Tisbury MA Impervious Cover Disconnection (ICD) Project: An Integrated Stormwater Management Approach for Promoting Urban Community Sustainability and Resilience

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Task 4B. Opti-Tool Analyses for Quantifying Stormwater Runoff Volume and Pollutant Loadings from Watershed Source Areas

Prepared for:

U.S. EPA Region 1

In Cooperation With:

Town of Tisbury, MA
Tisbury Waterways
Martha's Vineyard Commission
Massachusetts Department of Transportation

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To:	Ray Cody (US EPA Region 1)
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CC:	Project Team
Date:	June 27, 2019
Re:	Opti-Tool Analyses for Quantifying Stormwater Runoff Volume and Pollutant Loadings from Watershed Source Areas (Task 4B)

This technical memorandum describes the development of Hydrologic Response Units (HRUs), the setup of Storm Water Management Model (SWMM) model in Opti-Tool (U.S. EPA. 2016), and presents the results of existing condition runoff volume and total nitrogen loading from the source areas in the Town of Tisbury (Tisbury), MA. Nitrogen is typically the limiting nutrient in coastal and marine waters. Increases in nitrogen concentrations in estuarine systems such as Tisbury Great Pond/Black Point Pond can result in excessive algae growth that depletes oxygen within the waterbody. Some algal blooms can also be toxic. The SWMM-HRU model setup began by identifying, pre-processing, and analyzing the required climate inputs used to represent local precipitation and temperature conditions for a long-term planning time period (i.e., 20-years). Next, based on geographic information system (GIS) data and the methodology presented in the Task 4A technical memorandum, a set of HRUs were developed to represent landscape characteristics in the model which most influence hydrology and pollutant loading (U.S. EPA 2019). After the HRU categories were developed, SWMM-HRU model simulation was performed to develop HRU timeseries and to quantify the volume of stormwater runoff and mass of total nitrogen generated over the 20-year simulation period. The results of this analysis define the baseline condition upon which management strategies will be evaluated during future analyses.

This memorandum is organized into four sections:

- Climate Data Analysis (**Section 1**)
- Development of HRU Categories (**Section 2**)
- Development of HRU Timeseries (**Section 3**)
- Summary (**Section 4**)

1 CLIMATE DATA ANALYSIS

The Opti-Tool model requires hourly timeseries of flow and pollutant load, developed using the SWMM hydrology model, as a boundary condition to run simulations. The SWMM hydrology model developed previously for Opti-Tool was modified under this task to accommodate additional HRU categories representing the low, medium, and high slope areas and to conduct hourly rainfall-runoff and pollutant loading simulation. Hourly precipitation timeseries and daily air temperature data collected at the Martha's Vineyard Airport (USAF-ID 725066) were used to represent local precipitation characteristics like storm frequency, duration, and magnitude. Specific climate parameters required for the simulation included:

- Hourly continuous precipitation (inches/hour) for simulating rainfall-runoff, and
- Daily minimum and maximum temperature (°F) for simulating evapotranspiration

These climate data were reviewed for completeness and screened for data gaps using annual summary statistics, seasonal summary statistics, and timeseries plots. Quality flagging provided with the data from the National Climatic Data Center (NCDC) were also reviewed. A comparison against the NCDC Global Hourly Surface Data gauge located at the Boston Logan International Airport (USAF-ID 725090) was performed to assess variability in climate trends between the two locations. Finally, the data were translated to the required input format for the SWMM model.

1.1 Precipitation

Hourly precipitation data is required as the primary input to the SWMM hydrology model for simulating rainfall-runoff. Local hourly precipitation data were available as part of historical climate data from the NCDC Global Hourly Surface Data gauge located at the Martha's Vineyard Airport (NCDC 725066). A coincident timeseries from the Boston Logan International Airport (NCDC 725090) was also evaluated for comparison purposes. These two stations are approximately 70 miles apart. While both locations are coastal, their citing and orientation are unique in that the Logan Airport gauge sits on the western edge of Boston Harbor almost directly on the water. The Martha's Vineyard gauge is located approximately three miles from the southern coastline of Marsha's Vineyard and approximately four miles from downtown Tisbury. The entire island of Martha's Vineyard is exposed to the open ocean off the southeast corner of mainland Massachusetts.

Table 1-1 summarizes station metadata for these two gauges. The table lists two separate locations available for the Martha's Vineyard Airport gauge. The reporting location was switched on January 1, 2006. Records for these two locations were merged to develop a continuous timeseries representing a longer period (January 1, 1999 – December 31, 2018).

