Hampton Roads PDC
Resilient Stormwater Design Standards
DRAFT – November 17, 2021

Contact:
Benjamin J. McFarlane
Senior Regional Planner
Hampton Roads Planning District Commission
bmcfarlane@hrpdcva.gov

Table of Contents

List of Figures

List of Tables

Design Tidal Elevations - Methodology

The goal of this effort is to develop design tidal elevations for communities in Hampton Roads that incorporate future sea level rise. These design tidal elevations are intended for use as input tailwater conditions for stormwater management calculations using design storms based on specific recurrence intervals for individual tidal subwatersheds (12-digit Hydrologic Unit Code) throughout Hampton Roads.[1] This analysis builds on two previous studies conducted by the U.S. Army Corps of Engineers: the FEMA Region III Storm Surge Study[2] and the North Atlantic Coast Comprehensive Study.[3] The FEMA Region III Storm Surge Study (FEMA Study) was used in the development of the most recent flood insurance studies and corresponding flood insurance rate maps for coastal Hampton Roads localities. As part of the FEMA Study, the Advanced Circulation Model for Oceanic, Coastal and Estuarine Waters (ADCIRC) model was used to develop a two-dimensional, unstructured grid of storm surge stillwater (not including waves) elevations for six return periods: 10-year, 25-year, 50-year, 100-year, 500-year, and 1000-year (Figure 1). This dataset provided the baseline storm surge values used for the analysis.

[1] Subwatersheds are 12-digit Hydrologic Unit Code (HUC-12) watersheds.
[2] Hanson, Jeffrey L., Michael F. Forte, Brian Blanton, Mark Gravens, and Peter Vickery. FEMA Region III Storm Surge Study Coastal Storm Surge Analysis: Storm Surge Results. US. Army Corps of Engineers Engineer Research and Development Center. November 2013.
[3] U.S. Army Corps of Engineers. North Atlantic Coast Comprehensive Study: Resilient Adaptation to Increasing Risk. U.S. Army Corps of Engineers. January 2015. https://www.nad.usace.army.mil/CompStudy/

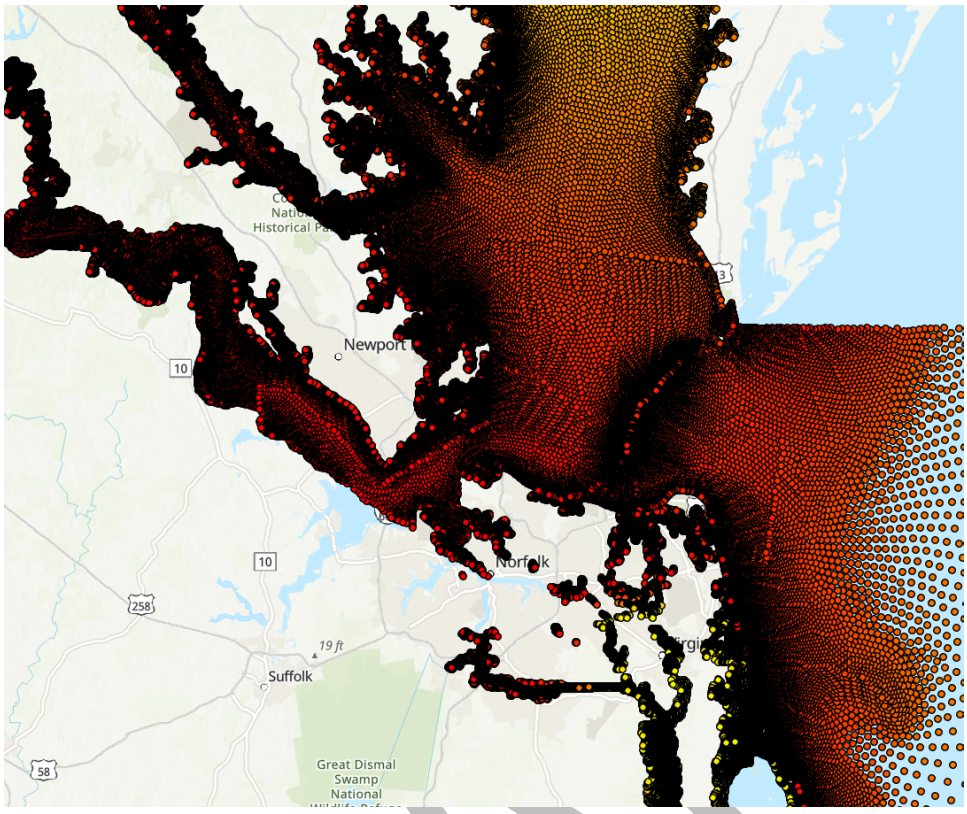


Figure 1: ADCIRC Grid from FEMA Region III Storm Surge Study

HRPDC staff developed representative tidal elevations for individual watersheds by calculating the 95th-percentile for each HUC-12 geography. A log-linear analysis was run on these values to calculated values for the 1-year, 2-year, 3-year, and 5-year return periods for each watershed. Figure 2 shows an example of this approach. Blue dots represent the 95th-percentile values calculated from the original dataset. Orange dots represent the values calculated using the log-linear analysis.

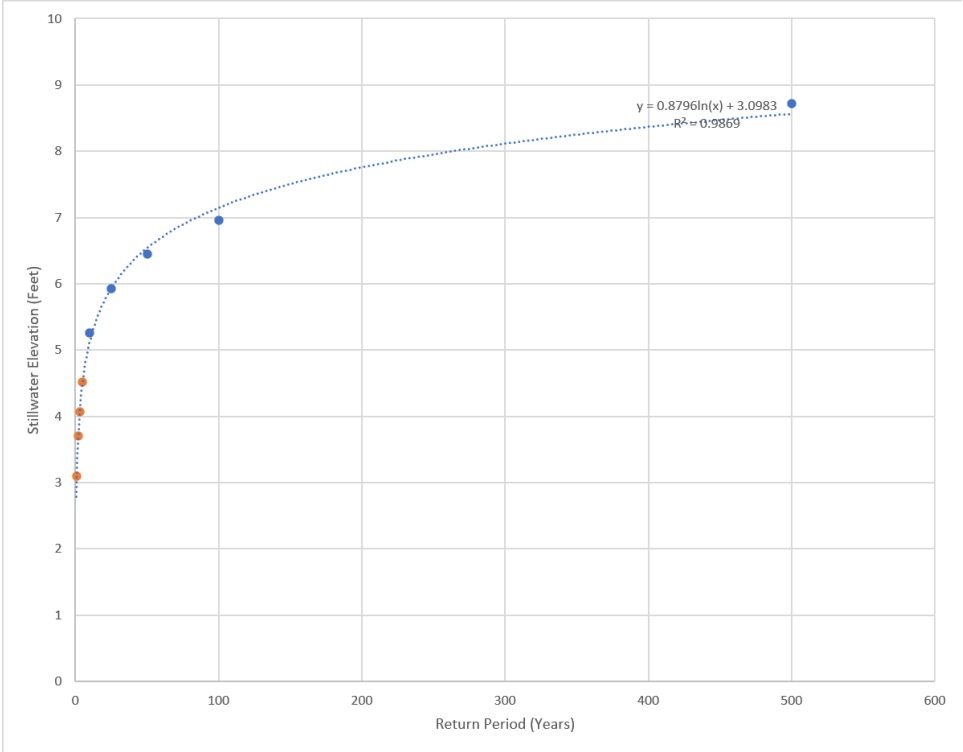


Figure 2: Chart Showing Results of Log-Linear Analysis of 1-, 2-, 3-, and 5-Year Return Periods

Separately, estimates of non-linear effects of sea level rise were calculated by comparing storm surge elevations from the North Atlantic Coast Comprehensive Study (NACCS) with and without sea level rise (Figure 3). This approach described here for calculating non-linearity factors is based on the methodology used by the City of Virginia Beach and Dewberry to develop design tidal elevations for the city's Public Works Design Standards Manual (June 2020). As part of the NACCS, the US. Army Corps of Engineers modeled storm surge under present conditions and with one meter of sea level rise. The results showed that storm surge in many areas was higher than simply adding one meter to the baseline value. This difference can be accounted for by using non-linearity factors, which are multipliers used to convert baseline values to future values.

For this analysis, non-linearity factors for all HUC-10 and HUC-12 watersheds in Hampton Roads were calculated by averaging factors for each NACCS grid point and return period (10-year, 20-year, 50-year, 100-year, and 500-year). HUC-10 watershed values were calculated for use when the NACCS did not include points within a given HUC-10. Design tidal elevations with sea level rise were then calculated by adding the three regional sea level rise scenarios (1.5', 3', and 4.5') to the calculated elevations. The non-linearity factors derived from the NACCS were then used to develop design tidal elevations for the 3' and 4.5' sea level rise scenarios. The Virginia Beach study found that non-linearity did not occur with 1.5' of sea level rise, so for that scenario the amount of sea level rise was just added to the baseline tidal elevation. Non-linearity factors for all watersheds included in this analysis are listed in Table 1.

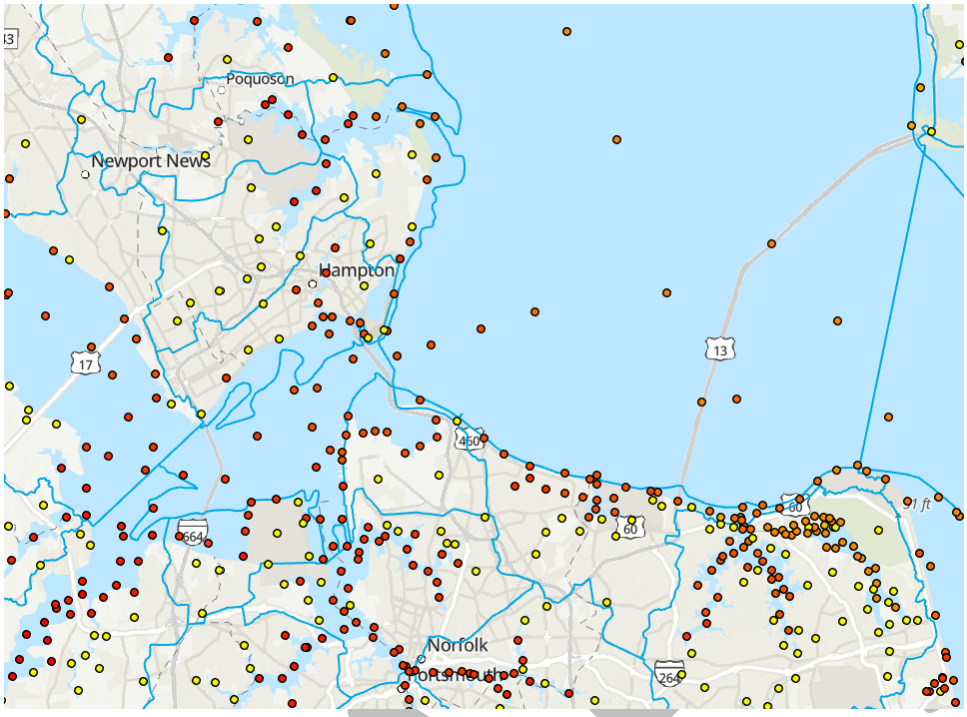


Figure 3: NACCS Storm Surge and Sea Level Rise Analysis Grid Points

Methodology for Design Tidal Elevations:

1. Spatially join Region III Storm Surge points to HUC-12 watersheds (Figure 4)
2. Export spatially joined table and convert to Excel format
3. Calculate 95th-percentile for 10-year, 25-year, 50-year, 100-year, 500-year, and 1000-year return periods for each HUC-12 watershed
4. Calculate SLOPE and INTERCEPT values for each watershed
5. Calculate values for 1-year, 2-year, 3-year, and 5-year return periods using log-linear model
6. (For 1.5' SLR) Add 1.5' to each baseline return period value
7. (For 3' and 4.5' SLR):

$$\textit{Future Design Tidal Elevation} = \textit{(Baseline Tidal Elevation + SLR Scenario) x Non-Linearity Factor}$$

Calculation of Non-Linearity Factors

$$\textit{Non-Linearity Factor} = \frac{\textit{(USACE Modeled Storm Surge Elevation with SLR)}}{\textit{(USACE Baseline Storm Surge Elevation + SLR)}}$$

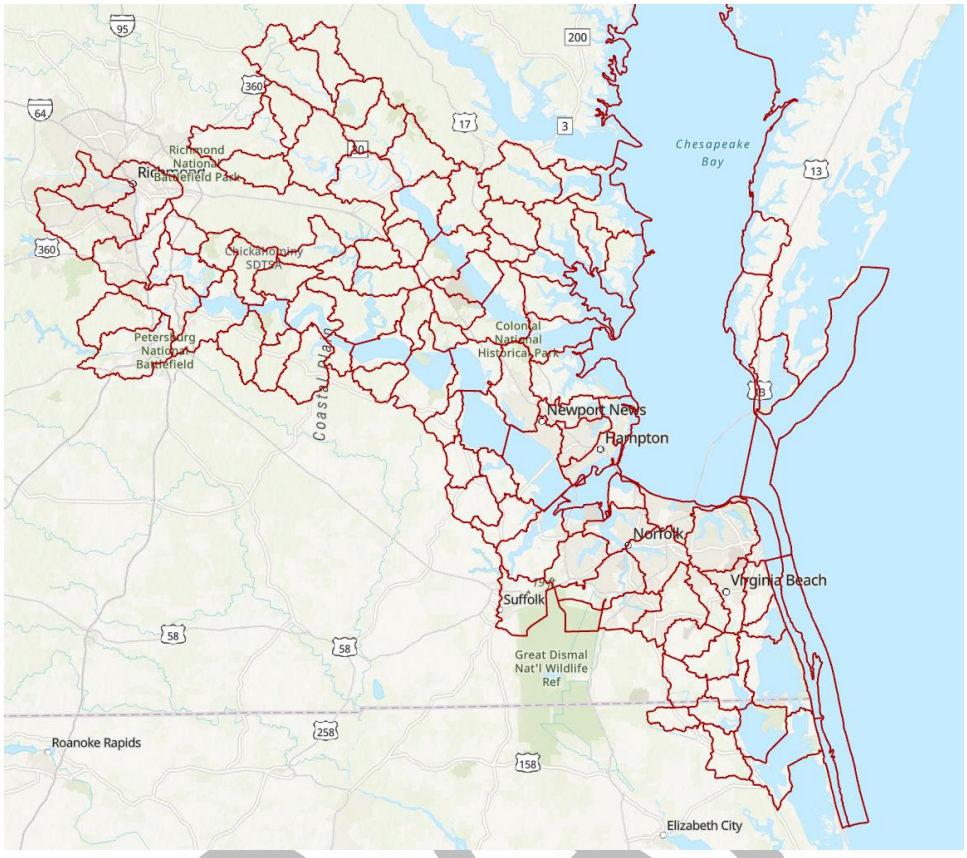


Figure 4: HUC-12 Watersheds Used for Tidal Elevation Analysis

Table 1: Non-Linearity Factors for Hampton Roads Tidal Watersheds

HUC12	Name	Non-Linearity Factor
020403040304	Smith Island Inlet-The Thorofare	1.07
020403040404	Lower Eastern Shore-Atlantic Ocean	1.09
020403040501	Rudee Inlet-Atlantic Ocean	1.07
020403040502	020403040502-Atlantic Ocean	1.08
020801010000	Lower Chesapeake Bay	1.03
020801020301	Carvers Creek-Piankatank River	1.00
020801020302	Hills Bay-Piankatank River	1.03
020801020303	Milford Haven-Lower Chesapeake Bay	1.01
020801020401	Beaverdam Swamp	1.03*
020801020402	Crany Creek-Fox Mill Run	1.01
020801020403	Ware River	1.02
020801020404	North River	1.03
020801020405	East River	1.04
020801020406	Winter Harbor-Lower Chesapeake Bay	1.02
020801020407	Severn River	1.02
020801020408	Monday Creek-Mobjack Bay	1.03
020801050504	Aylett Creek-Mattaponi River	1.03
020801050601	Garnetts Creek	1.04*
020801050602	Courthouse Creek-Mattaponi River	1.05
020801050603	Heartquake Creek-Mattaponi River	1.04
020801050604	Cabin Creek-Mattaponi River	1.04
020801061003	Black Creek	1.10*
020801061004	Montague Creek-Pamunkey River	1.10
020801061005	Jacks Creek	1.10*
020801061101	Cohoke Mill Creek-Pamunkey River	1.11
020801061102	Mill Creek-Pamunkey River	1.04
020801070101	Ware Creek	1.04*
020801070102	Philbates Creek-York River	1.03
020801070103	Poropotank River	1.09
020801070104	Skimino Creek-York River	1.05
020801070201	Jones Creek-York River	1.03
020801070202	Queen Creek	1.03
020801070203	Carter Creek-York River	1.03
020801070204	Sarah Creek-York River	1.02
020801080101	Poquoson River-Lower Chesapeake Bay	1.02
020801080102	Northwest Branch Back River	1.02
020801080103	Southwest Branch Back River	1.01
020801080104	Back River-Lower Chesapeake Bay	1.03
020801080201	Lynnhaven River	1.03
020801080202	Little Creek-Lower Chesapeake Bay	1.03
020801110901	Hungars Creek-Lower Chesapeake Bay	1.03
020801110902	Cherrystone Inlet-Lower Chesapeake Bay	1.04
020802050607	Little Westham Creek-James River	2.73

HUC12	Name	Non-Linearity Factor
020802060101	Almond Creek-James River	2.54
020802060102	Falling Creek	1.85*
020802060103	Proctors Creek-James River	2.09
020802060104	Fourmile Creek	1.85*
020802060105	Turkey Island Creek	1.85*
020802060106	Curles Creek-James River	1.48
020802060201	Bailey Creek-James River	1.12
020802060202	Powell Creek	1.11
020802060203	Herring Creek	1.12*
020802060204	Courthouse Creek-Queens Creek	1.12*
020802060205	Flowerdew Hundred Creek-James River	1.09
020802060301	Wards Creek	1.07*
020802060302	Kittewan Creek-James River	1.07
020802060303	Upper Chippokes Creek	1.10
020802060304	Sunken Meadow Pond-James River	1.06
020802060506	Big Swamp-Chickahominy River	1.04
020802060601	Barrows Creek-Chickahominy River	1.04
020802060603	Mill Creek-Diascund Creek	1.05*
020802060604	Yarmouth Creek-Chickahominy River	1.05
020802060605	Morris Creek-Chickahominy River	1.05
020802060701	Broad Swamp-James River	1.05
020802060702	Powhatan Creek	1.05
020802060703	Grays Creek	1.05
020802060704	Lower Chippokes Creek-James River	1.04
020802060801	College Creek	1.04*
020802060802	Skiffes Creek-James River	1.04
020802060803	Lawnes Creek	1.04*
020802060804	Morrisons Creek-James River	1.04
020802060901	Warwick River	1.07
020802060902	Warren Creek-Pagan River	1.03*
020802060903	Cypress Creek	1.03*
020802060904	Jones Creek-Pagan River	1.02
020802060905	Chuckatuck Creek	1.01
020802060906	Cooper Creek-James River	1.03
020802070904	Franks Branch-Swift Creek	1.15
020802071001	Oldtown Creek-Appomattox River	1.14
020802071002	Ashton Creek-Appomattox River	1.14
020802080105	Cedar Lake-Nansemond River	1.05
020802080106	Bennett Creek-Nansemond River	1.02
020802080201	New Mill Creek-Southern Branch Elizabeth River	0.99
020802080202	Big Entry Ditch-Dismal Swamp	1.01*
020802080203	Deep Creek-Southern Branch Elizabeth River	1.00
020802080204	Eastern Branch Elizabeth River	1.02
020802080205	Western Branch Elizabeth River	1.02
020802080206	Elizabeth River	1.02

HUC12	Name	Non-Linearity Factor
020802080301	Streeter Creek-Hampton Roads	1.03
020802080302	Willoughby Bay	1.02
020802080303	Hampton River-Hampton Roads	1.03
020802080304	Hampton Roads Channel	1.03
030102051104	Indian Creek-Northwest River	1.04
030102051105	Moyock Run	1.04*
030102051107	Tull Creek	1.04*
030102051108	Tull Bay-Northwest River	1.04
030102051201	Chesapeake Canal	1.00
030102051202	West Neck Creek	1.04*
030102051203	Upper North Landing River	1.04
030102051204	Pocaty River	1.04*
030102051205	Blackwater Creek-North Landing River	1.03
030102051206	Milldam Creek-North Landing River	1.03
030102051207	Town of Currituck-North Landing River	1.06
030102051301	Ashville Bridge Creek	1.07*
030102051302	North Bay-Shipps Bay	1.08
030102051303	Back Bay	1.09
030102051304	Coinjock Bay-Currituck Sound	1.05
030102051701	Sand Ridge-Atlantic Ocean	1.09
030102051702	Town of Corolla-Oceanside Seashore	1.12
030102051706	030102051706-Atlantic Ocean	1.10

* Non-Linearity Factor for corresponding HUC-10 watershed

Design Tidal Elevations for Hampton Roads Localities

Notes:

1. Sea level rise scenarios are based on HRPDC Sea Level Rise Planning Policy and Approach (2018).
2. Except where noted, all elevations sourced from statistical analysis of the distribution of water elevations in each watershed from the FEMA Region III Storm Surge Study conducted by the U.S. Army Corps of Engineers Engineer Research and Development Center (2013).
3. Conditions related to the 3-ft and 4.5-ft sea level rise design levels include non-linear increases derived from numerical modeling completed by the U.S. Army Corps of Engineers as part of the North Atlantic Coast Comprehensive Study.
4. Non-linearity factors for HUC-10 watersheds used in cases where HUC-12 watersheds had no data points to calculate non-linearity factors.

