
3	Flow Length, L (total L , 300')		ft	300
4	Two-year, 24hr. Rainfall, P_2		in	3.61
5	Land Slope, s		ft/ft	0.002
6	$Tt = 0.007(nL)^{0.8}/P_2^{0.5}s^{0.4})$	Compute Tt	hr	0.35

SHALLOW CONCENTRATED FLOW

7	Surface Description (paved or unpaved)			Paved
8	Flow Length, L		ft	595
9	Watercourse Slope, s		ft/ft	0.002
10	Average Velocity, V		ft/s	1.00
11	Tt=L/(3600*V)	Compute Tt	hr	0.165

CHANNEL FLOW

			Ditch	Pipes
12	Cross Sectional Area	ft^2	10.00	5.1
13	Wetted Permiter, Pw	ft	13.30	7.85
14	Hydraulic Radius, R_h=a/Pw	ft	0.75	0.65
15	Channel Slope, s	ft/ft	0.005	0.003
16	Mannings Open Channel Flow Coefficient, n		0.060	0.060
17	$V=(1.486/n)*R_h^{2/3}*s^{1/2}$	ft/s	1.45	1.02
18	Flow Length, L	ft	400	4348
19	Tt=L/(3600*V)	hr	0.08	1.19
20	**Watershed or subarea Tc or Tt (add Tt in steps 6, 11, and 19)**	hr	1.78	
		min	107.03	

Use 108 Minutes

STORMWATER MANAGEMENT POND SUMMARY SHEET
EXISTING DITCH SOUTH OF CSX PROPERTY

I. DRAINAGE AREAS

POST-DEVELOPMENT

Area	Soil Type	Type	Area (acres)	CN	CR	CRA	Isite
EX CSX DIT(	D	Pavement	0.06	98	0.9	0.05	
		Industrial	3.82	93	0.85	3.25	
		Grass	5.71	80	0.3	1.71	
		Residential	0.81	92	0.45	0.36	
		Water	0.00	100	1	0.00	
			10.40	**86**	**CR**	**0.52**	**45**

Weighted "C" (proposed) 0.52
% impervious (proposed) 45

Time of Concentration (Tc) = 48 minutes (See TOC calculation sheet)

PARSONS BRINCKERHOFF
COMPUTATION SHEET

Page 1 of 1
Made by Melissa Pritchard
Date
Checked by Lewis White
Date
PB PROJECT NO. 173513A

Subject **Elizabeth River Tunnels Project**
Norfolk/Portsmouth, VA
Post Development Tc Calculations

TIME OF CONCENTRATION (Tc) OR TRAVEL TIME (Tt)

Drainage Basin: Existing CSX Ditch

SHEET FLOW

1	Surface Description			Grass
2	Mannings Roughness Coefficient, n			0.05
3	Flow Length, L (total L , 300')		ft	300
4	Two-year, 24hr. Rainfall, P_2		in	3.61
5	Land Slope, s		ft/ft	0.003
6	$Tt = 0.007(nL)^{0.8}/P_2^{0.5}s^{0.4})$	Compute Tt	hr	0.33

SHALLOW CONCENTRATED FLOW

7	Surface Description (paved or unpaved)			Gravel
8	Flow Length, L		ft	145
9	Watercourse Slope, s		ft/ft	0.002
10	Average Velocity, V		ft/s	1.00
11	Tt=L/(3600*V)	Compute Tt	hr	0.040

CHANNEL FLOW

			Ditch	Pipes
12	Cross Sectional Area	ft^2	2.00	5.1
13	Wetted Permiter, Pw	ft	5.20	7.85
14	Hydraulic Radius, R_h=a/Pw	ft	0.45	0.65
15	Channel Slope, s	ft/ft	0.003	0.003
16	Mannings Open Channel Flow Coefficient, n		0.045	0.060
17	$V=(1.486/n)*R_h^{2/3}*s^{1/2}$	ft/s	1.01	1.02
18	Flow Length, L	ft	1512	0
19	Tt=L/(3600*V)	hr	0.42	0.00
20	**Watershed or subarea Tc or Tt (add Tt in steps 6, 11, and 19)**	hr	0.78	
		min	47.07	

Use 48 Minutes

LD-229
STORM SEWER DESIGN COMPUTATIONS

STORM FREQUENCY **10**

PROJECT: Elizabeth River Tunnels Project
LOCATION: MLK-Pond 20 Outfall
COUNTY: Portsmouth (City)

Designed by: MJP
Checked by: LRW

UNITS **ENGLISH**

PIPE NO.	FROM POINT REFERENCE (1)	FROM POINT STA.	TO POINT REFERENCE (2)	TO POINT STA.	DRAIN. AREA "A" Acre (3)	RUNOFF COEFF. "C" (4)	CA INCRE-MENT (5)	CA ACCUM-ULATED (6)	TOTAL INLET TIME Minutes (7)	RAIN FALL In/Hr (8)	RUNOFF Lateral CFS	RUNOFF Total Q CFS (9)	INVERT ELEVATIONS UPPER END (10)	INVERT ELEVATIONS LOWER END (11)	LENGTH of Pipe Ft. (12)	SLOPE Ft./Ft. (13)	SIZE (Dia. Or Span/Rise) In. (14)	SHAPE	Number of Pipes	Capacity CFS (15)	Friction Slope Ft./Ft.	NORMAL FLOW Depth of Flow, dn Ft.	NORMAL FLOW Area of Flow, An SqFt	NORMAL FLOW Hm Ft.	NORMAL FLOW Vn Ft/Sec (16)	NORMAL FLOW En Ft.	FLOW TIME Sec. (17)	REMARKS (18)
2018/2109	20-18		21-09		8.50	0.61	5.18	5.18	30.00	3.70	0.00	19.13	4.50	2.55	131.00	0.01489	45 X 29	Elliptical	1	80.84	0.00080	0.81	2.08	0.55	9.32	2.16	14.05	
2109/2113	21-09		21-13		174.14	0.47	80.94	86.11	150.00	1.35	0.00	116.08	2.55	2.26	7.51	0.03862	60 X 36	Box	1	322.77	0.00500	1.19	5.96	0.81	19.48	7.08	0.39	
2113/Ex	21-13		26-1		0.00		0.00	86.11	150.01	0.85	0.00	67.28	2.26	1.49	444.00	0.00173	60 X 36	Box	1	68.31	0.00200	3.00	15.00	0.94	4.89	3.37	90.88	