Table 1-1. Summary of NCDC gauge location metadata

Station Name	USAF-ID	Latitude	Longitude	Elevation (ft.)
Martha's Vineyard Airport	725066	41.393	-70.615	20.7
Martha's Vineyard	725066	41.400	-70.617	20.0
Logan International Airport	725090	42.361	-71.010	3.7

The data obtained from the Martha's Vineyard Airport and Logan International Airport gauges cover a common 20-year period beginning January 1, 1999 through December 31, 2018. No significant data gaps (missing records) were found during the data review with intervals flagged as suspect accounting for less than 1% of the long-term timeseries. Table 1-2 presents annual precipitation totals for the 20-year period at both gauges, comparing the long-term average precipitation at both locations. Figure 1-1 and Figure 1-2 summarize the total annual precipitation, presented as bar charts, and plotted against the 20-year average to assess annual trends and variability.

Table 1-2. Annual precipitation for Martha's Vineyard & Boston Logan International Airports

Year	Total Precipitation (in./yr.)	
	Martha's Vineyard Airport (USAF-ID 725066)	Boston Logan Intl. Airport (USAF-ID 725090)
1999	36.3	35.2
2000	39.9	41.1
2001	27.5	28.8
2002	40.1	38.0
2003	41.5	38.7
2004	37.3	42.4
2005	42.6	43.2
2006	43.4	51.1
2007	33.7	38.9
2008	39.2	52.5
2009	42.8	42.2
2010	46.3	47.1
2011	43.8	49.1
2012	40.5	36.7

Year	Total Precipitation (in./yr.)	
	Martha's Vineyard Airport (USAF-ID 725066)	Boston Logan Intl. Airport (USAF-ID 725090)
2013	40.4	36.8
2014	40.3	45.0
2015	37.5	34.7
2016	30.8	32.9
2017	46.5	41.2
2018	51.8	49.4
Average	**40.1**	**41.2**

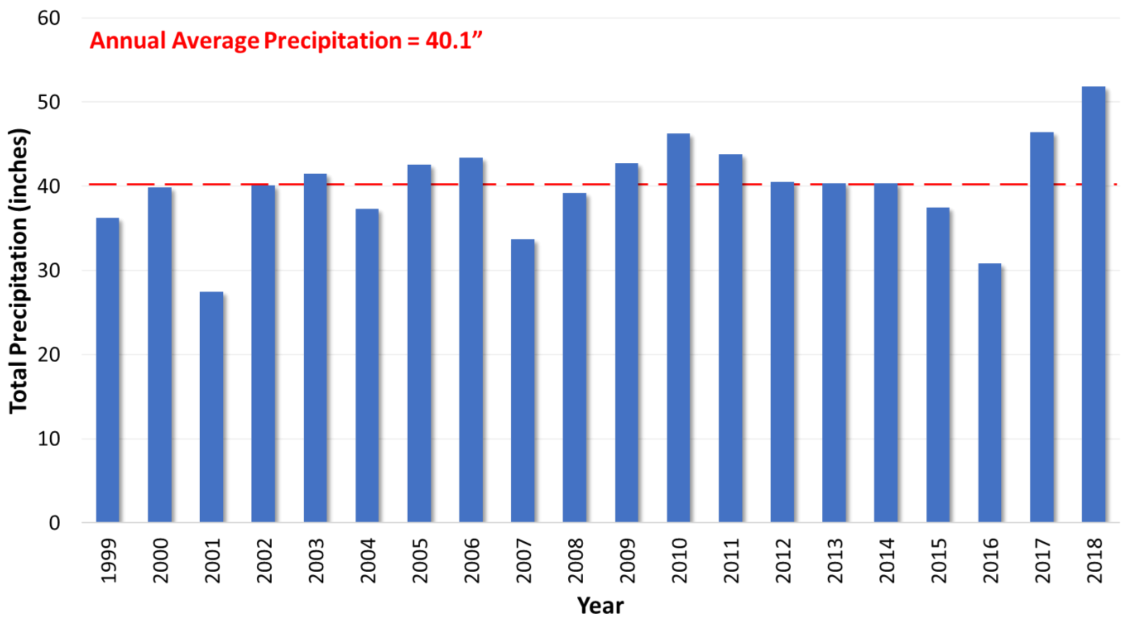

Figure 1-1. Summary of annual precipitation for the Martha's Vineyard Airport (USAF-ID 725066).