Design Tidal Elevations – Chesapeake

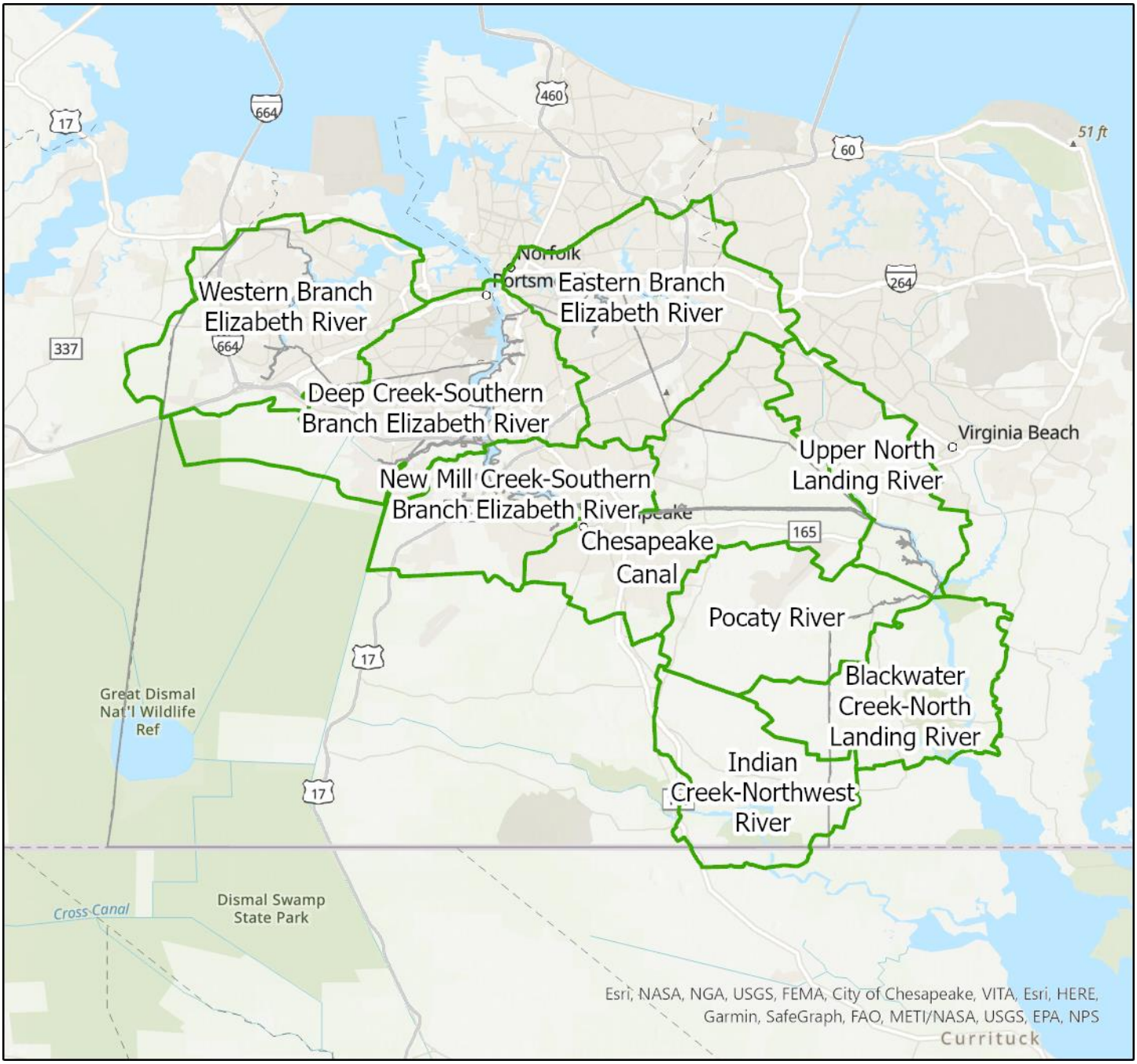
Note: All elevations in feet relative to the North American Vertical Datum (NAVD) of 1988

HUC12	Watershed	Design Level	1-Year	2-Year	3-Year	5-Year	10-Year	25-Year	50-Year	100-Year	500-Year
020802080201	New Mill Creek-Southern Branch Elizabeth River	Current	3.9	4.5	4.8	5.2	5.8	6.6	7.2	7.8	9.2
		1.5 ft SLR	5.4	6.0	6.3	6.7	7.3	8.1	8.7	9.3	10.7
		3.0 ft SLR	6.9	7.5	7.8	8.2	8.8	9.6	10.2	10.8	12.2
		4.5 ft SLR	8.4	9.0	9.3	9.7	10.3	11.1	11.7	12.3	13.7
020802080203	Deep Creek-Southern Branch Elizabeth River	Current	3.4	4.1	4.5	5.1	5.9	6.7	7.3	8.0	10.0
		1.5 ft SLR	4.9	5.6	6.0	6.6	7.4	8.2	8.8	9.5	11.5
		3.0 ft SLR	6.4	7.1	7.5	8.1	8.9	9.7	10.3	11.0	13.0
		4.5 ft SLR	7.9	8.6	9.0	9.6	10.4	11.2	11.8	12.5	14.5
020802080204	Eastern Branch Elizabeth River	Current	2.9	3.7	4.2	4.8	5.9	6.6	7.3	8.0	10.4
		1.5 ft SLR	4.4	5.2	5.7	6.3	7.4	8.1	8.8	9.5	11.9
		3.0 ft SLR	6.0	6.8	7.3	7.9	9.1	9.8	10.5	11.2	13.6
		4.5 ft SLR	7.5	8.3	8.9	9.5	10.6	11.3	12.0	12.7	15.2
020802080205	Western Branch Elizabeth River	Current	3.7	4.5	4.9	5.4	6.1	7.0	7.9	8.6	10.3
		1.5 ft SLR	5.2	6.0	6.4	6.9	7.6	8.5	9.4	10.1	11.8
		3.0 ft SLR	6.9	7.7	8.1	8.6	9.3	10.2	11.2	11.9	13.6
		4.5 ft SLR	8.4	9.2	9.6	10.1	10.9	11.8	12.7	13.4	15.2
030102051104	Indian Creek-Northwest River	Current	-	-	-	-	-	2.0	2.4	2.8	3.8
		1.5 ft SLR	-	-	-	-	-	3.5	3.9	4.3	5.3
		3.0 ft SLR	-	-	-	-	-	5.2	5.6	6.0	7.1
		4.5 ft SLR	-	-	-	-	-	6.8	7.2	7.6	8.6
030102051201	Chesapeake Canal	Current	3.0	3.6	4.0	4.4	5.0	5.8	6.4	7.0	8.4
		1.5 ft SLR	4.5	5.1	5.5	5.9	6.5	7.3	7.9	8.5	9.9
		3.0 ft SLR	6.0	6.6	7.0	7.4	8.0	8.8	9.4	10.0	11.4
		4.5 ft SLR	7.5	8.1	8.5	8.9	9.5	10.3	10.9	11.5	12.9
030102051203 030102051204 030102051205	North Landing River	Current	-	-	-	-	-	2.8	3.4	3.9	4.9
		1.5 ft SLR	-	-	-	-	-	4.3	4.9	5.4	6.4
		3.0 ft SLR	-	-	-	-	-	6.3	6.9	7.5	8.5
		4.5 ft SLR	-	-	-	-	-	7.9	8.5	9.1	10.2

Notes:

1. North Landing River watershed includes Upper North Landing River, Pocaty River, and Blackwater Creek-North Landing River watersheds. Sourced from Virginia Beach Public Works Design Standards Manual, June 2020.
2. Due to recurring wind tides, it is recommended to use the 25-year design tidal elevations for 1-year to 10-year return periods for the Indian Creek-Northwest River and North Landing River watersheds.

Figure 5: Watershed Boundaries for Design Tidal Elevations – Chesapeake



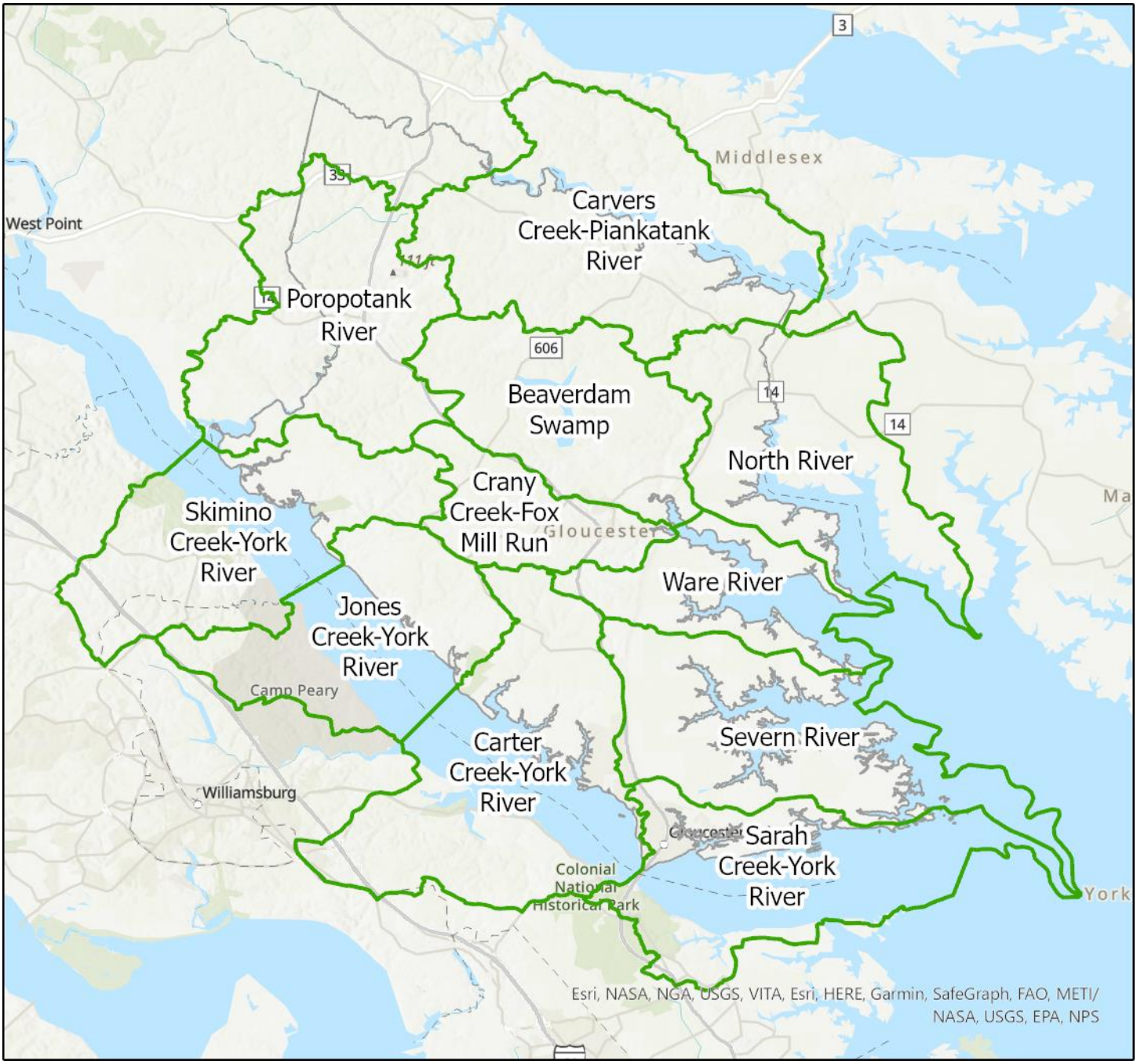
Design Tidal Elevations – Gloucester County

Note: All elevations in feet relative to the North American Vertical Datum (NAVD) of 1988

HUC12	Watershed	Design Level	1-Year	2-Year	3-Year	5-Year	10-Year	25-Year	50-Year	100-Year	500-Year
020801020301	Carvers Creek-Piankatank River	Current	1.8	2.5	2.9	3.4	4.2	5.0	5.3	5.9	7.8
		1.5 ft SLR	3.3	4.0	4.4	4.9	5.7	6.5	6.8	7.4	9.3
		3.0 ft SLR	4.8	5.5	5.9	6.4	7.2	8.0	8.3	8.9	10.8
		4.5 ft SLR	6.3	7.0	7.4	7.9	8.7	9.5	9.8	10.4	12.3
020801020401	Beaverdam Swamp	Current	1.2	2.2	2.7	3.4	4.9	5.6	6.1	6.9	10.0
		1.5 ft SLR	2.7	3.7	4.2	4.9	6.4	7.1	7.6	8.4	11.5
		3.0 ft SLR	4.3	5.4	5.9	6.6	8.1	8.9	9.4	10.2	13.4
		4.5 ft SLR	5.9	6.9	7.4	8.1	9.7	10.4	10.9	11.7	14.9
020801020402	Crany Creek-Fox Mill Run	Current	1.6	2.5	3.0	3.6	4.9	5.6	6.1	6.8	9.6
		1.5 ft SLR	3.1	4.0	4.5	5.1	6.4	7.1	7.6	8.3	11.1
		3.0 ft SLR	4.7	5.6	6.1	6.7	8.0	8.7	9.2	9.9	12.8
		4.5 ft SLR	6.2	7.1	7.6	8.2	9.5	10.2	10.8	11.5	14.3
020801020403	Ware River	Current	1.8	2.6	3.1	3.7	4.9	5.6	6.0	6.6	9.3
		1.5 ft SLR	3.3	4.1	4.6	5.2	6.4	7.1	7.5	8.1	10.8
		3.0 ft SLR	4.9	5.7	6.2	6.8	8.1	8.8	9.2	9.8	12.5
		4.5 ft SLR	6.4	7.2	7.7	8.4	9.6	10.3	10.7	11.3	14.1
020801020404	North River	Current	1.5	2.3	2.8	3.5	4.8	5.4	5.9	6.6	9.4
		1.5 ft SLR	3.0	3.8	4.3	5.0	6.3	6.9	7.4	8.1	10.9
		3.0 ft SLR	4.6	5.5	6.0	6.7	8.1	8.7	9.2	9.9	12.8
		4.5 ft SLR	6.2	7.0	7.5	8.3	9.6	10.2	10.7	11.5	14.4
020801020407	Severn River	Current	2.6	3.2	3.6	4.1	4.9	5.7	6.0	6.5	8.5
		1.5 ft SLR	4.1	4.7	5.1	5.6	6.4	7.2	7.5	8.0	10.0
		3.0 ft SLR	5.7	6.3	6.8	7.3	8.1	8.9	9.2	9.7	11.8
		4.5 ft SLR	7.3	7.9	8.3	8.8	9.6	10.4	10.7	11.3	13.3
020801070103	Poropotank River	Current	2.7	3.4	3.9	4.4	5.4	6.1	6.5	6.9	9.2
		1.5 ft SLR	4.2	4.9	5.4	5.9	6.9	7.6	8.0	8.4	10.7
		3.0 ft SLR	6.2	7.0	7.5	8.0	9.1	9.9	10.3	10.8	13.3
		4.5 ft SLR	7.8	8.6	9.1	9.7	10.8	11.5	12.0	12.4	14.9
020801070104	Skimino Creek-York River	Current	3.0	3.6	4.0	4.5	5.3	6.1	6.4	6.9	8.8
		1.5 ft SLR	4.5	5.1	5.5	6.0	6.8	7.6	7.9	8.4	10.3
		3.0 ft SLR	6.3	6.9	7.3	7.9	8.7	9.5	9.8	10.4	12.4
		4.5 ft SLR	7.9	8.5	8.9	9.4	10.3	11.1	11.4	11.9	13.9
020801070201	Jones Creek-York River	Current	3.2	3.8	4.1	4.6	5.2	6.0	6.4	6.8	8.5
		1.5 ft SLR	4.7	5.3	5.6	6.1	6.7	7.5	7.9	8.3	10.0
		3.0 ft SLR	6.4	7.0	7.3	7.8	8.5	9.3	9.7	10.1	11.9
		4.5 ft SLR	7.9	8.6	8.9	9.4	10.0	10.8	11.2	11.7	13.4

HUC12	Watershed	Design Level	1-Year	2-Year	3-Year	5-Year	10-Year	25-Year	50-Year	100-Year	500-Year
020801070203	Carter Creek-York River	Current	3.1	3.7	4.0	4.5	5.1	5.8	6.3	6.8	8.3
		1.5 ft SLR	4.6	5.2	5.5	6.0	6.6	7.3	7.8	8.3	9.8
		3.0 ft SLR	6.3	6.9	7.2	7.7	8.3	9.1	9.6	10.1	11.6
		4.5 ft SLR	7.8	8.4	8.7	9.3	9.9	10.6	11.1	11.6	13.2
020801070204	Sarah Creek-York River	Current	3.0	3.6	3.9	4.3	4.9	5.5	6.1	6.6	7.9
		1.5 ft SLR	4.5	5.1	5.4	5.8	6.4	7.0	7.6	8.1	9.4
		3.0 ft SLR	6.1	6.7	7.1	7.5	8.1	8.7	9.3	9.8	11.1
		4.5 ft SLR	7.7	8.3	8.6	9.0	9.6	10.2	10.8	11.4	12.7