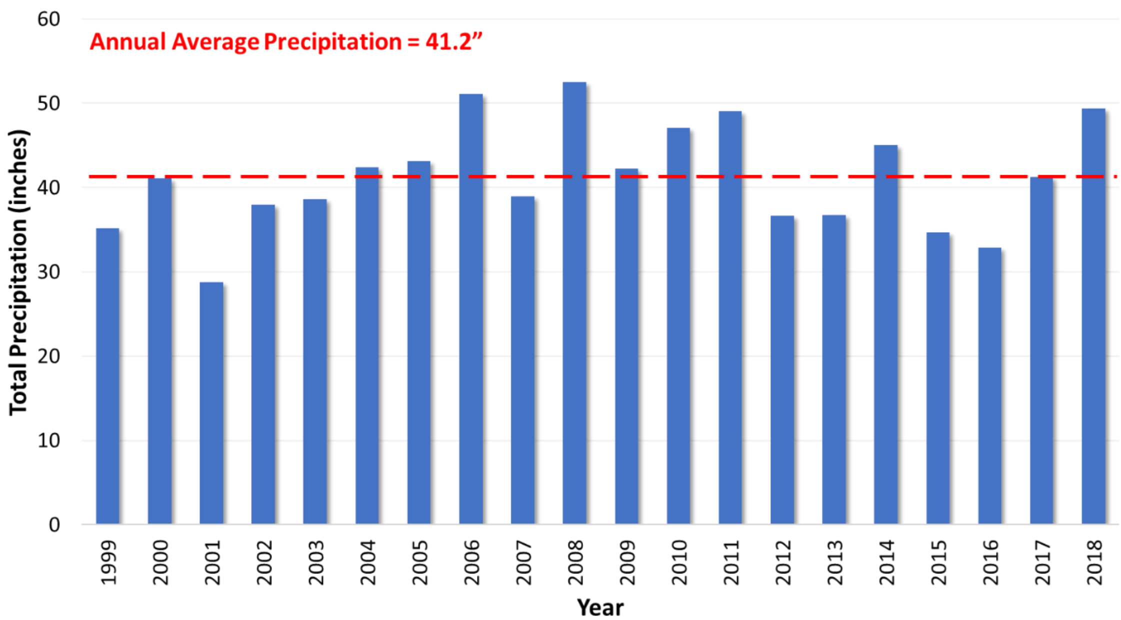

Figure 1-2. Summary of annual precipitation for the Boston Logan International Airport (USAF-ID 725090).

Both the Martha's Vineyard Airport and Boston Logan Airport gauges show a wide range of annual precipitation depths over the 20-years with the wettest years totaling greater than 50 inches and the driest years closer to 30 inches. In one case, year 2001, the total annual precipitation dropped below 30 inches to 27.5 inches at Martha's Vineyard and 28.8 inches at Boston Logan. The most recent year, 2018, was the wettest year in the 20-year record for Martha's Vineyard with 51.8 inches of precipitation.

Table 1-3 compares the distribution of daily precipitation depths between the Martha's Vineyard Airport and Boston Logan International Airport for the period 1/1/1999 through 12/31/2018 based on analysis of the precipitation timeseries and expressed at the percentile depth of the 20-year time period. Daily rainfall was summarized from the hourly rainfall records at both stations and represents total accumulated precipitation between midnight and midnight of the following day.

Table 1-3. Precipitation percentile value at Martha's Vineyard vs. Boston Logan Intl. Airport (1/1/1999-12/31/2018)

Daily Precipitation Depth (in.)	Percentile Depth	
	Martha's Vineyard Airport	Boston Logan Airport
0.10	48.5%	42.1%
0.25	66.0%	61.7%
0.50	80.3%	77.7%
0.75	87.9%	87.1%
1.00	92.5%	92.4%
1.50	96.9%	97.0%
2.00	98.7%	98.6%
3.00	99.7%	99.7%

Comparing the values in the table shows that the quarter-inch storm for Martha's Vineyard represents a higher percentile than Boston Logan Airport suggesting that Martha's Vineyard is subjected to storms with smaller depths more frequently. In other words, more of Marth's Vineyards precipitation falls during smaller storms compared to Boston. Around the one-inch storm depth and above both gauges appear to converge at about the same percentile values.

1.2 Air Temperature

Air temperature is also required for the SWMMS hydrology model when using the Hargreaves method for calculating potential evapotranspiration (U.S. EPA 2015). This method was included within the Opti-Tool for SWMM-HRU model simulation as it has minimal input requirements, needing only daily minimum and maximum air temperature data as inputs to estimate the daily potential evapotranspiration. Air temperature data was available as part of the same Global Hourly Surface Dataset used for precipitation data which was presented in the previous section. The hourly air temperature data was assessed for data gaps by reviewing the quality flags provided with the raw data and reviewing summary statistics. Daily maximum and minimum temperatures were derived from hourly temperature data by searching the 24-hour period between midnight and midnight of each day for the highest and lowest temperatures. Data quality was assessed using NCDC supplied flagging like the precipitation data presented in the previous section. Values were filled forward to patch short-term data gaps. Figure 1-3 and Figure 1-4 show the annual average temperature and monthly average temperature comparisons at Martha's Vineyard Airport and Boston Logan Airport locations. The plots show that both locations have similar seasonal air temperature patterns.

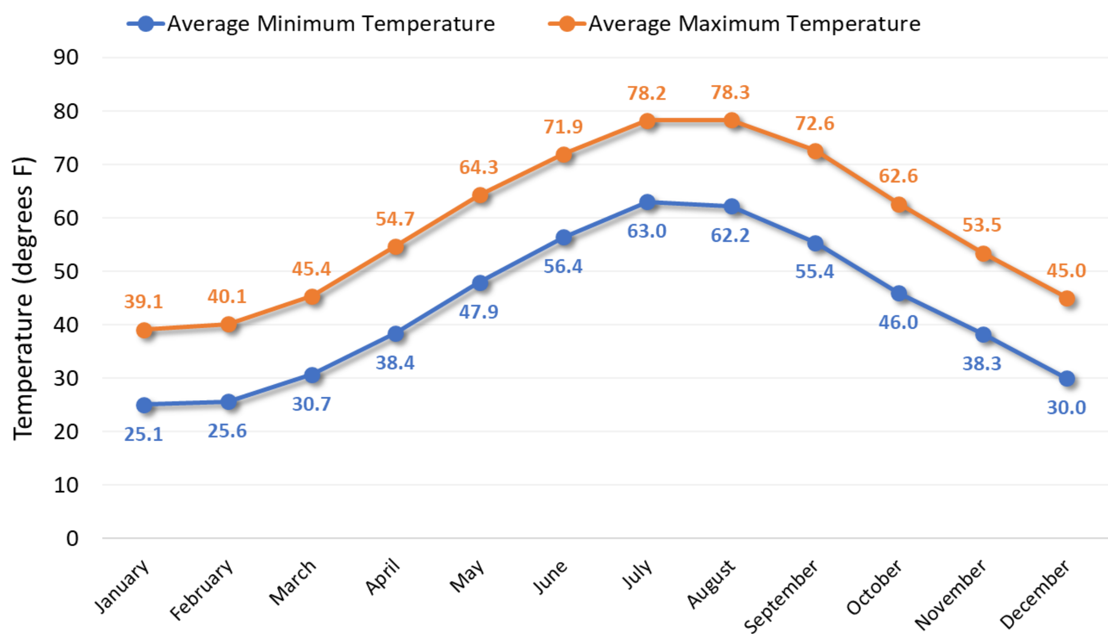

Figure 1-3. Monthly average minimum and maximum temperature recorded at Martha's Vineyard Airport (1/1/1999-12/31/2018).