Figure 6: Watershed Boundaries for Design Tidal Elevations – Gloucester County

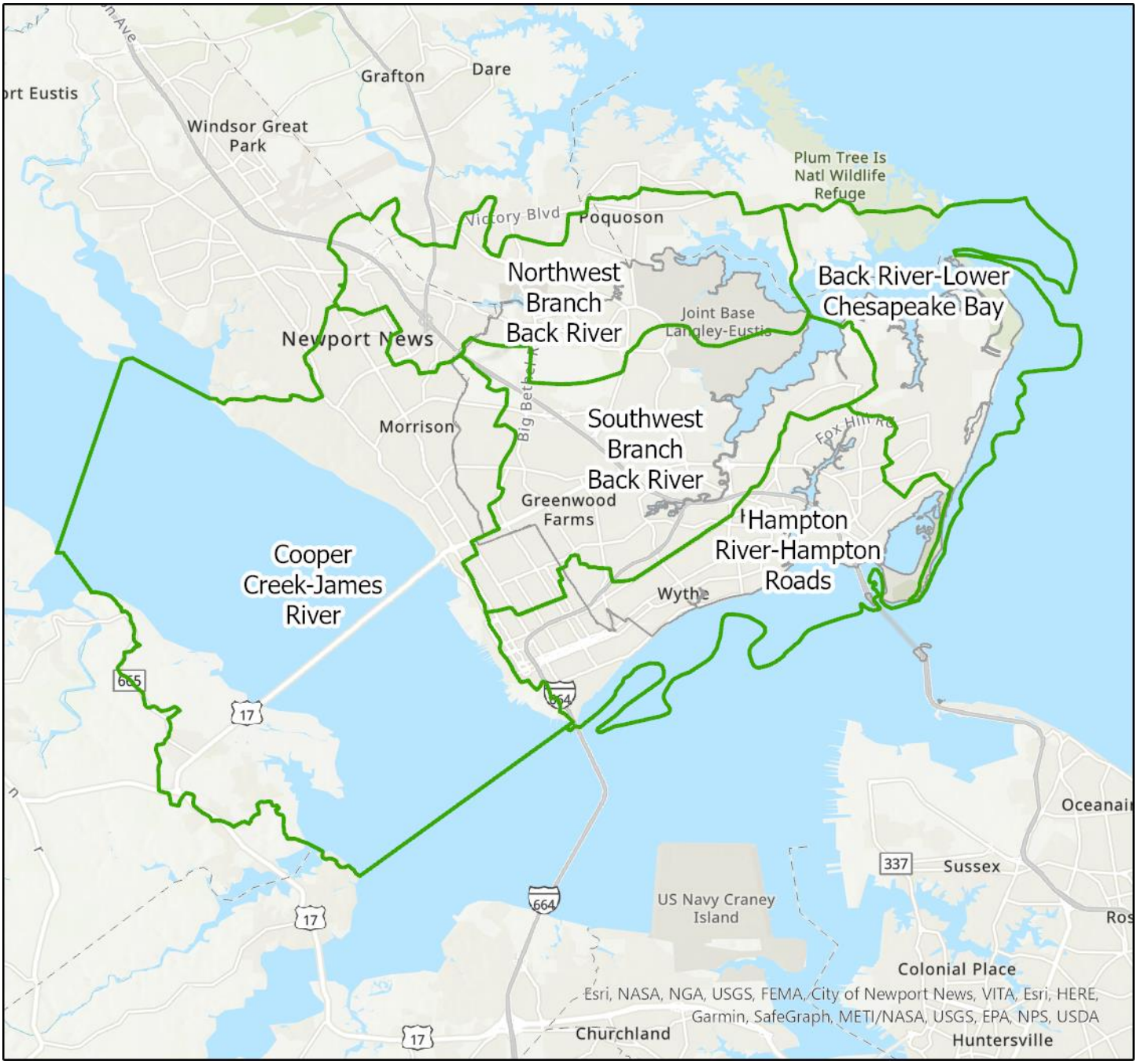


Design Tidal Elevations – Hampton

Note: All elevations in feet relative to the North American Vertical Datum (NAVD) of 1988

HUC12	Watershed	Design Level	1-Year	2-Year	3-Year	5-Year	10-Year	25-Year	50-Year	100-Year	500-Year
020801080102	Northwest Branch Back River	Current	3.2	3.9	4.3	4.9	5.6	6.4	7.2	7.9	9.6
		1.5 ft SLR	4.7	5.4	5.8	6.4	7.1	7.9	8.7	9.4	11.1
		3.0 ft SLR	6.4	7.1	7.5	8.1	8.8	9.6	10.5	11.2	12.9
		4.5 ft SLR	7.9	8.6	9.0	9.6	10.4	11.2	12.0	12.7	14.5
020801080103	Southwest Branch Back River	Current	3.3	4.0	4.4	5.0	5.6	6.5	7.4	8.1	9.7
		1.5 ft SLR	4.8	5.5	5.9	6.5	7.1	8.0	8.9	9.6	11.2
		3.0 ft SLR	6.4	7.1	7.5	8.1	8.7	9.6	10.5	11.3	12.9
		4.5 ft SLR	7.9	8.6	9.0	9.6	10.2	11.2	12.1	12.8	14.4
020801080104	Back River-Lower Chesapeake Bay	Current	3.2	3.9	4.3	4.7	5.4	6.1	6.8	7.5	9.0
		1.5 ft SLR	4.7	5.4	5.8	6.2	6.9	7.6	8.3	9.0	10.5
		3.0 ft SLR	6.4	7.1	7.5	7.9	8.6	9.3	10.1	10.8	12.3
		4.5 ft SLR	7.9	8.6	9.0	9.4	10.2	10.9	11.6	12.3	13.9
020802060906	Cooper Creek-James River	Current	3.7	4.4	4.8	5.2	5.8	6.7	7.5	8.1	9.6
		1.5 ft SLR	5.2	5.9	6.3	6.7	7.3	8.2	9.0	9.6	11.1
		3.0 ft SLR	6.9	7.6	8.0	8.4	9.1	10.0	10.8	11.4	13.0
		4.5 ft SLR	8.4	9.2	9.6	10.0	10.6	11.5	12.3	13.0	14.5
020802080303	Hampton River-Hampton Roads	Current	3.5	4.1	4.4	4.9	5.4	6.2	7.0	7.6	8.9
		1.5 ft SLR	5.0	5.6	5.9	6.4	6.9	7.7	8.5	9.1	10.4
		3.0 ft SLR	6.7	7.3	7.6	8.1	8.6	9.5	10.3	10.9	12.2
		4.5 ft SLR	8.2	8.9	9.2	9.7	10.2	11.0	11.8	12.5	13.8

Figure 7: Watershed Boundaries for Design Tidal Elevations - Hampton

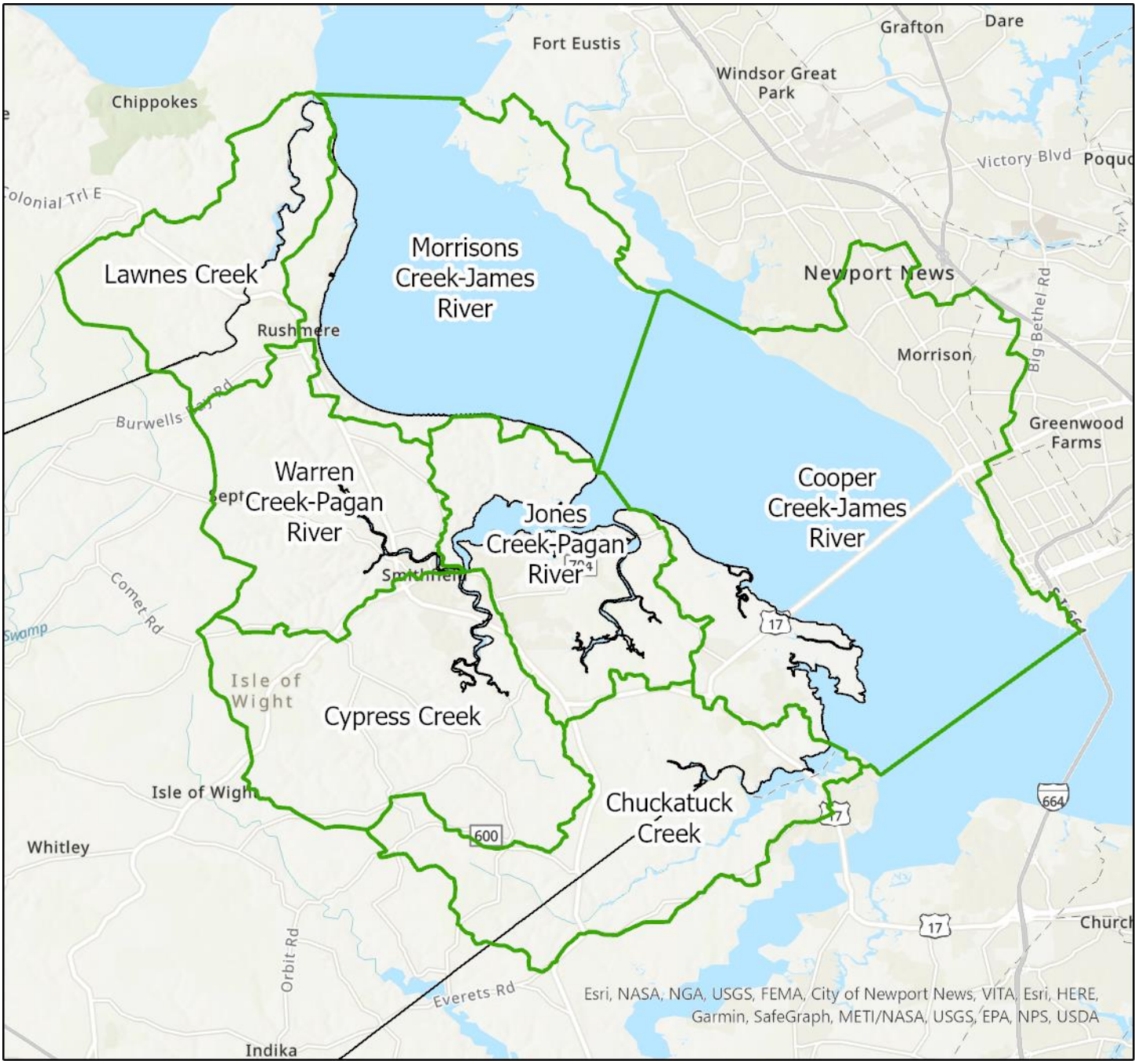


Design Tidal Elevations – Isle of Wight County

Note: All elevations in feet relative to the North American Vertical Datum (NAVD) of 1988

HUC12	Watershed	Design Level	1-Year	2-Year	3-Year	5-Year	10-Year	25-Year	50-Year	100-Year	500-Year
		Current	4.0	4.5	4.8	5.2	5.6	6.4	6.8	7.3	8.4
		1.5 ft SLR	5.5	6.0	6.3	6.7	7.1	7.9	8.3	8.8	9.9
		3.0 ft SLR	7.3	7.8	8.1	8.5	8.9	9.8	10.2	10.7	11.9
020802060803	Lawnes Creek	4.5 ft SLR	8.8	9.4	9.7	10.1	10.5	11.3	11.8	12.3	13.4
		Current	4.0	4.6	4.9	5.3	5.7	6.5	7.1	7.6	8.7
	Morrisons	1.5 ft SLR	5.5	6.1	6.4	6.8	7.2	8.0	8.6	9.1	10.2
	Creek-James	3.0 ft SLR	7.2	7.9	8.2	8.6	9.0	9.8	10.5	11.0	12.1
020802060804	River	4.5 ft SLR	8.8	9.4	9.7	10.1	10.6	11.4	12.0	12.5	13.7
		Current	4.0	4.6	5.0	5.5	6.0	6.9	7.8	8.4	9.7
		1.5 ft SLR	5.5	6.1	6.5	7.0	7.5	8.4	9.3	9.9	11.2
	Warren Creek-	3.0 ft SLR	7.2	7.8	8.2	8.8	9.3	10.2	11.1	11.7	13.1
020802060902	Pagan River	4.5 ft SLR	8.8	9.4	9.8	10.3	10.8	11.7	12.7	13.3	14.6
		Current	3.9	4.6	5.0	5.5	6.0	6.9	7.8	8.5	9.8
		1.5 ft SLR	5.4	6.1	6.5	7.0	7.5	8.4	9.3	10.0	11.3
		3.0 ft SLR	7.1	7.8	8.2	8.8	9.3	10.2	11.1	11.8	13.2
020802060903	Cypress Creek	4.5 ft SLR	8.7	9.4	9.8	10.3	10.8	11.7	12.7	13.4	14.7
		Current	3.9	4.6	5.0	5.4	5.9	6.8	7.6	8.3	9.5
		1.5 ft SLR	5.4	6.1	6.5	6.9	7.4	8.3	9.1	9.8	11.0
	Jones Creek-	3.0 ft SLR	7.0	7.8	8.2	8.6	9.1	10.0	10.8	11.5	12.8
020802060904	Pagan River	4.5 ft SLR	8.6	9.3	9.7	10.1	10.6	11.5	12.3	13.1	14.3
		Current	4.0	4.7	5.1	5.7	6.2	7.3	8.2	8.9	10.4
		1.5 ft SLR	5.5	6.2	6.6	7.2	7.7	8.8	9.7	10.4	11.9
	Chuckatuck	3.0 ft SLR	7.1	7.8	8.2	8.8	9.3	10.5	11.4	12.1	13.6
020802060905	Creek	4.5 ft SLR	8.6	9.3	9.7	10.4	10.9	12.0	12.9	13.6	15.1
		Current	3.7	4.4	4.8	5.2	5.8	6.7	7.5	8.1	9.6
		1.5 ft SLR	5.2	5.9	6.3	6.7	7.3	8.2	9.0	9.6	11.1
	Cooper Creek-	3.0 ft SLR	6.9	7.6	8.0	8.4	9.1	10.0	10.8	11.4	13.0
020802060906	James River	4.5 ft SLR	8.4	9.2	9.6	10.0	10.6	11.5	12.3	13.0	14.5

Figure 8: Watershed Boundaries for Design Tidal Elevations – Isle of Wight County



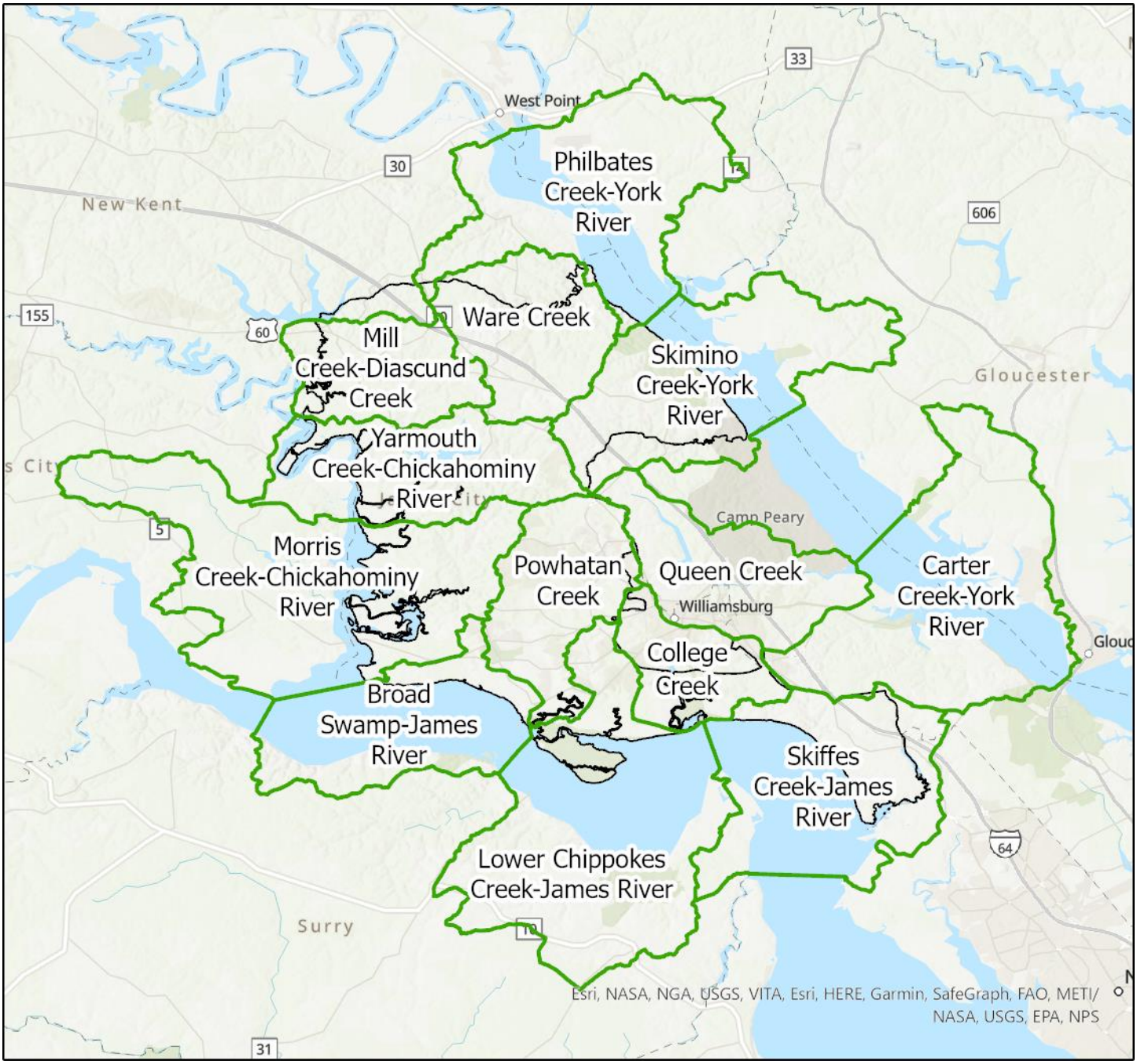
Design Tidal Elevations – James City County

Note: All elevations in feet relative to the North American Vertical Datum (NAVD) of 1988

HUC12	Watershed	Design Level	1-Year	2-Year	3-Year	5-Year	10-Year	25-Year	50-Year	100-Year	500-Year
		Current	2.8	3.5	3.9	4.5	5.5	6.2	6.6	7.1	9.3
		1.5 ft SLR	4.3	5.0	5.4	6.0	7.0	7.7	8.1	8.6	10.8
		3.0 ft SLR	6.0	6.8	7.2	7.8	8.8	9.6	10.0	10.5	12.8
020801070101	Ware Creek	4.5 ft SLR	7.6	8.3	8.7	9.4	10.4	11.1	11.5	12.1	14.4
		Current	2.1	3.0	3.5	4.2	5.5	6.3	6.6	7.2	10.2
		1.5 ft SLR	3.6	4.5	5.0	5.7	7.0	7.8	8.1	8.7	11.7
	Philbates Creek-	3.0 ft SLR	5.3	6.2	6.7	7.4	8.8	9.6	9.9	10.6	13.7
020801070102	York River	4.5 ft SLR	6.8	7.8	8.3	9.0	10.3	11.2	11.5	12.1	15.2
		Current	3.0	3.6	4.0	4.5	5.3	6.1	6.4	6.9	8.8
		1.5 ft SLR	4.5	5.1	5.5	6.0	6.8	7.6	7.9	8.4	10.3
	Skimino Creek-	3.0 ft SLR	6.3	6.9	7.3	7.9	8.7	9.5	9.8	10.4	12.4
020801070104	York River	4.5 ft SLR	7.9	8.5	8.9	9.4	10.3	11.1	11.4	11.9	13.9
		Current	2.9	3.5	3.9	4.4	5.1	5.9	6.3	6.8	8.6
		1.5 ft SLR	4.4	5.0	5.4	5.9	6.6	7.4	7.8	8.3	10.1
		3.0 ft SLR	6.1	6.7	7.1	7.6	8.4	9.2	9.6	10.1	12.0
020801070202	Queen Creek	4.5 ft SLR	7.6	8.3	8.7	9.2	9.9	10.8	11.2	11.7	13.5
		Current	3.1	3.7	4.0	4.5	5.1	5.8	6.3	6.8	8.3
		1.5 ft SLR	4.6	5.2	5.5	6.0	6.6	7.3	7.8	8.3	9.8
	Carter Creek-	3.0 ft SLR	6.3	6.9	7.2	7.7	8.3	9.1	9.6	10.1	11.6
020801070203	York River	4.5 ft SLR	7.8	8.4	8.7	9.3	9.9	10.6	11.1	11.6	13.2
		Current	4.0	4.6	4.9	5.3	5.9	6.6	7.0	7.3	8.7
		1.5 ft SLR	5.5	6.1	6.4	6.8	7.4	8.1	8.5	8.8	10.2
	Mill Creek-	3.0 ft SLR	7.4	8.0	8.3	8.7	9.3	10.1	10.5	10.8	12.3
020802060603	Descend Creek	4.5 ft SLR	8.9	9.6	9.9	10.3	10.9	11.7	12.1	12.4	13.9
		Current	3.8	4.4	4.7	5.2	5.9	6.6	7.0	7.3	8.9
	Yarmouth Creek-	1.5 ft SLR	5.3	5.9	6.2	6.7	7.4	8.1	8.5	8.8	10.4
	Chickahominy	3.0 ft SLR	7.1	7.7	8.1	8.6	9.3	10.1	10.5	10.8	12.5
020802060604	River	4.5 ft SLR	8.7	9.3	9.6	10.2	10.9	11.6	12.0	12.4	14.0
		Current	3.8	4.4	4.7	5.2	5.9	6.7	7.0	7.4	9.0
	Morris Creek-	1.5 ft SLR	5.3	5.9	6.2	6.7	7.4	8.2	8.5	8.9	10.5
	Chickahominy	3.0 ft SLR	7.2	7.8	8.1	8.6	9.4	10.2	10.5	11.0	12.6
020802060605	River	4.5 ft SLR	8.7	9.4	9.7	10.2	11.0	11.8	12.1	12.5	14.2
		Current	4.0	4.6	4.9	5.3	5.8	6.7	7.1	7.4	8.8
		1.5 ft SLR	5.5	6.1	6.4	6.8	7.3	8.2	8.6	8.9	10.3
	Broad Swamp-	3.0 ft SLR	7.3	8.0	8.3	8.7	9.2	10.2	10.6	10.9	12.4
020802060701	James River	4.5 ft SLR	8.9	9.6	9.9	10.3	10.8	11.8	12.2	12.5	14.0

HUC12	Watershed	Design Level	1-Year	2-Year	3-Year	5-Year	10-Year	25-Year	50-Year	100-Year	500-Year
		Current	3.7	4.3	4.6	5.0	5.6	6.3	6.7	7.0	8.5
		1.5 ft SLR	5.2	5.8	6.1	6.5	7.1	7.8	8.2	8.5	10.0
		3.0 ft SLR	7.0	7.6	8.0	8.4	9.0	9.7	10.2	10.5	12.0
020802060702	Powhatan Creek	4.5 ft SLR	8.6	9.2	9.5	9.9	10.6	11.3	11.7	12.0	13.6
	Lower Chippokes Creek-James	Current	3.9	4.5	4.8	5.2	5.7	6.5	6.9	7.3	8.6
		1.5 ft SLR	5.4	6.0	6.3	6.7	7.2	8.0	8.4	8.8	10.1
		3.0 ft SLR	7.2	7.8	8.1	8.5	9.1	9.9	10.3	10.7	12.1
020802060704	River	4.5 ft SLR	8.7	9.4	9.7	10.1	10.6	11.4	11.9	12.3	13.6
		Current	3.3	3.9	4.3	4.8	5.6	6.3	6.7	7.1	9.0
		1.5 ft SLR	4.8	5.4	5.8	6.3	7.1	7.8	8.2	8.6	10.5
		3.0 ft SLR	6.6	7.2	7.6	8.1	8.9	9.7	10.1	10.5	12.5
020802060801	College Creek	4.5 ft SLR	8.1	8.7	9.2	9.7	10.5	11.2	11.6	12.1	14.0
		Current	3.6	4.2	4.5	4.9	5.6	6.3	6.7	7.1	8.6
		1.5 ft SLR	5.1	5.7	6.0	6.4	7.1	7.8	8.2	8.6	10.1
	Skiffes Creek-	3.0 ft SLR	6.9	7.5	7.8	8.2	8.9	9.7	10.1	10.5	12.1
020802060802	James River	4.5 ft SLR	8.4	9.0	9.4	9.8	10.5	11.2	11.6	12.1	13.6

Figure 9: Watershed Boundaries for Design Tidal Elevations – James City County

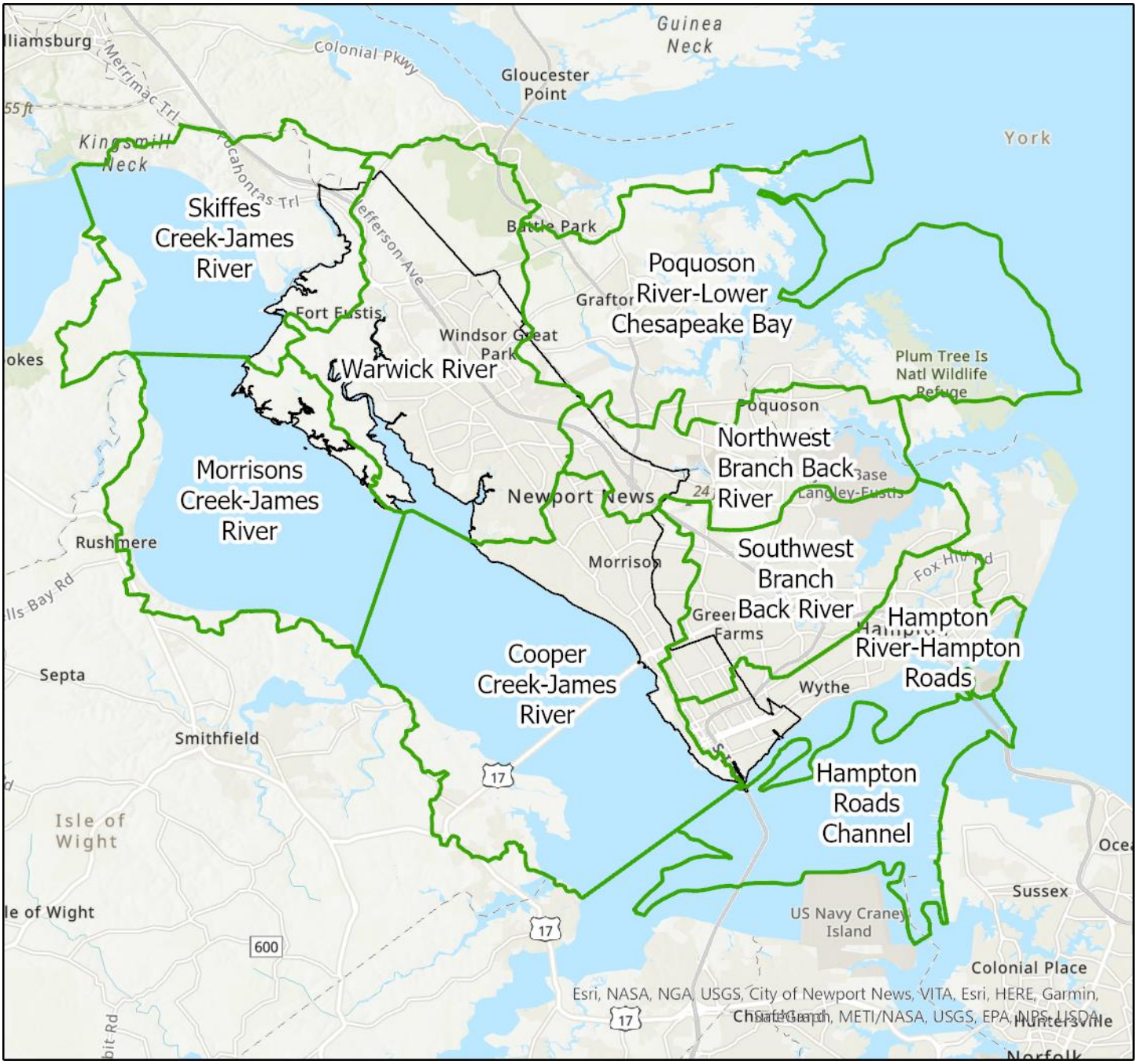


Design Tidal Elevations – Newport News

Note: All elevations in feet relative to the North American Vertical Datum (NAVD) of 1988

HUC12	Watershed	Design Level	1-Year	2-Year	3-Year	5-Year	10-Year	25-Year	50-Year	100-Year	500-Year
020801080101	Poquoson River-Lower Chesapeake Bay	Current	2.8	3.5	3.9	4.4	5.1	5.9	6.8	7.4	9.0
		1.5 ft SLR	4.3	5.0	5.4	5.9	6.6	7.4	8.3	8.9	10.5
		3.0 ft SLR	5.9	6.6	7.0	7.5	8.3	9.1	10.0	10.6	12.2
		4.5 ft SLR	7.4	8.2	8.6	9.1	9.8	10.6	11.5	12.1	13.8
020801080102	Northwest Branch Back River	Current	3.2	3.9	4.3	4.9	5.6	6.4	7.2	7.9	9.6
		1.5 ft SLR	4.7	5.4	5.8	6.4	7.1	7.9	8.7	9.4	11.1
		3.0 ft SLR	6.4	7.1	7.5	8.1	8.8	9.6	10.5	11.2	12.9
		4.5 ft SLR	7.9	8.6	9.0	9.6	10.4	11.2	12.0	12.7	14.5
020801080103	Southwest Branch Back River	Current	3.3	4.0	4.4	5.0	5.6	6.5	7.4	8.1	9.7
		1.5 ft SLR	4.8	5.5	5.9	6.5	7.1	8.0	8.9	9.6	11.2
		3.0 ft SLR	6.4	7.1	7.5	8.1	8.7	9.6	10.5	11.3	12.9
		4.5 ft SLR	7.9	8.6	9.0	9.6	10.2	11.2	12.1	12.8	14.4
020802060802	Skiffes Creek-James River	Current	3.6	4.2	4.5	4.9	5.6	6.3	6.7	7.1	8.6
		1.5 ft SLR	5.1	5.7	6.0	6.4	7.1	7.8	8.2	8.6	10.1
		3.0 ft SLR	6.9	7.5	7.8	8.2	8.9	9.7	10.1	10.5	12.1
		4.5 ft SLR	8.4	9.0	9.4	9.8	10.5	11.2	11.6	12.1	13.6
020802060804	Morrisons Creek-James River	Current	4.0	4.6	4.9	5.3	5.7	6.5	7.1	7.6	8.7
		1.5 ft SLR	5.5	6.1	6.4	6.8	7.2	8.0	8.6	9.1	10.2
		3.0 ft SLR	7.2	7.9	8.2	8.6	9.0	9.8	10.5	11.0	12.1
		4.5 ft SLR	8.8	9.4	9.7	10.1	10.6	11.4	12.0	12.5	13.7
020802060901	Warwick River	Current	3.7	4.2	4.6	5.0	5.6	6.3	6.8	7.2	8.7
		1.5 ft SLR	5.2	5.7	6.1	6.5	7.1	7.8	8.3	8.7	10.2
		3.0 ft SLR	7.1	7.7	8.1	8.5	9.2	9.9	10.4	10.9	12.5
		4.5 ft SLR	8.7	9.3	9.7	10.1	10.8	11.5	12.0	12.5	14.1
020802060906	Cooper Creek-James River	Current	3.7	4.4	4.8	5.2	5.8	6.7	7.5	8.1	9.6
		1.5 ft SLR	5.2	5.9	6.3	6.7	7.3	8.2	9.0	9.6	11.1
		3.0 ft SLR	6.9	7.6	8.0	8.4	9.1	10.0	10.8	11.4	13.0
		4.5 ft SLR	8.4	9.2	9.6	10.0	10.6	11.5	12.3	13.0	14.5
020802080303	Hampton River-Hampton Roads	Current	3.5	4.1	4.4	4.9	5.4	6.2	7.0	7.6	8.9
		1.5 ft SLR	5.0	5.6	5.9	6.4	6.9	7.7	8.5	9.1	10.4
		3.0 ft SLR	6.7	7.3	7.6	8.1	8.6	9.5	10.3	10.9	12.2
		4.5 ft SLR	8.2	8.9	9.2	9.7	10.2	11.0	11.8	12.5	13.8
020802080304	Hampton Roads Channel	Current	3.3	4.0	4.4	4.9	5.5	6.4	7.1	7.8	9.4
		1.5 ft SLR	4.8	5.5	5.9	6.4	7.0	7.9	8.6	9.3	10.9
		3.0 ft SLR	6.5	7.2	7.6	8.1	8.7	9.6	10.4	11.1	12.7
		4.5 ft SLR	8.0	8.7	9.1	9.6	10.3	11.2	11.9	12.6	14.3

Figure 10: Watershed Boundaries for Design Tidal Elevations – Newport News

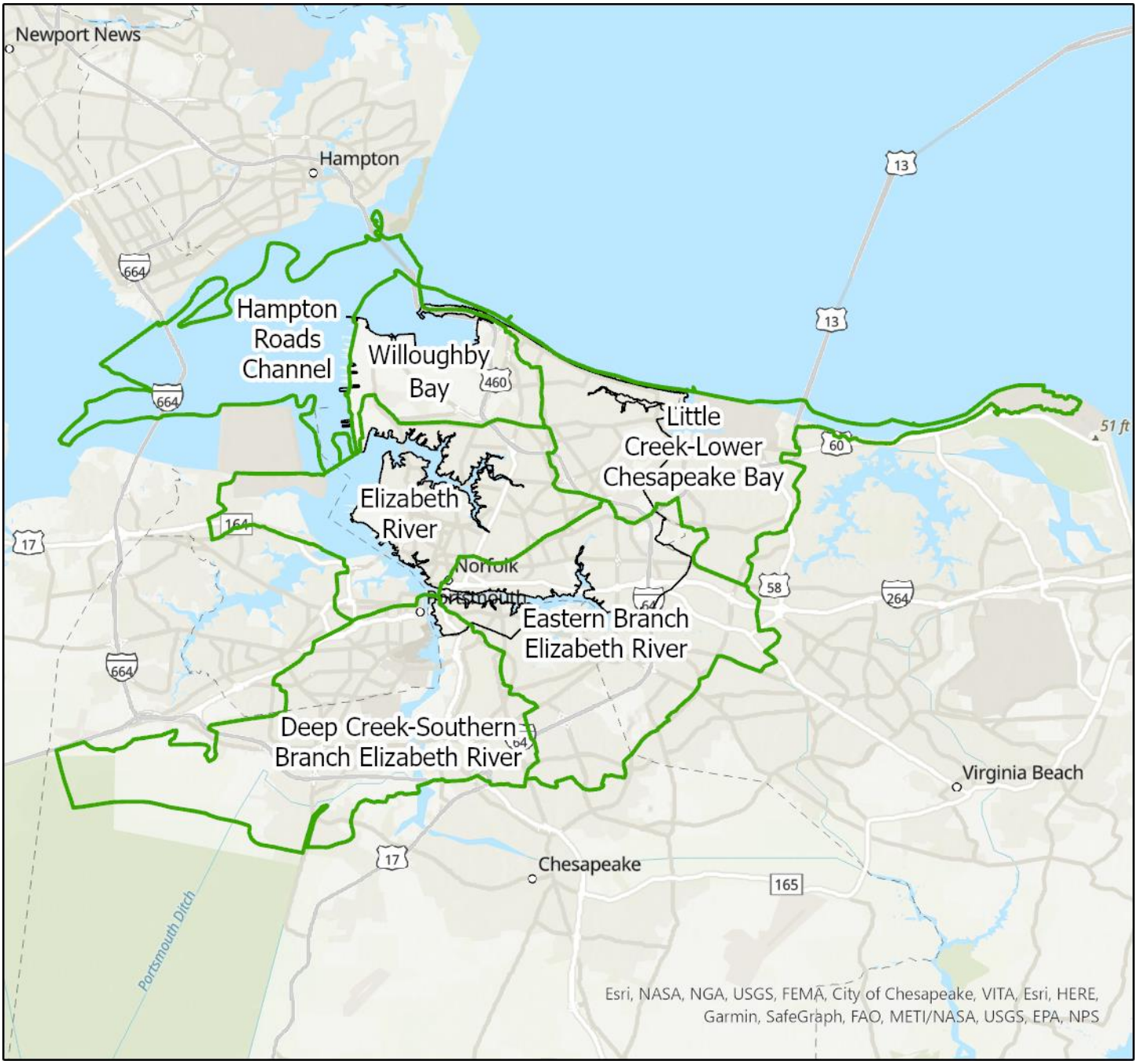


Design Tidal Elevations – Norfolk

Note: All elevations in feet relative to the North American Vertical Datum (NAVD) of 1988

HUC12	Watershed	Design Level	1-Year	2-Year	3-Year	5-Year	10-Year	25-Year	50-Year	100-Year	500-Year
020801080202	Little Creek-Lower Chesapeake Bay	Current	3.2	3.8	4.2	4.7	5.3	6.1	6.8	7.4	8.9
		1.5 ft SLR	4.7	5.3	5.7	6.2	6.8	7.6	8.3	8.9	10.4
		3.0 ft SLR	6.4	7.0	7.4	8.0	8.6	9.4	10.1	10.7	12.3
		4.5 ft SLR	8.0	8.6	9.0	9.5	10.1	10.9	11.7	12.3	13.8
020802080203	Deep Creek-Southern Branch Elizabeth River	Current	3.4	4.1	4.5	5.1	5.9	6.7	7.3	8.0	10.0
		1.5 ft SLR	4.9	5.6	6.0	6.6	7.4	8.2	8.8	9.5	11.5
		3.0 ft SLR	6.4	7.1	7.5	8.1	8.9	9.7	10.3	11.0	13.0
		4.5 ft SLR	7.9	8.6	9.0	9.6	10.4	11.2	11.8	12.5	14.5
020802080204	Eastern Branch Elizabeth River	Current	2.9	3.7	4.2	4.8	5.9	6.6	7.3	8.0	10.4
		1.5 ft SLR	4.4	5.2	5.7	6.3	7.4	8.1	8.8	9.5	11.9
		3.0 ft SLR	6.0	6.8	7.3	7.9	9.1	9.8	10.5	11.2	13.6
		4.5 ft SLR	7.5	8.3	8.9	9.5	10.6	11.3	12.0	12.7	15.2
020802080206	Elizabeth River	Current	3.2	3.9	4.4	4.9	5.8	6.5	7.3	7.9	9.9
		1.5 ft SLR	4.7	5.4	5.9	6.4	7.3	8.0	8.8	9.4	11.4
		3.0 ft SLR	6.3	7.1	7.6	8.1	9.0	9.7	10.5	11.2	13.2
		4.5 ft SLR	7.9	8.6	9.1	9.6	10.5	11.3	12.1	12.7	14.7
020802080302	Willoughby Bay	Current	3.2	3.8	4.2	4.7	5.4	6.2	6.9	7.6	9.2
		1.5 ft SLR	4.7	5.3	5.7	6.2	6.9	7.7	8.4	9.1	10.7
		3.0 ft SLR	6.3	6.9	7.3	7.8	8.6	9.4	10.1	10.8	12.4
		4.5 ft SLR	7.8	8.5	8.9	9.4	10.1	10.9	11.6	12.3	14.0
020802080304	Hampton Roads Channel	Current	3.3	4.0	4.4	4.9	5.5	6.4	7.1	7.8	9.4
		1.5 ft SLR	4.8	5.5	5.9	6.4	7.0	7.9	8.6	9.3	10.9
		3.0 ft SLR	6.5	7.2	7.6	8.1	8.7	9.6	10.4	11.1	12.7
		4.5 ft SLR	8.0	8.7	9.1	9.6	10.3	11.2	11.9	12.6	14.3

Figure 11: Watershed Boundaries for Design Tidal Elevations – Norfolk

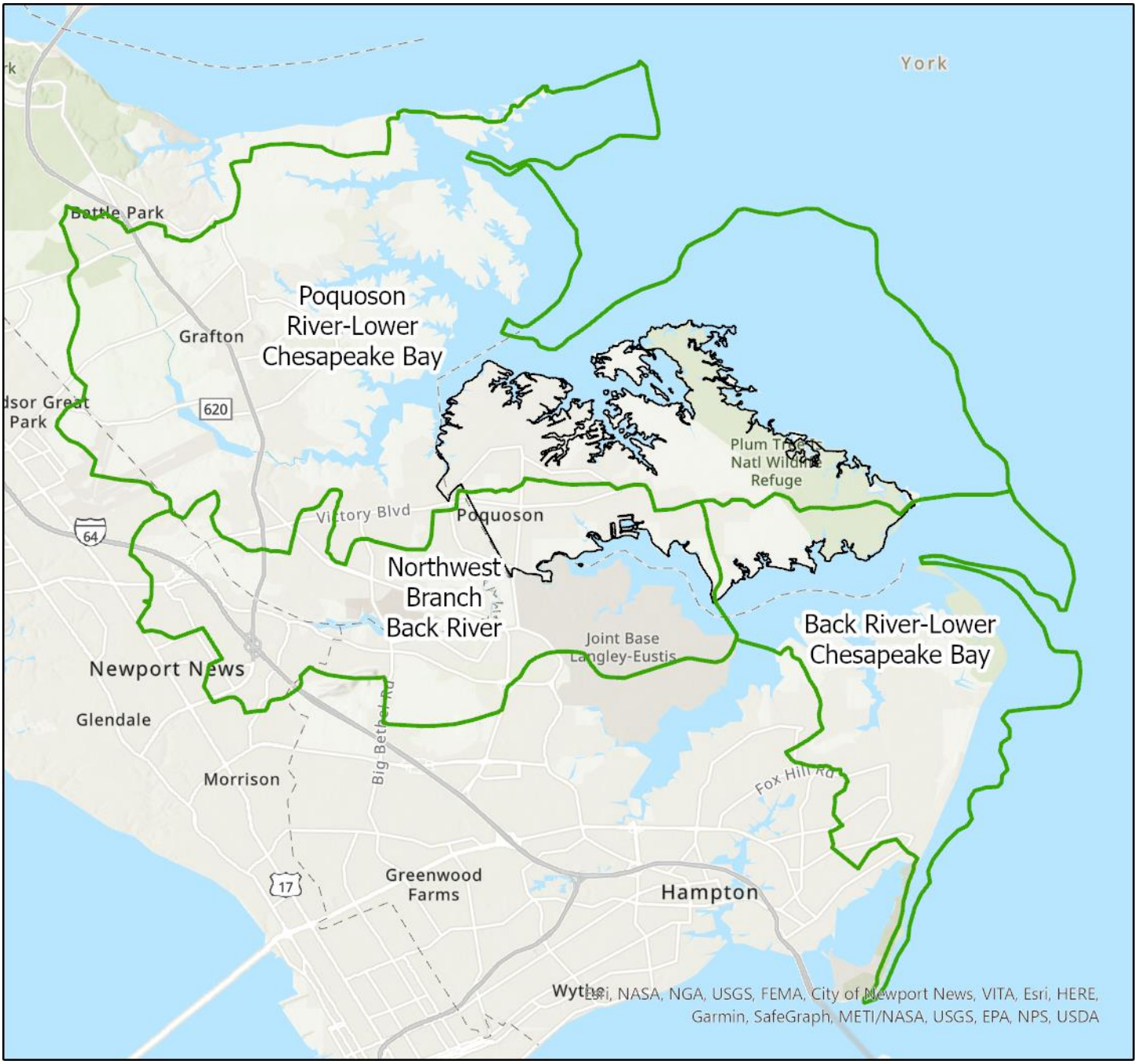


Design Tidal Elevations – Poquoson

Note: All elevations in feet relative to the North American Vertical Datum (NAVD) of 1988

HUC12	Watershed	Design Level	1-Year	2-Year	3-Year	5-Year	10-Year	25-Year	50-Year	100-Year	500-Year
020801080101	Poquoson River-Lower Chesapeake Bay	Current	2.8	3.5	3.9	4.4	5.1	5.9	6.8	7.4	9.0
		1.5 ft SLR	4.3	5.0	5.4	5.9	6.6	7.4	8.3	8.9	10.5
		3.0 ft SLR	5.9	6.6	7.0	7.5	8.3	9.1	10.0	10.6	12.2
		4.5 ft SLR	7.4	8.2	8.6	9.1	9.8	10.6	11.5	12.1	13.8
020801080102	Northwest Branch Back River	Current	3.2	3.9	4.3	4.9	5.6	6.4	7.2	7.9	9.6
		1.5 ft SLR	4.7	5.4	5.8	6.4	7.1	7.9	8.7	9.4	11.1
		3.0 ft SLR	6.4	7.1	7.5	8.1	8.8	9.6	10.5	11.2	12.9
		4.5 ft SLR	7.9	8.6	9.0	9.6	10.4	11.2	12.0	12.7	14.5
020801080104	Back River-Lower Chesapeake Bay	Current	3.2	3.9	4.3	4.7	5.4	6.1	6.8	7.5	9.0
		1.5 ft SLR	4.7	5.4	5.8	6.2	6.9	7.6	8.3	9.0	10.5
		3.0 ft SLR	6.4	7.1	7.5	7.9	8.6	9.3	10.1	10.8	12.3
		4.5 ft SLR	7.9	8.6	9.0	9.4	10.2	10.9	11.6	12.3	13.9

Figure 12: Watershed Boundaries for Design Tidal Elevations - Poquoson

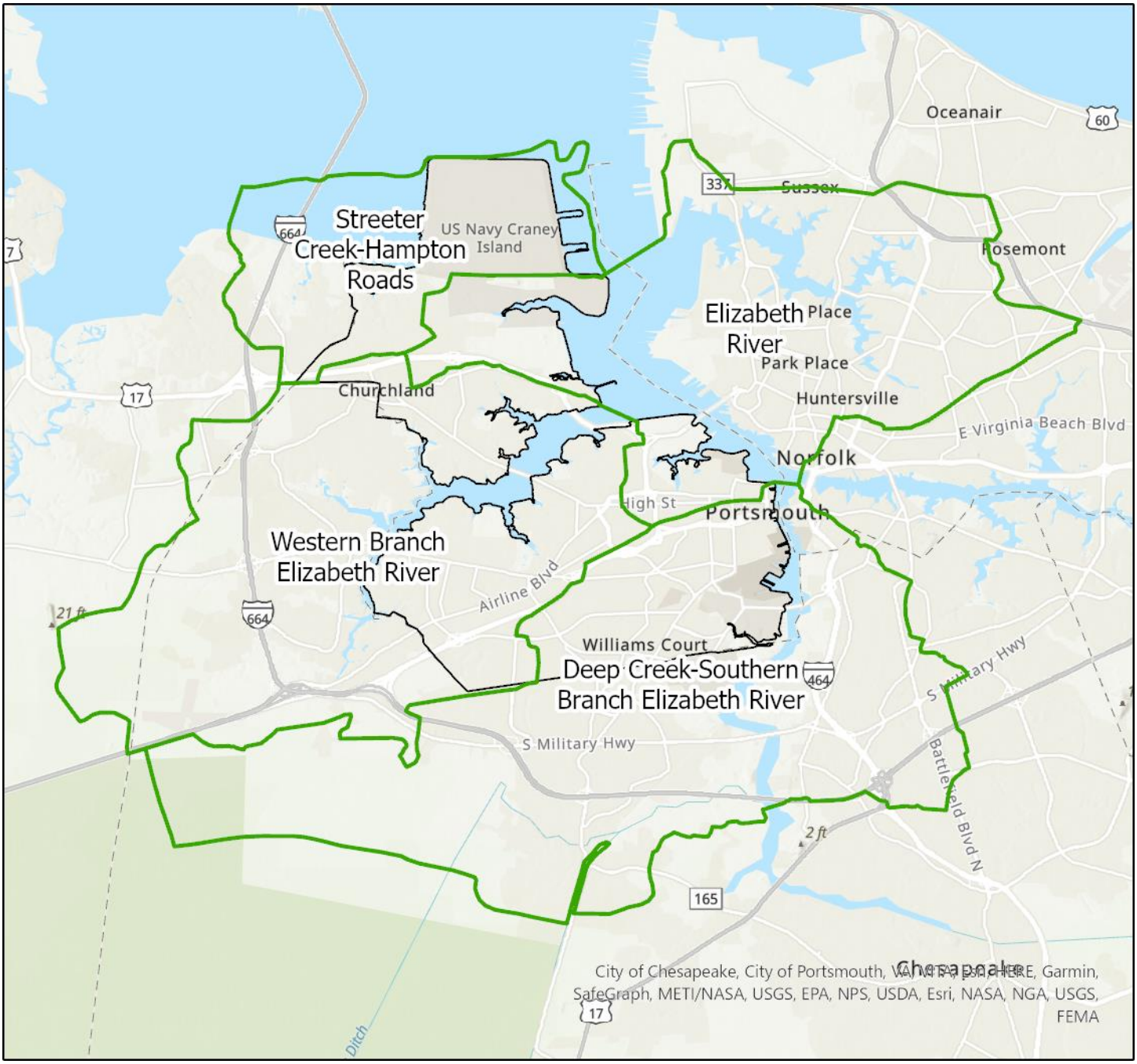


Design Tidal Elevations – Portsmouth

Note: All elevations in feet relative to the North American Vertical Datum (NAVD) of 1988

HUC12	Watershed	Design Level	1-Year	2-Year	3-Year	5-Year	10-Year	25-Year	50-Year	100-Year	500-Year
020802080203	Deep Creek-Southern Branch Elizabeth River	Current	3.4	4.1	4.5	5.1	5.9	6.7	7.3	8.0	10.0
		1.5 ft SLR	4.9	5.6	6.0	6.6	7.4	8.2	8.8	9.5	11.5
		3.0 ft SLR	6.4	7.1	7.5	8.1	8.9	9.7	10.3	11.0	13.0
		4.5 ft SLR	7.9	8.6	9.0	9.6	10.4	11.2	11.8	12.5	14.5
020802080205	Western Branch Elizabeth River	Current	3.7	4.5	4.9	5.4	6.1	7.0	7.9	8.6	10.3
		1.5 ft SLR	5.2	6.0	6.4	6.9	7.6	8.5	9.4	10.1	11.8
		3.0 ft SLR	6.9	7.7	8.1	8.6	9.3	10.2	11.2	11.9	13.6
		4.5 ft SLR	8.4	9.2	9.6	10.1	10.9	11.8	12.7	13.4	15.2
020802080206	Elizabeth River	Current	3.2	3.9	4.4	4.9	5.8	6.5	7.3	7.9	9.9
		1.5 ft SLR	4.7	5.4	5.9	6.4	7.3	8.0	8.8	9.4	11.4
		3.0 ft SLR	6.3	7.1	7.6	8.1	9.0	9.7	10.5	11.2	13.2
		4.5 ft SLR	7.9	8.6	9.1	9.6	10.5	11.3	12.1	12.7	14.7
020802080301	Streeter Creek-Hampton Roads	Current	3.3	4.0	4.5	5.0	5.7	6.6	7.4	8.1	9.9
		1.5 ft SLR	4.8	5.5	6.0	6.5	7.2	8.1	8.9	9.6	11.4
		3.0 ft SLR	6.5	7.2	7.7	8.2	8.9	9.9	10.7	11.4	13.2
		4.5 ft SLR	8.0	8.7	9.2	9.7	10.5	11.4	12.2	12.9	14.8

Figure 13: Watershed Boundaries for Design Tidal Elevations – Portsmouth

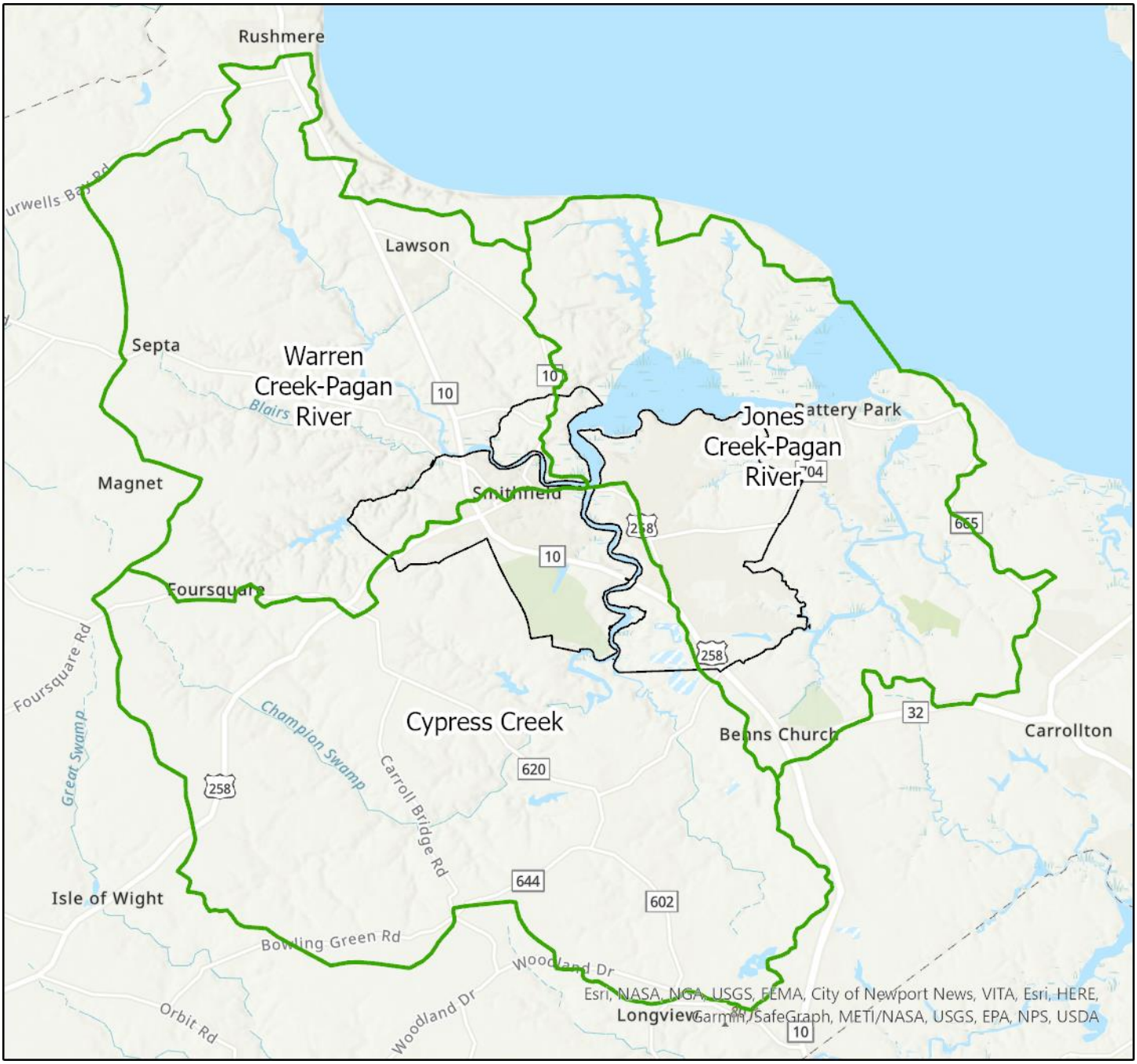


Design Tidal Elevations – Smithfield

Note: All elevations in feet relative to the North American Vertical Datum (NAVD) of 1988

HUC12	Watershed	Design Level	1-Year	2-Year	3-Year	5-Year	10-Year	25-Year	50-Year	100-Year	500-Year
020802060902	Warren Creek-Pagan River	Current	4.0	4.6	5.0	5.5	6.0	6.9	7.8	8.4	9.7
		1.5 ft SLR	5.5	6.1	6.5	7.0	7.5	8.4	9.3	9.9	11.2
		3.0 ft SLR	7.2	7.8	8.2	8.8	9.3	10.2	11.1	11.7	13.1
		4.5 ft SLR	8.8	9.4	9.8	10.3	10.8	11.7	12.7	13.3	14.6
020802060903	Cypress Creek	Current	3.9	4.6	5.0	5.5	6.0	6.9	7.8	8.5	9.8
		1.5 ft SLR	5.4	6.1	6.5	7.0	7.5	8.4	9.3	10.0	11.3
		3.0 ft SLR	7.1	7.8	8.2	8.8	9.3	10.2	11.1	11.8	13.2
		4.5 ft SLR	8.7	9.4	9.8	10.3	10.8	11.7	12.7	13.4	14.7
020802060904	Jones Creek-Pagan River	Current	3.9	4.6	5.0	5.4	5.9	6.8	7.6	8.3	9.5
		1.5 ft SLR	5.4	6.1	6.5	6.9	7.4	8.3	9.1	9.8	11.0
		3.0 ft SLR	7.0	7.8	8.2	8.6	9.1	10.0	10.8	11.5	12.8
		4.5 ft SLR	8.6	9.3	9.7	10.1	10.6	11.5	12.3	13.1	14.3

Figure 14: Watershed Boundaries for Design Tidal Elevations - Smithfield

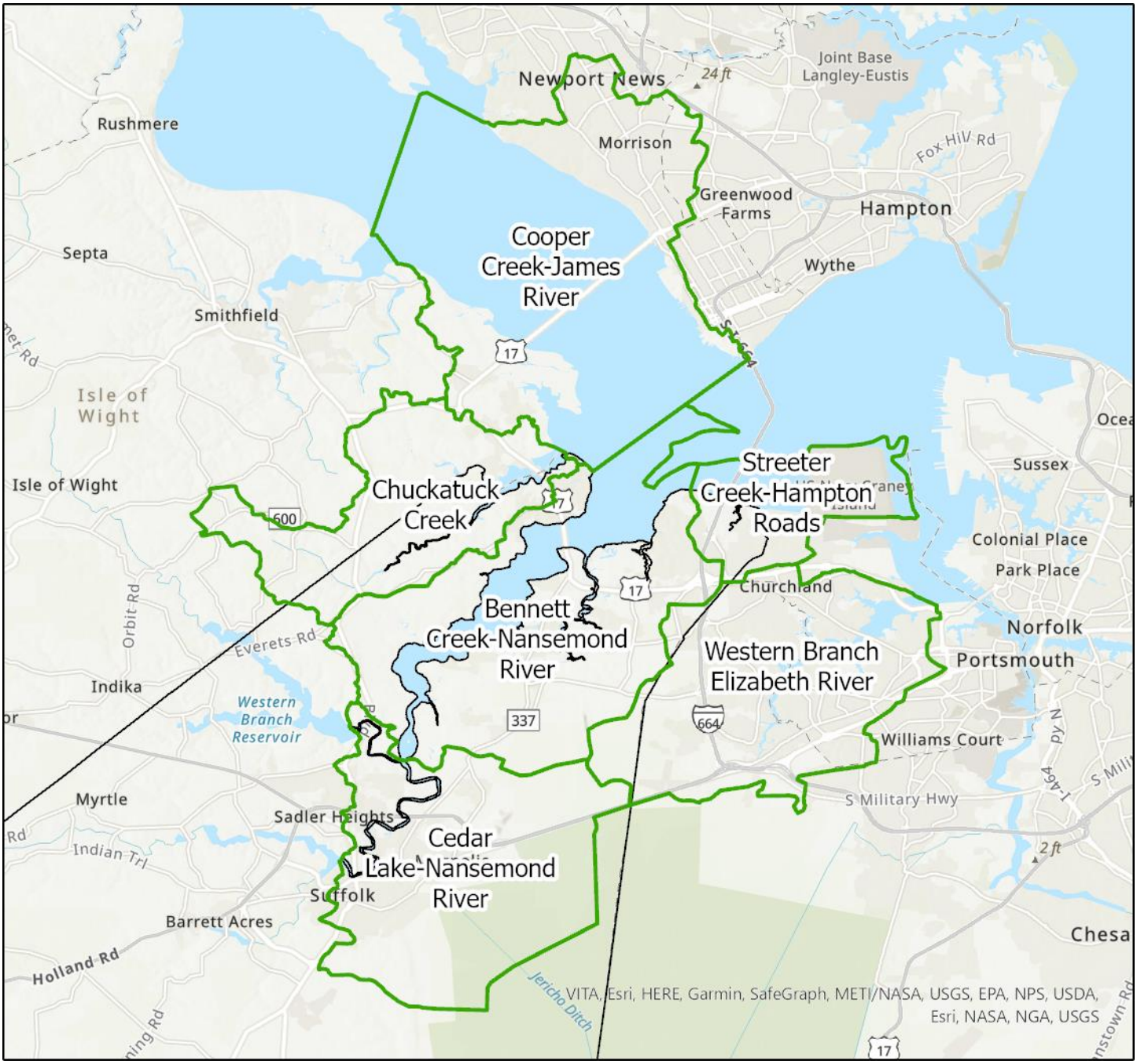


Design Tidal Elevations – Suffolk

Note: All elevations in feet relative to the North American Vertical Datum (NAVD) of 1988

HUC12	Watershed	Design Level	1-Year	2-Year	3-Year	5-Year	10-Year	25-Year	50-Year	100-Year	500-Year
020802060905	Chuckatuck Creek	Current	4.0	4.7	5.1	5.7	6.2	7.3	8.2	8.9	10.4
		1.5 ft SLR	5.5	6.2	6.6	7.2	7.7	8.8	9.7	10.4	11.9
		3.0 ft SLR	7.1	7.8	8.2	8.8	9.3	10.5	11.4	12.1	13.6
		4.5 ft SLR	8.6	9.3	9.7	10.4	10.9	12.0	12.9	13.6	15.1
020802060906	Cooper Creek-James River	Current	3.7	4.4	4.8	5.2	5.8	6.7	7.5	8.1	9.6
		1.5 ft SLR	5.2	5.9	6.3	6.7	7.3	8.2	9.0	9.6	11.1
		3.0 ft SLR	6.9	7.6	8.0	8.4	9.1	10.0	10.8	11.4	13.0
		4.5 ft SLR	8.4	9.2	9.6	10.0	10.6	11.5	12.3	13.0	14.5
020802080105	Cedar Lake-Nansemond River	Current	4.0	4.9	5.4	6.1	6.9	8.0	9.1	9.9	12.0
		1.5 ft SLR	5.5	6.4	6.9	7.6	8.4	9.5	10.6	11.4	13.5
		3.0 ft SLR	7.4	8.3	8.8	9.6	10.4	11.6	12.7	13.6	15.8
		4.5 ft SLR	8.9	9.9	10.4	11.1	12.0	13.1	14.3	15.1	17.3
020802080106	Bennett Creek-Nansemond River	Current	4.0	4.9	5.4	6.0	6.8	7.9	8.9	9.8	11.7
		1.5 ft SLR	5.5	6.4	6.9	7.5	8.3	9.4	10.4	11.3	13.2
		3.0 ft SLR	7.1	8.1	8.6	9.2	10.0	11.1	12.2	13.1	15.0
		4.5 ft SLR	8.7	9.6	10.1	10.7	11.5	12.7	13.7	14.6	16.5
020802080205	Western Branch Elizabeth River	Current	3.7	4.5	4.9	5.4	6.1	7.0	7.9	8.6	10.3
		1.5 ft SLR	5.2	6.0	6.4	6.9	7.6	8.5	9.4	10.1	11.8
		3.0 ft SLR	6.9	7.7	8.1	8.6	9.3	10.2	11.2	11.9	13.6
		4.5 ft SLR	8.4	9.2	9.6	10.1	10.9	11.8	12.7	13.4	15.2
020802080301	Streeter Creek-Hampton Roads	Current	3.3	4.0	4.5	5.0	5.7	6.6	7.4	8.1	9.9
		1.5 ft SLR	4.8	5.5	6.0	6.5	7.2	8.1	8.9	9.6	11.4
		3.0 ft SLR	6.5	7.2	7.7	8.2	8.9	9.9	10.7	11.4	13.2
		4.5 ft SLR	8.0	8.7	9.2	9.7	10.5	11.4	12.2	12.9	14.8

Figure 15: Watershed Boundaries for Design Tidal Elevations - Suffolk

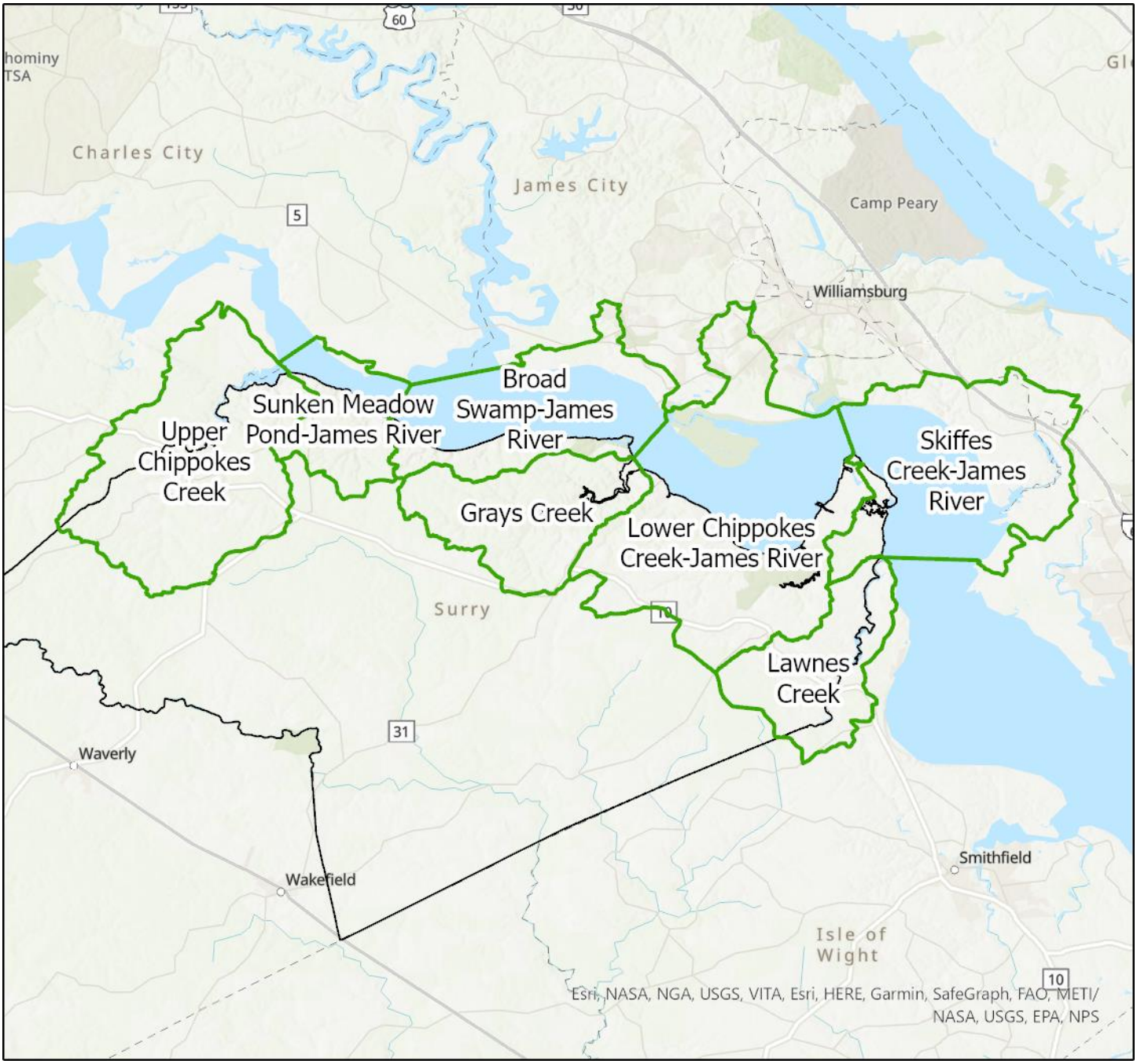


Design Tidal Elevations – Surry County

Note: All elevations in feet relative to the North American Vertical Datum (NAVD) of 1988

HUC12	Watershed	Design Level	1-Year	2-Year	3-Year	5-Year	10-Year	25-Year	50-Year	100-Year	500-Year
020802060303	Upper Chippokes Creek	Current	4.2	4.8	5.1	5.5	6.0	7.0	7.3	7.6	9.0
		1.5 ft SLR	5.7	6.3	6.6	7.0	7.5	8.5	8.8	9.1	10.5
		3.0 ft SLR	7.9	8.6	8.9	9.4	9.9	11.0	11.4	11.7	13.2
		4.5 ft SLR	9.6	10.3	10.6	11.0	11.6	12.7	13.0	13.3	14.9
020802060304	Sunken Meadow Pond-James River	Current	4.0	4.5	4.9	5.3	5.9	6.8	7.2	7.5	9.0
		1.5 ft SLR	5.5	6.0	6.4	6.8	7.4	8.3	8.7	9.0	10.5
		3.0 ft SLR	7.4	7.9	8.4	8.8	9.4	10.4	10.8	11.1	12.7
		4.5 ft SLR	9.0	9.5	10.0	10.4	11.0	12.0	12.4	12.7	14.3
020802060701	Broad Swamp-James River	Current	4.0	4.6	4.9	5.3	5.8	6.7	7.1	7.4	8.8
		1.5 ft SLR	5.5	6.1	6.4	6.8	7.3	8.2	8.6	8.9	10.3
		3.0 ft SLR	7.3	8.0	8.3	8.7	9.2	10.2	10.6	10.9	12.4
		4.5 ft SLR	8.9	9.6	9.9	10.3	10.8	11.8	12.2	12.5	14.0
020802060703	Grays Creek	Current	4.1	4.6	4.9	5.3	5.7	6.6	7.0	7.3	8.5
		1.5 ft SLR	5.6	6.1	6.4	6.8	7.2	8.1	8.5	8.8	10.0
		3.0 ft SLR	7.5	8.0	8.3	8.7	9.2	10.1	10.5	10.8	12.1
		4.5 ft SLR	9.1	9.6	9.9	10.3	10.7	11.7	12.1	12.4	13.7
020802060704	Lower Chippokes Creek-James River	Current	3.9	4.5	4.8	5.2	5.7	6.5	6.9	7.3	8.6
		1.5 ft SLR	5.4	6.0	6.3	6.7	7.2	8.0	8.4	8.8	10.1
		3.0 ft SLR	7.2	7.8	8.1	8.5	9.1	9.9	10.3	10.7	12.1
		4.5 ft SLR	8.7	9.4	9.7	10.1	10.6	11.4	11.9	12.3	13.6
020802060802	Skiffes Creek-James River	Current	3.6	4.2	4.5	4.9	5.6	6.3	6.7	7.1	8.6
		1.5 ft SLR	5.1	5.7	6.0	6.4	7.1	7.8	8.2	8.6	10.1
		3.0 ft SLR	6.9	7.5	7.8	8.2	8.9	9.7	10.1	10.5	12.1
		4.5 ft SLR	8.4	9.0	9.4	9.8	10.5	11.2	11.6	12.1	13.6
020802060803	Lawnes Creek	Current	4.0	4.5	4.8	5.2	5.6	6.4	6.8	7.3	8.4
		1.5 ft SLR	5.5	6.0	6.3	6.7	7.1	7.9	8.3	8.8	9.9
		3.0 ft SLR	7.3	7.8	8.1	8.5	8.9	9.8	10.2	10.7	11.9
		4.5 ft SLR	8.8	9.4	9.7	10.1	10.5	11.3	11.8	12.3	13.4

Figure 16: Watershed Boundaries for Design Tidal Elevations – Surry County

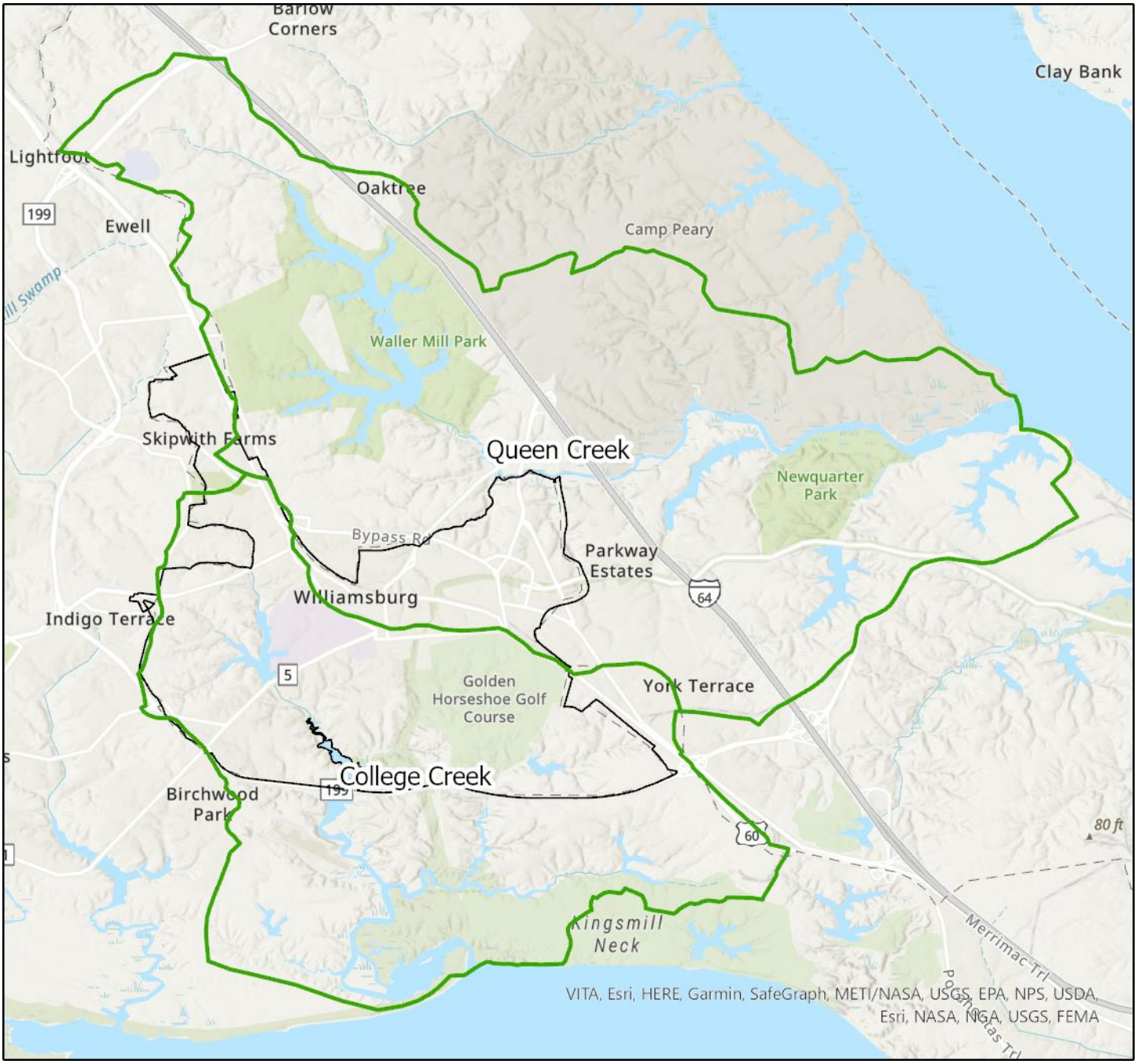


Design Tidal Elevations – Williamsburg

Note: All elevations in feet relative to the North American Vertical Datum (NAVD) of 1988

HUC12	Watershed	Design Level	1-Year	2-Year	3-Year	5-Year	10-Year	25-Year	50-Year	100-Year	500-Year
020801070202	Queen Creek	Current	2.9	3.5	3.9	4.4	5.1	5.9	6.3	6.8	8.6
		1.5 ft SLR	4.4	5.0	5.4	5.9	6.6	7.4	7.8	8.3	10.1
		3.0 ft SLR	6.1	6.7	7.1	7.6	8.4	9.2	9.6	10.1	12.0
		4.5 ft SLR	7.6	8.3	8.7	9.2	9.9	10.8	11.2	11.7	13.5
020802060801	College Creek	Current	3.3	3.9	4.3	4.8	5.6	6.3	6.7	7.1	9.0
		1.5 ft SLR	4.8	5.4	5.8	6.3	7.1	7.8	8.2	8.6	10.5
		3.0 ft SLR	6.6	7.2	7.6	8.1	8.9	9.7	10.1	10.5	12.5
		4.5 ft SLR	8.1	8.7	9.2	9.7	10.5	11.2	11.6	12.1	14.0

Figure 17: Watershed Boundaries for Design Tidal Elevations - Williamsburg

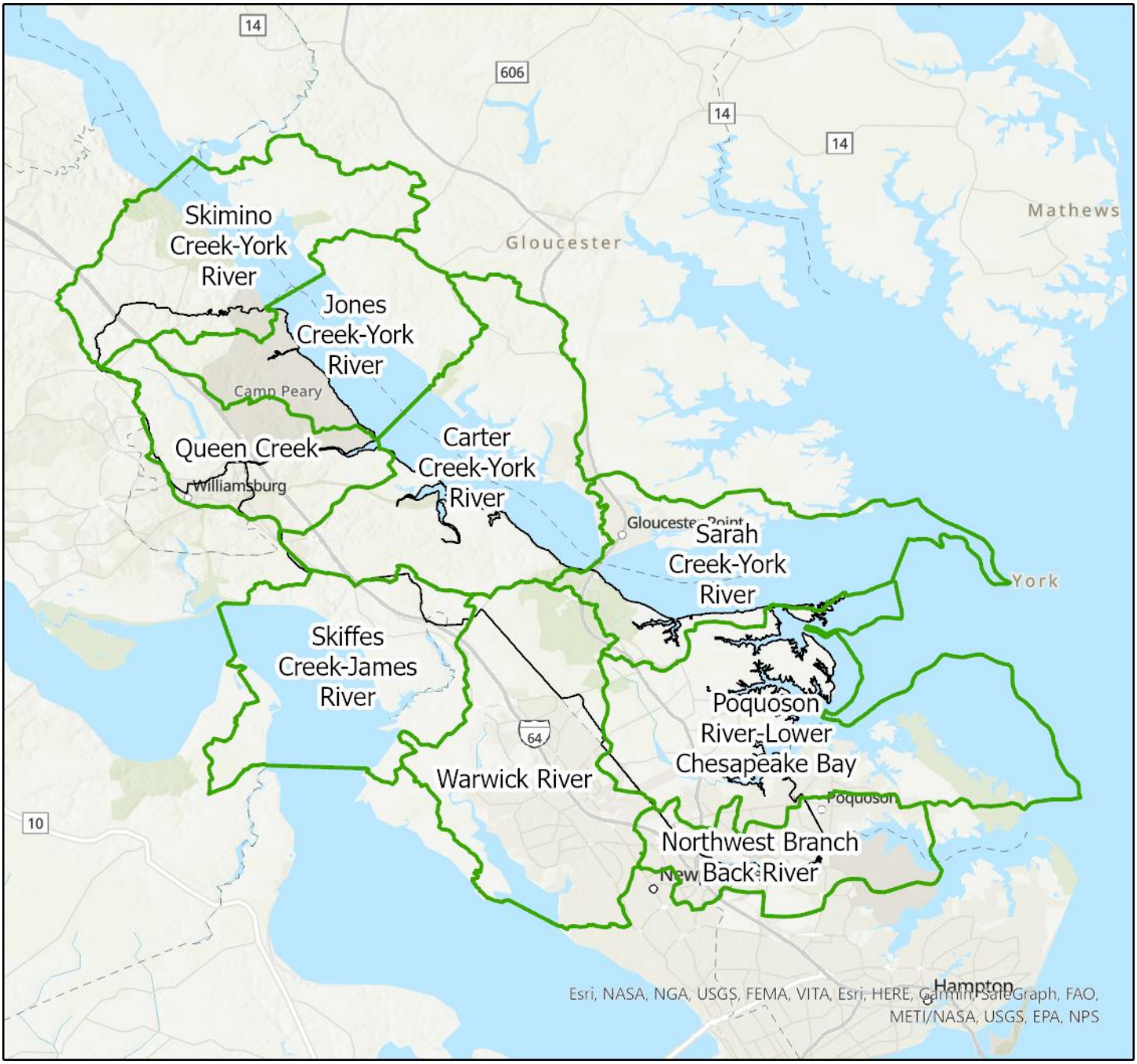


Design Tidal Elevations – York County

Note: All elevations in feet relative to the North American Vertical Datum (NAVD) of 1988

HUC12	Watershed	Design Level	1-Year	2-Year	3-Year	5-Year	10-Year	25-Year	50-Year	100-Year	500-Year
020801070104	Skimino Creek-York River	Current	3.0	3.6	4.0	4.5	5.3	6.1	6.4	6.9	8.8
		1.5 ft SLR	4.5	5.1	5.5	6.0	6.8	7.6	7.9	8.4	10.3
		3.0 ft SLR	6.3	6.9	7.3	7.9	8.7	9.5	9.8	10.4	12.4
		4.5 ft SLR	7.9	8.5	8.9	9.4	10.3	11.1	11.4	11.9	13.9
020801070201	Jones Creek-York River	Current	3.2	3.8	4.1	4.6	5.2	6.0	6.4	6.8	8.5
		1.5 ft SLR	4.7	5.3	5.6	6.1	6.7	7.5	7.9	8.3	10.0
		3.0 ft SLR	6.4	7.0	7.3	7.8	8.5	9.3	9.7	10.1	11.9
		4.5 ft SLR	7.9	8.6	8.9	9.4	10.0	10.8	11.2	11.7	13.4
020801070202	Queen Creek	Current	2.9	3.5	3.9	4.4	5.1	5.9	6.3	6.8	8.6
		1.5 ft SLR	4.4	5.0	5.4	5.9	6.6	7.4	7.8	8.3	10.1
		3.0 ft SLR	6.1	6.7	7.1	7.6	8.4	9.2	9.6	10.1	12.0
		4.5 ft SLR	7.6	8.3	8.7	9.2	9.9	10.8	11.2	11.7	13.5
020801070203	Carter Creek-York River	Current	3.1	3.7	4.0	4.5	5.1	5.8	6.3	6.8	8.3
		1.5 ft SLR	4.6	5.2	5.5	6.0	6.6	7.3	7.8	8.3	9.8
		3.0 ft SLR	6.3	6.9	7.2	7.7	8.3	9.1	9.6	10.1	11.6
		4.5 ft SLR	7.8	8.4	8.7	9.3	9.9	10.6	11.1	11.6	13.2
020801070204	Sarah Creek-York River	Current	3.0	3.6	3.9	4.3	4.9	5.5	6.1	6.6	7.9
		1.5 ft SLR	4.5	5.1	5.4	5.8	6.4	7.0	7.6	8.1	9.4
		3.0 ft SLR	6.1	6.7	7.1	7.5	8.1	8.7	9.3	9.8	11.1
		4.5 ft SLR	7.7	8.3	8.6	9.0	9.6	10.2	10.8	11.4	12.7
020801080101	Poquoson River-Lower Chesapeake Bay	Current	2.8	3.5	3.9	4.4	5.1	5.9	6.8	7.4	9.0
		1.5 ft SLR	4.3	5.0	5.4	5.9	6.6	7.4	8.3	8.9	10.5
		3.0 ft SLR	5.9	6.6	7.0	7.5	8.3	9.1	10.0	10.6	12.2
		4.5 ft SLR	7.4	8.2	8.6	9.1	9.8	10.6	11.5	12.1	13.8
020801080102	Northwest Branch Back River	Current	3.2	3.9	4.3	4.9	5.6	6.4	7.2	7.9	9.6
		1.5 ft SLR	4.7	5.4	5.8	6.4	7.1	7.9	8.7	9.4	11.1
		3.0 ft SLR	6.4	7.1	7.5	8.1	8.8	9.6	10.5	11.2	12.9
		4.5 ft SLR	7.9	8.6	9.0	9.6	10.4	11.2	12.0	12.7	14.5
020802060802	Skiffes Creek-James River	Current	3.6	4.2	4.5	4.9	5.6	6.3	6.7	7.1	8.6
		1.5 ft SLR	5.1	5.7	6.0	6.4	7.1	7.8	8.2	8.6	10.1
		3.0 ft SLR	6.9	7.5	7.8	8.2	8.9	9.7	10.1	10.5	12.1
		4.5 ft SLR	8.4	9.0	9.4	9.8	10.5	11.2	11.6	12.1	13.6
020802060901	Warwick River	Current	3.7	4.2	4.6	5.0	5.6	6.3	6.8	7.2	8.7
		1.5 ft SLR	5.2	5.7	6.1	6.5	7.1	7.8	8.3	8.7	10.2
		3.0 ft SLR	7.1	7.7	8.1	8.5	9.2	9.9	10.4	10.9	12.5
		4.5 ft SLR	8.7	9.3	9.7	10.1	10.8	11.5	12.0	12.5	14.1

Figure 18: Watershed Boundaries for Design Tidal Elevations – York County



Design Rainfall Depths – Methodology

The goal of this effort is to develop design rainfall depths for communities in Hampton Roads that account for project climate change for use as inputs for stormwater management calculations. Design rainfall depths are commonly based on the NOAA Atlas 14 Precipitation-Frequency Atlas for the United States. Virginia is included in Volume 2, which covers the states in and around the Ohio River basin. Volume 2 was last published in 2004 and revised in 2006. It only includes data through 2000, so does not account for observed changes in precipitation patterns since then, nor does it account for future climate change.

This analysis is based on two previous projects. The first was conducted by the City of Virginia Beach to help inform the development of the city's revised public facilities manual. The second was completed by RAND and the Mid-Atlantic Regional Integrated Sciences and Assessments (MARISA) program to develop a Chesapeake Bay watershed-wide tool for the Chesapeake Bay Program. Both efforts use NOAA's Atlas 14[4] precipitation data as a starting point along with multiple downscaled climate projections to generate future precipitation values.

The primary deliverable from the RAND study was the development of change factors for individual counties and county-equivalent units (e.g., independent cities in Virginia) in the Chesapeake Bay watershed and all of Virginia (Figure 5). Change factors are multipliers applied to values from the current NOAA Atlas 14 volume to generate estimates that correspond to future climate conditions.

Future Precipitation = NOAA Atlas 14 Precipitation x Change Factor

Change factors were developed for different combinations of climate scenarios, time periods, and recurrence intervals. For example, a change factor would be calculated for the 2-year recurrence interval for 2020-2069 under representative concentration pathway 4.5.

- Climate scenarios: representative concentration pathways (RCPs) 4.5 and 8.5[5]
- Time periods: 2020-2069 and 2050-2099 (baseline time period is 1950-2000)
- Recurrence intervals: 2-year, 5-year, 10-year, 25-year, 50-year, and 100-year

In order to account for uncertainty, the RAND/MARISA team calculated multiple values for each factor, including the 10th-percentile, 25th-percentile, 50th-percentile, 75th-percentile, and 90th-percentile, in addition to minimum and maximum values.

[4] NOAA Atlas 14 Precipitation-Frequency Atlas of the United States, Volume 2 (2006) https://www.weather.gov/media/owp/oh/hdsc/docs/Atlas14_Volume2.pdf

[5] Representative concentration pathways (RCPs) are greenhouse gas emissions scenarios based on different assumptions about energy usage and economic activity in the future. RCP 4.5 represents a decline in emissions around 2045. RCP 8.5 represents increasing emissions through the 21st century.

The Virginia Beach study[6] included both a statistical analysis of rainfall data after the cutoff for NOAA Atlas 14 and projections of future rainfall with climate change. The analysis found that the current 10-year event was approximately 10% larger in the Hampton Roads region than what is in NOAA Atlas 14. The climate analysis also considered both climate scenarios RCP 4.5 and RCP 8.5. The Virginia Beach study included mid-term (2045) and long-term (2075) estimates for the 24-hour rainfall duration for the 1-year, 2-year, 5-year, 10-year, 20-year, 50-year, and 100-year return periods. The study also modeled historical values to compare with NOAA Atlas 14. The change between the modeled historical value and the future projected value ranged from 11% to 23% for the mid-term and from 19% to 36% for the long-term. Although the Virginia Beach study provided both mid-term and long-term estimates of future rainfall depths for each return period, the final recommendation was for the city to apply a 20% increase above NOAA Atlas 14 values for all return periods instead of using the individual calculated values.

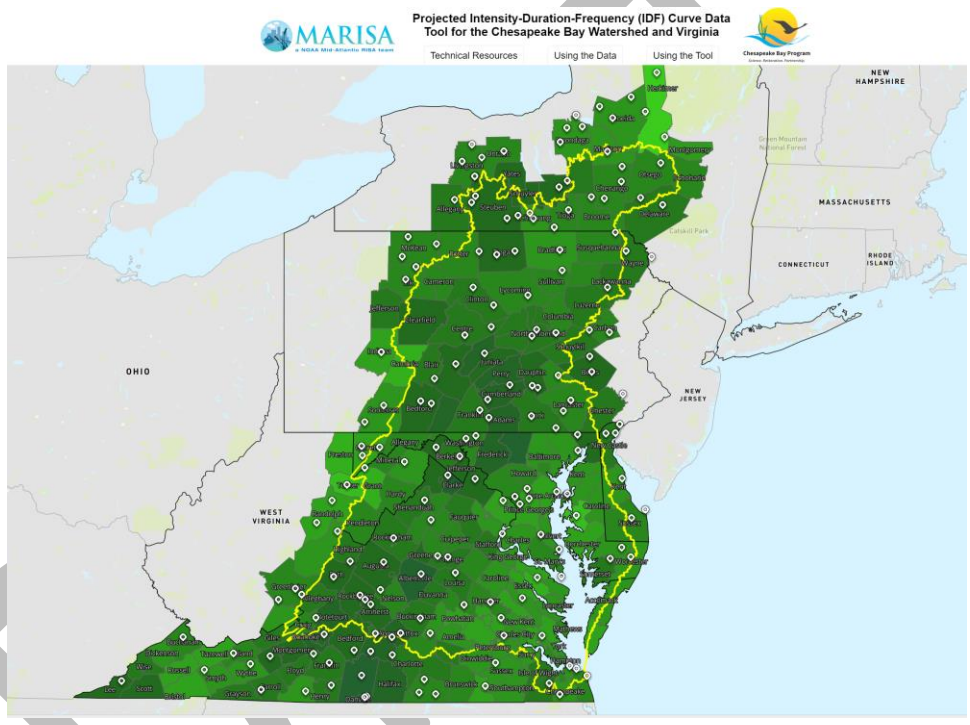


Figure 19: Screenshot of MARISA IDF Curve Data Tool Showing Median County Change Factors[7]

For these guidelines, the results of the MARISA tool were used in conjunction with the approach used by Virginia Beach to calculate an average multiplier for each locality. For each locality, all median values for all 2020-2070 scenarios (2-year through 100-year storm events, RCP 4.5 and RCP 8.5) were averaged to calculate a single median multiplier. The same was done for all 75th percentile values for each locality. The average median and 75th percentile change factors for each locality are listed below. The final recommended multiplier for each locality was then selected from either the average of the median

[6] "Analysis of Historical and Future Heavy Precipitation," March 26, 2018 (CIP 7-030, PWCN-15-0014, Work Order 9A) https://www.vbgov.com/government/departments/public-works/comp-sea-level-rise/Documents/anaylsis-hist-and-future-hvy-precip-4-2-18.pdf

[7] Projected Intensity-Duration-Frequency (IDF) Curve Data Tool for the Chesapeake Bay Watershed and Virginia (https://midatlantic-idf.rcc-acis.org/)

values or the average of the 75th percentile values based on existing impervious cover. The methodology for calculating impervious cover is described below.

Table 2: Average Median and 75th Percentile Change Factors for Hampton Roads Localities

Locality	Median	75th Percentile
Chesapeake	1.10	1.21
Franklin	1.12	1.21
Gloucester County	1.06	1.14
Hampton	1.08	1.18
Isle of Wight County	1.12	1.20
James City County	1.05	1.13
Newport News	1.08	1.17
Norfolk	1.09	1.22
Poquoson	1.07	1.18
Portsmouth	1.09	1.21
Southampton County	1.09	1.19
Suffolk	1.13	1.21
Surry County	1.08	1.16
Virginia Beach	1.10	1.20
Williamsburg	1.04	1.13
York County	1.06	1.14

Impervious Cover Calculations

Impervious cover for each locality was calculated using the best available one-meter resolution land cover data. For Franklin, Smithfield, and Southampton County, the source of the data was the 2013-2014 land cover data developed by Worldview Solutions and the Virginia Geographic Information Network. For all other localities, draft data from the 2018 Chesapeake Bay High Resolution Land Cover was acquired from the Chesapeake Conservancy and used instead. Data from the 2013-2014 is available online at the Chesapeake Conservancy website.[8] Data from the 2018 update is expected to be available for download through the same website in early 2022.

To calculate the percentage of impervious cover using the 2013-2014 data, locality boundaries for all seventeen jurisdictions were clipped using a shoreline file to remove major tidal water bodies. Federal properties such as Department of Defense installations and Department of the Interior facilities were then removed to identify those areas within each locality that are under local authority. The 2013-2014 land cover data is divided into twelve classifications.[9] For the 2013-2014 data, the percentage of impervious cover was calculated using the following function.

[8] https://www.chesapeakeconservancy.org/conservation-innovation-center/high-resolution-data/land-cover-data-project/

[9] Hydro, Impervious (extracted), Impervious (local), Barren, Forest, Tree, Scrub/Shrub, Harvested/Disturbed, Turf Grass, Pasture, Cropland, Woody Wetlands

$$\text{Impervious Cover Percentage} = \frac{\text{(Impervious (Extracted) + Impervious (Local))}}{\text{(All Land Cover Classifications minus Hydro)}}$$

The 2018 data was only provided in tabular format. The 2018 land cover data is divided into eleven classifications.[10] For the 2018 data, the percentage of impervious cover was calculated using the following function.

$$\text{Impervious Cover Percentage} = \frac{\text{(Impervious Structures + Other Impervious + Impervious Roads)}}{\text{(All Land Cover Classifications minus Water)}}$$

Impervious cover percentages for Hampton Roads localities range from less than two percent in Southampton County and Surry County to over fifty percent in Norfolk. The results of this analysis are listed below.

Table 3: Impervious Cover Percentages for Hampton Roads Localities

Locality	2013-2014	2018
Chesapeake	11.78%	10.82%
Franklin	14.89%	N/A*
Gloucester County	3.23%	4.33%
Hampton	36.89%	40.07%
Isle of Wight County	3.93%	4.28%
James City County	9.71%	10.37%
Newport News	38.98%	38.49%
Norfolk	48.59%	52.07%
Poquoson	14.91%	12.21%
Portsmouth	44.13%	41.40%
Smithfield	17.72%	N/A**
Southampton County	1.42%	N/A*
Suffolk	6.40%	5.70%
Surry County	1.41%	1.82%
Virginia Beach	22.54%	19.41%
Williamsburg	19.98%	24.16%
York County	14.91%	14.06%

* 2018 land cover data for Franklin and Southampton County is not expected to be developed, since both localities are outside of the Chesapeake Bay watershed.
** 2018 land cover data for Smithfield is expected to become available once the data is released in raster format.

[10] Water, Tree Canopy, Scrub/Shrub, Herbaceous, Barren, Impervious Structures, Other Impervious, Impervious Roads, Tree Canopy over Impervious Structures, Tree Canopy over Other Impervious, Tree Canopy over Impervious Roads

Development of Recommended Multipliers

Recommended multipliers for each locality were calculated based on either the average median or average 75th percentile for 2020-2070. For localities with less than 10% impervious cover, the average median value was used, while the average 75th percentile value was used for localities with greater than 10% impervious cover. For ease of use, these average multipliers were rounded to the nearest 0.05, with a minimum multiplier of 1.10 (10% increase above NOAA Atlas 14). The recommended multipliers Hampton Roads localities are listed below. Recommended precipitation values for each locality are included in the individual locality summaries.

Table 4: Recommended Multipliers for Hampton Roads Localities

Locality	Recommended Multiplier
Chesapeake	1.2
Franklin	1.2
Gloucester County	1.1
Hampton	1.2
Isle of Wight County	1.1
James City County	1.15
Newport News	1.15
Norfolk	1.2
Poquoson	1.2
Portsmouth	1.2
Smithfield*	1.2
Southampton County	1.1
Suffolk	1.15
Surry County	1.1
Virginia Beach	1.2
Williamsburg	1.15
York County	1.15

* The recommended multiplier for Smithfield is based on the 75th percentile value for Isle of Wight County due to the town's impervious cover percentage.

Methodology for Design Rainfall Depths[11]

1. Calculate centroid of locality in ArcGIS using Convert Feature To Point
2. Use Extract Multi Values to Points to append NOAA Atlas 14 rainfall depths[12] to Locality Centroid Feature
3. Export Feature and convert to Excel format
4. Multiply NOAA Atlas 14 rainfall depths for locality centroids by recommended change factor to calculate future rainfall depths for 2020-2070

[11] This methodology is used for all localities except for Virginia Beach, which establish a separate representative point as part of adopting the city's Public Works Design Standards Manual in June 2020.

[12] NOAA Atlas 14 GIS data was obtained from NOAA's Precipitation Frequency Data Server (PF Data Server-PFDS/HDSC/OWP (noaa.gov))

Design Rainfall Depths for Hampton Roads Localities

Notes:

1. All values are in inches.
2. All values are for the 24-hour duration event.
3. Atlas 14 values are for the centroid of each locality unless otherwise noted.

Recommended Design Rainfall Depths - Chesapeake

Table 5: NOAA Atlas 14 (Vol. 2) Precipitation Values for Chesapeake, Virginia

Design Storm	Minimum	Maximum	Mean	Median	90th Percentile	Centroid
1-Year	2.95	3.08	3.03	3.03	3.07	3.04
2-Year	3.59	3.75	3.69	3.69	3.74	3.70
5-Year	4.64	4.84	4.76	4.76	4.82	4.78
10-Year	5.53	5.76	5.67	5.67	5.74	5.69
25-Year	6.85	7.12	7.01	7.01	7.10	7.04
50-Year	7.98	8.29	8.17	8.17	8.26	8.19
100-Year	9.23	9.58	9.44	9.44	9.54	9.47

Table 6: Recommended Design Rainfall Depths for Chesapeake, Virginia

Design Storm Frequency	NOAA Atlas 14 Rainfall (24-Hour Duration)	Design Rainfall (NOAA Atlas 14 * Multiplier)
1-Year	3.04	**3.65**
2-Year	3.70	**4.44**
5-Year	4.78	**5.73**
10-Year	5.69	**6.83**
25-Year	7.04	**8.44**
50-Year	8.19	**9.83**
100-Year	9.47	**11.36**

Notes:

1. All values are in inches.
2. All values are for the 24-hour duration event.
3. NOAA Atlas 14 rainfall values for Recommended Design Rainfall Depths are based on the centroid of the city (latitude 36.6793761, longitude -76.3017883).

Recommended Design Rainfall Depths - Franklin

Table 7: NOAA Atlas 14 (Vol. 2) Precipitation Values for Franklin, Virginia

Design Storm	Minimum	Maximum	Mean	Median	90th Percentile	Centroid
1-Year	2.94	2.96	2.95	2.95	2.96	2.95
2-Year	3.57	3.60	3.59	3.59	3.59	3.59
5-Year	4.61	4.64	4.62	4.62	4.64	4.63
10-Year	5.48	5.52	5.50	5.50	5.52	5.50
25-Year	6.76	6.81	6.79	6.79	6.81	6.79
50-Year	7.86	7.92	7.89	7.90	7.92	7.90
100-Year	9.07	9.13	9.10	9.11	9.13	9.11

Table 8: Recommended Design Rainfall Depths for Franklin, Virginia

Design Storm Frequency	NOAA Atlas 14 Rainfall (24-Hour Duration)	Design Rainfall (NOAA Atlas 14 * Multiplier)
1-Year	2.95	**3.54**
2-Year	3.59	**4.31**
5-Year	4.63	**5.55**
10-Year	5.50	**6.6**
25-Year	6.79	**8.15**
50-Year	7.90	**9.48**
100-Year	9.11	**10.93**

Notes:

1. All values are in inches.
2. All values are for the 24-hour duration event.
3. NOAA Atlas 14 rainfall values for Recommended Design Rainfall Depths are based on the centroid of the city (latitude 36.6840142, longitude -76.9413955).

Recommended Design Rainfall Depths – Gloucester County

Table 9: NOAA Atlas 14 (Vol. 2) Precipitation Values for Gloucester County, Virginia

Design Storm	Minimum	Maximum	Mean	Median	90th Percentile	Centroid
1-Year	2.78	2.92	2.86	2.86	2.91	2.87
2-Year	3.38	3.55	3.48	3.48	3.53	3.49
5-Year	4.38	4.60	4.51	4.52	4.58	4.52
10-Year	5.24	5.49	5.39	5.40	5.47	5.41
25-Year	6.54	6.83	6.72	6.73	6.81	6.74
50-Year	7.67	7.99	7.88	7.89	7.97	7.90
100-Year	8.93	9.28	9.17	9.18	9.26	9.19

Table 10: Recommended Design Rainfall Depths for Gloucester County, Virginia

Design Storm Frequency	NOAA Atlas 14 Rainfall (24-Hour Duration)	Design Rainfall (NOAA Atlas 14 * Multiplier)
1-Year	2.87	**3.15**
2-Year	3.49	**3.84**
5-Year	4.52	**4.97**
10-Year	5.41	**5.95**
25-Year	6.74	**7.41**
50-Year	7.90	**8.69**
100-Year	9.19	**10.11**

Notes:

1. All values are in inches.
2. All values are for the 24-hour duration event.
3. NOAA Atlas 14 rainfall values for Recommended Design Rainfall Depths are based on the centroid of the county (latitude 37.4035413, longitude -76.523505).

Recommended Design Rainfall Depths - Hampton

Table 11: NOAA Atlas 14 (Vol. 2) Precipitation Values for Hampton, Virginia

Design Storm	Minimum	Maximum	Mean	Median	90th Percentile	Centroid
1-Year	2.92	2.95	2.94	2.94	2.94	2.94
2-Year	3.56	3.59	3.57	3.57	3.58	3.58
5-Year	4.61	4.64	4.63	4.63	4.64	4.63
10-Year	5.50	5.54	5.53	5.53	5.54	5.53
25-Year	6.82	6.89	6.87	6.87	6.88	6.88
50-Year	7.97	8.07	8.04	8.04	8.06	8.05
100-Year	9.23	9.38	9.33	9.33	9.36	9.35

Table 12: Recommended Design Rainfall Depths for Hampton, Virginia

Design Storm Frequency	NOAA Atlas 14 Rainfall (24-Hour Duration)	Design Rainfall (NOAA Atlas 14 * Multiplier)
1-Year	2.94	**3.52**
2-Year	3.58	**4.29**
5-Year	4.63	**5.56**
10-Year	5.53	**6.64**
25-Year	6.88	**8.26**
50-Year	8.05	**9.66**
100-Year	9.35	**11.22**

Notes:

1. All values are in inches.
2. All values are for the 24-hour duration event.
3. NOAA Atlas 14 rainfall values for Recommended Design Rainfall Depths are based on the centroid of the city (latitude 37.0480302, longitude -76.2971486).

Recommended Design Rainfall Depths – Isle of Wight County

Table 13: Atlas 14 (Vol. 2) Precipitation Values for Isle of Wight County, Virginia

Design Storm	Minimum	Maximum	Mean	Median	90th Percentile	Centroid
1-Year	2.92	2.98	2.95	2.96	2.97	2.96
2-Year	3.56	3.62	3.59	3.60	3.61	3.60
5-Year	4.59	4.68	4.64	4.64	4.66	4.65
10-Year	5.47	5.57	5.53	5.53	5.55	5.53
25-Year	6.75	6.88	6.83	6.84	6.87	6.83
50-Year	7.85	8.02	7.95	7.96	8.00	7.95
100-Year	9.06	9.27	9.19	9.19	9.25	9.18

Table 14: Recommended Design Rainfall Depths for Isle of Wight County, Virginia

Design Storm Frequency	NOAA Atlas 14 Rainfall (24-Hour Duration)	Design Rainfall (NOAA Atlas 14 * Multiplier)
1-Year	2.96	**3.26**
2-Year	3.60	**3.96**
5-Year	4.65	**5.11**
10-Year	5.53	**6.08**
25-Year	6.83	**7.52**
50-Year	7.95	**8.75**
100-Year	9.18	**10.1**

Notes:

1. All values are in inches.
2. All values are for the 24-hour duration event.
3. NOAA Atlas 14 rainfall values for Recommended Design Rainfall Depths are based on the centroid of the county (latitude 36.9014184, longitude -76.7075687).

Recommended Design Rainfall Depths – James City County

Table 15: Atlas 14 (Vol. 2) Precipitation Values for James City County, Virginia

Design Storm	Minimum	Maximum	Mean	Median	90th Percentile	Centroid
1-Year	2.83	2.94	2.90	2.90	2.94	2.92
2-Year	3.44	3.58	3.52	3.53	3.57	3.55
5-Year	4.44	4.63	4.56	4.56	4.62	4.59
10-Year	5.30	5.52	5.44	5.44	5.51	5.47
25-Year	6.59	6.85	6.74	6.75	6.83	6.78
50-Year	7.71	8.00	7.88	7.89	7.98	7.91
100-Year	8.95	9.29	9.14	9.14	9.24	9.17

Table 16: Recommended Design Rainfall Depths for James City County, Virginia

Design Storm Frequency	NOAA Atlas 14 Rainfall (24-Hour Duration)	Design Rainfall (NOAA Atlas 14 * Multiplier)
1-Year	2.92	**3.35**
2-Year	3.55	**4.08**
5-Year	4.59	**5.27**
10-Year	5.47	**6.29**
25-Year	6.78	**7.79**
50-Year	7.91	**9.1**
100-Year	9.17	**10.55**

Notes:

1. All values are in inches.
2. All values are for the 24-hour duration event.
3. NOAA Atlas 14 rainfall values for Recommended Design Rainfall Depths are based on the centroid of the county (latitude 37.3244273, longitude -76.7783194).

Recommended Design Rainfall Depths – Newport News

Table 17: Atlas 14 (Vol. 2) Precipitation Values for Newport News, Virginia

Design Storm	Minimum	Maximum	Mean	Median	90th Percentile	Centroid
1-Year	2.93	2.95	2.94	2.94	2.95	2.94
2-Year	3.57	3.59	3.58	3.58	3.59	3.58
5-Year	4.62	4.65	4.63	4.63	4.64	4.63
10-Year	5.51	5.54	5.53	5.52	5.54	5.53
25-Year	6.84	6.87	6.86	6.86	6.87	6.86
50-Year	7.99	8.04	8.01	8.01	8.02	8.01
100-Year	9.26	9.33	9.29	9.29	9.31	9.30

Table 18: Recommended Design Rainfall Depths for Newport News, Virginia

Design Storm Frequency	NOAA Atlas 14 Rainfall (24-Hour Duration)	Design Rainfall (NOAA Atlas 14 * Multiplier)
1-Year	2.94	**3.38**
2-Year	3.58	**4.11**
5-Year	4.63	**5.32**
10-Year	5.53	**6.35**
25-Year	6.86	**7.89**
50-Year	8.01	**9.22**
100-Year	9.30	**10.69**

Notes:

1. All values are in inches.
2. All values are for the 24-hour duration event.
3. NOAA Atlas 14 rainfall values for Recommended Design Rainfall Depths are based on the centroid of the city (latitude 37.0759783, longitude -76.5217186).

Recommended Design Rainfall Depths - Norfolk

Table 19: Atlas 14 (Vol. 2) Precipitation Values for Norfolk, Virginia

Design Storm	Minimum	Maximum	Mean	Median	90th Percentile	Centroid
1-Year	2.92	2.96	2.94	2.93	2.95	2.93
2-Year	3.55	3.60	3.57	3.57	3.59	3.56
5-Year	4.59	4.65	4.62	4.61	4.64	4.60
10-Year	5.47	5.55	5.50	5.50	5.53	5.49
25-Year	6.78	6.87	6.82	6.82	6.85	6.80
50-Year	7.91	8.01	7.95	7.95	7.98	7.93
100-Year	9.16	9.27	9.20	9.20	9.23	9.18

Table 20: Recommended Design Rainfall Depths for Norfolk, Virginia

Design Storm Frequency	NOAA Atlas 14 Rainfall (24-Hour Duration)	Design Rainfall (NOAA Atlas 14 * Multiplier)
1-Year	2.93	**3.51**
2-Year	3.56	**4.28**
5-Year	4.60	**5.52**
10-Year	5.49	**6.59**
25-Year	6.80	**8.16**
50-Year	7.93	**9.51**
100-Year	9.18	**11.01**

Notes:

1. All values are in inches.
2. All values are for the 24-hour duration event.
3. NOAA Atlas 14 rainfall values for Recommended Design Rainfall Depths are based on the centroid of the city (latitude 36.9230148, longitude -76.2446413).

Recommended Design Rainfall Depths - Poquoson

Table 21: Atlas 14 (Vol. 2) Precipitation Values for Poquoson, Virginia

Design Storm	Minimum	Maximum	Mean	Median	90th Percentile	Centroid
1-Year	2.92	2.93	2.93	2.93	2.93	2.93
2-Year	3.55	3.57	3.56	3.56	3.57	3.56
5-Year	4.60	4.62	4.61	4.62	4.62	4.62
10-Year	5.50	5.53	5.52	5.52	5.53	5.52
25-Year	6.85	6.88	6.87	6.87	6.88	6.87
50-Year	8.03	8.06	8.05	8.05	8.06	8.05
100-Year	9.33	9.37	9.35	9.36	9.37	9.36

Table 22: Recommended Design Rainfall Depths for Poquoson, Virginia

Design Storm Frequency	NOAA Atlas 14 Rainfall (24-Hour Duration)	Design Rainfall (NOAA Atlas 14 * Multiplier)
1-Year	2.93	**3.51**
2-Year	3.56	**4.27**
5-Year	4.62	**5.54**
10-Year	5.52	**6.63**
25-Year	6.87	**8.25**
50-Year	8.05	**9.66**
100-Year	9.36	**11.23**

Notes:

1. All values are in inches.
2. All values are for the 24-hour duration event.
3. NOAA Atlas 14 rainfall values for Recommended Design Rainfall Depths are based on the centroid of the city (latitude 37.1283599, longitude -76.3035337).

Recommended Design Rainfall Depths - Portsmouth

Table 23: Atlas 14 (Vol. 2) Precipitation Values for Portsmouth, Virginia

Design Storm	Minimum	Maximum	Mean	Median	90th Percentile	Centroid
1-Year	2.95	2.99	2.97	2.97	2.98	2.97
2-Year	3.59	3.63	3.61	3.61	3.63	3.61
5-Year	4.64	4.69	4.66	4.66	4.68	4.66
10-Year	5.53	5.59	5.56	5.56	5.58	5.55
25-Year	6.85	6.91	6.88	6.88	6.90	6.88
50-Year	7.99	8.06	8.02	8.02	8.04	8.01
100-Year	9.24	9.31	9.27	9.27	9.30	9.27

Table 24: Recommended Design Rainfall Depths for Portsmouth, Virginia

Design Storm Frequency	NOAA Atlas 14 Rainfall (24-Hour Duration)	Design Rainfall (NOAA Atlas 14 * Multiplier)
1-Year	2.97	**3.56**
2-Year	3.61	**4.33**
5-Year	4.66	**5.59**
10-Year	5.55	**6.66**
25-Year	6.88	**8.25**
50-Year	8.01	**9.62**
100-Year	9.27	**11.12**

Notes:

1. All values are in inches.
2. All values are for the 24-hour duration event.
3. NOAA Atlas 14 rainfall values for Recommended Design Rainfall Depths are based on the centroid of the city (latitude 36.8594298, longitude -76.3562686).

Recommended Design Rainfall Depths – Smithfield

Table 25: Atlas 14 (Vol. 2) Precipitation Values for Smithfield, Virginia

Design Storm	Minimum	Maximum	Mean	Median	90th Percentile	Centroid
1-Year	2.95	2.96	2.95	2.95	2.96	2.95
2-Year	3.59	3.60	3.59	3.59	3.60	3.59
5-Year	4.63	4.65	4.64	4.64	4.65	4.64
10-Year	5.52	5.54	5.53	5.53	5.54	5.53
25-Year	6.84	6.86	6.85	6.85	6.86	6.85
50-Year	7.97	8.00	7.99	7.99	8.00	7.98
100-Year	9.21	9.25	9.24	9.24	9.25	9.24

Table 26: Recommended Design Rainfall Depths for Smithfield, Virginia

Design Storm Frequency	NOAA Atlas 14 Rainfall (24-Hour Duration)	Design Rainfall (NOAA Atlas 14 * Multiplier)
1-Year	2.95	**3.54**
2-Year	3.59	**4.31**
5-Year	4.64	**5.57**
10-Year	5.53	**6.64**
25-Year	6.85	**8.22**
50-Year	7.98	**9.58**
100-Year	9.24	**11.08**

Notes:

1. All values are in inches.
2. All values are for the 24-hour duration event.
3. NOAA Atlas 14 rainfall values for Recommended Design Rainfall Depths are based on the centroid of the town (latitude 36.9718727, longitude -76.612997).

Recommended Design Rainfall Depths – Southampton County

Table 27: Atlas 14 (Vol. 2) Precipitation Values for Southampton County, Virginia

Design Storm	Minimum	Maximum	Mean	Median	90th Percentile	Centroid
1-Year	2.70	2.97	2.87	2.88	2.94	2.87
2-Year	3.28	3.61	3.49	3.50	3.57	3.49
5-Year	4.22	4.65	4.50	4.51	4.61	4.50
10-Year	5.01	5.53	5.34	5.36	5.48	5.34
25-Year	6.16	6.83	6.59	6.60	6.76	6.58
50-Year	7.13	7.94	7.66	7.67	7.86	7.64
100-Year	8.18	9.16	8.82	8.84	9.06	8.79

Table 28: Recommended Design Rainfall Depths for Southampton County, Virginia

Design Storm Frequency	NOAA Atlas 14 Rainfall (24-Hour Duration)	Design Rainfall (NOAA Atlas 14 * Multiplier)
1-Year	2.87	**3.16**
2-Year	3.49	**3.84**
5-Year	4.50	**4.95**
10-Year	5.34	**5.88**
25-Year	6.58	**7.24**
50-Year	7.64	**8.4**
100-Year	8.79	**9.67**

Notes:

1. All values are in inches.
2. All values are for the 24-hour duration event.
3. NOAA Atlas 14 rainfall values for Recommended Design Rainfall Depths are based on the centroid of the county (latitude 36.7201725, longitude -77.1038556).

Recommended Design Rainfall Depths - Suffolk

Table 29: Atlas 14 (Vol. 2) Precipitation Values for Suffolk, Virginia

Design Storm	Minimum	Maximum	Mean	Median	90th Percentile	Centroid
1-Year	2.96	3.07	2.99	2.99	3.03	2.99
2-Year	3.60	3.73	3.64	3.63	3.68	3.64
5-Year	4.63	4.81	4.70	4.69	4.75	4.69
10-Year	5.51	5.72	5.59	5.58	5.65	5.59
25-Year	6.80	7.07	6.91	6.89	6.98	6.90
50-Year	7.91	8.23	8.04	8.03	8.13	8.04
100-Year	9.13	9.50	9.28	9.27	9.38	9.28

Table 30: Recommended Design Rainfall Depths for Suffolk, Virginia

Design Storm Frequency	NOAA Atlas 14 Rainfall (24-Hour Duration)	Design Rainfall (NOAA Atlas 14 * Multiplier)
1-Year	2.99	**3.44**
2-Year	3.64	**4.18**
5-Year	4.69	**5.4**
10-Year	5.59	**6.43**
25-Year	6.90	**7.94**
50-Year	8.04	**9.24**
100-Year	9.28	**10.67**

Notes:

1. All values are in inches.
2. All values are for the 24-hour duration event.
3. NOAA Atlas 14 rainfall values for Recommended Design Rainfall Depths are based on the centroid of the city (latitude 36.6971573, longitude -76.6347807).

Recommended Design Rainfall Depths – Surry County

Table 31: Atlas 14 (Vol. 2) Precipitation Values for Surry County, Virginia

Design Storm	Minimum	Maximum	Mean	Median	90th Percentile	Centroid
1-Year	2.83	2.93	2.90	2.90	2.93	2.90
2-Year	3.43	3.57	3.52	3.53	3.56	3.52
5-Year	4.42	4.62	4.55	4.56	4.60	4.55
10-Year	5.26	5.51	5.41	5.42	5.49	5.42
25-Year	6.47	6.83	6.69	6.70	6.79	6.70
50-Year	7.51	7.97	7.79	7.80	7.92	7.80
100-Year	8.63	9.24	9.00	9.01	9.16	9.01

Table 32: Recommended Design Rainfall Depths for Surry County, Virginia

Design Storm Frequency	NOAA Atlas 14 Rainfall (24-Hour Duration)	Design Rainfall (NOAA Atlas 14 * Multiplier)
1-Year	2.90	**3.19**
2-Year	3.52	**3.87**
5-Year	4.55	**5.00**
10-Year	5.42	**5.96**
25-Year	6.70	**7.37**
50-Year	7.80	**8.58**
100-Year	9.01	**9.91**

Notes:

1. All values are in inches.
2. All values are for the 24-hour duration event.
3. NOAA Atlas 14 rainfall values for Recommended Design Rainfall Depths are based on the centroid of the county (latitude 37.119761, longitude -76.8801717).

Recommended Design Rainfall Depths – Virginia Beach

Table 33: Atlas 14 (Vol. 2) Precipitation Values for Virginia Beach, Virginia

Design Storm	Minimum	Maximum	Mean	Median	90th Percentile	Centroid
1-Year	2.93	3.06	3.01	3.01	3.04	3.01
2-Year	3.57	3.72	3.66	3.66	3.70	3.66
5-Year	4.61	4.81	4.73	4.73	4.77	4.73
10-Year	5.50	5.72	5.64	5.64	5.68	5.64
25-Year	6.82	7.08	6.98	6.99	7.02	6.98
50-Year	7.95	8.24	8.14	8.15	8.18	8.13
100-Year	9.21	9.52	9.42	9.43	9.46	9.40

Table 34: Recommended Design Rainfall Depths for Virginia Beach, Virginia

Design Storm Frequency	NOAA Atlas 14 Rainfall (24-Hour Duration)	Design Rainfall (NOAA Atlas 14 * Multiplier)
1-Year	3.00	**3.60**
2-Year	3.65	**4.38**
5-Year	4.73	**5.68**
10-Year	5.64	**6.77**
25-Year	6.99	**8.39**
50-Year	8.16	**9.79**
100-Year	9.45	**11.34**

Notes:

1. All values are in inches.
2. All values are for the 24-hour duration event.
3. NOAA Atlas 14 rainfall values for Recommended Design Rainfall Depths are based on latitude 36.8201, longitude -76.0756, as incorporated in the city's Public Works Design Standards Manual, adopted June 2020.

Recommended Design Rainfall Depths - Williamsburg

Table 35: Atlas 14 (Vol. 2) Precipitation Values for Williamsburg, Virginia

Design Storm	Minimum	Maximum	Mean	Median	90th Percentile	Centroid
1-Year	2.93	2.94	2.94	2.94	2.94	2.94
2-Year	3.57	3.58	3.57	3.58	3.58	3.58
5-Year	4.61	4.63	4.62	4.62	4.63	4.62
10-Year	5.50	5.52	5.51	5.51	5.52	5.51
25-Year	6.82	6.84	6.83	6.83	6.84	6.83
50-Year	7.95	7.99	7.97	7.97	7.98	7.97
100-Year	9.22	9.26	9.24	9.24	9.25	9.24

Table 36: Recommended Design Rainfall Depths for Williamsburg, Virginia

Design Storm Frequency	NOAA Atlas 14 Rainfall (24-Hour Duration)	Design Rainfall (NOAA Atlas 14 * Multiplier)
1-Year	2.94	**3.38**
2-Year	3.58	**4.11**
5-Year	4.62	**5.32**
10-Year	5.51	**6.34**
25-Year	6.83	**7.85**
50-Year	7.97	**9.17**
100-Year	9.24	**10.62**

Notes:

1. All values are in inches.
2. All values are for the 24-hour duration event.
3. NOAA Atlas 14 rainfall values for Recommended Design Rainfall Depths are based on the centroid of the city (latitude 37.2692929, longitude -76.7067172).

Recommended Design Rainfall Depths – York County

Table 37: Atlas 14 (Vol. 2) Precipitation Values for York County, Virginia

Design Storm	Minimum	Maximum	Mean	Median	90th Percentile	Centroid
1-Year	2.91	2.94	2.93	2.93	2.94	2.93
2-Year	3.54	3.58	3.56	3.57	3.57	3.57
5-Year	4.58	4.63	4.61	4.62	4.62	4.61
10-Year	5.46	5.53	5.51	5.51	5.52	5.51
25-Year	6.78	6.88	6.84	6.84	6.86	6.84
50-Year	7.92	8.06	8.00	8.00	8.03	8.00
100-Year	9.19	9.36	9.28	9.29	9.32	9.29

Table 38: Recommended Design Rainfall Depths for York County, Virginia

Design Storm Frequency	NOAA Atlas 14 Rainfall (24-Hour Duration)	Design Rainfall (NOAA Atlas 14 * Multiplier)
1-Year	2.93	**3.37**
2-Year	3.57	**4.1**
5-Year	4.61	**5.31**
10-Year	5.51	**6.34**
25-Year	6.84	**7.87**
50-Year	8.00	**9.2**
100-Year	9.29	**10.68**

Notes:

1. All values are in inches.
2. All values are for the 24-hour duration event.
3. NOAA Atlas 14 rainfall values for Recommended Design Rainfall Depths are based on the centroid of the county (latitude 37.2209138, longitude -76.3955329).