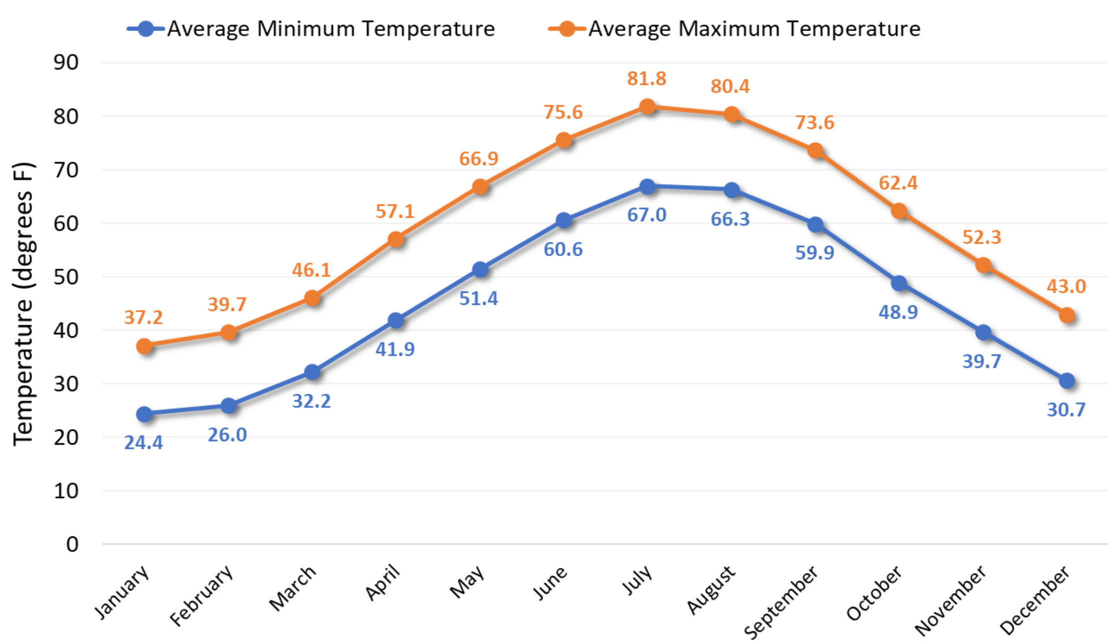

Figure 1-4. Monthly average minimum and maximum temperature recorded at Logan Intl. Airport (1/1/1999-12/31/2018).

Seasonal variation in daily minimum and maximum temperature presents a similar trend between the two gauges. Both locations show peak temperatures in July and August with lows in January and February. The July daily temperatures show a four-degree difference between Martha's Vineyard and Logan Airport with the gauge in Boston having a higher average for both minimum and maximum. The higher peaks at Logan Airport may be attributable to the gauge's proximity to an urban center. The Martha's Vineyard gauge may also be affected by its location on an island and the influence of wind and/or ocean currents, including the Labrador Current, a cold current originating from the Arctic Ocean.

2 DEVELOPMENT OF HRU CATEGORIES

The Task 4A technical memorandum presented a GIS data compilation and proposed a methodology for developing HRUs to represent the watershed landscape features within the Opti-Tool (U.S. EPA 2019). The HRU-based approach reflects the key physical features that influence runoff and pollutant loading such as land use, slope, soils, and impervious cover and is based on the best available local datasets characterizing existing conditions for Tisbury.

GIS data for these features was obtained primarily from the Massachusetts Bureau of Geographic Information Systems (MassGIS) website. Other local data sources identified may be used throughout the project to supplement the regional data available from MassGIS. A full inventory of the GIS datasets identified and compiled to support this memorandum were presented in Task 4A technical memorandum (U.S. EPA 2019). The following datasets were identified as primary inputs for the watershed characterization and are discussed further in this section:

- **Land Use:** *Describes the principal programmatic use and/or vegetation type. The programmatic, or zoning, element of this attribute is critical for water quality simulation.*
- **Land Cover Type:** *Defines the landscape as having either pervious or impervious cover.*
- **Hydrologic Soil Group:** *Represents one of four soil classes (i.e., A, B, C and D) commonly associated with a spectrum of infiltration rates with HSG-A having the highest and HSG-D having the lowest.*
- **Landscape Slope:** *Represents the overland flow slope derived from a digital elevation model. The percent slope was categorized into three groups; low (<5%), medium (5% - 15%), and high (>15%).*

Each of the above four key data elements were classified into HRU groups and were assigned a unique HRU code to convert them into raster format. Spatial data in raster format are displayed as a grid of cells (or pixels) where each cell contains a value representing information, such as the hydrologic group or slope associated with that area. Table 2-1, Table 2-2, Table 2-3, and Table 2-4 show the HRU classification of land use, land cover, soil, and slope for Tisbury, respectively. After overlaying each of these layers within a GIS raster framework, 33 unique categories were identified for representation within the Opti-Tool Tisbury model. These 33 HRUs are presented in Table 2-5 and Figure 2-1. All areas in Tisbury were classified into one of these HRU categories and represented within the Opti-Tool simulation.

Table 2-1. HRU Land Use classification for Tisbury

Land Use ID	Land Use HRU Code	Land Use	Land Use HRU Group	Land Cover
1	1	Forest	Forest	Impervious
	12		Forest Pervious	Pervious
2	2	Agriculture	Agriculture	Impervious
	13		Agriculture Pervious	Pervious
3	3	Commercial	Commercial	Impervious
	11		Developed Pervious	Pervious
4	4	Industrial	Industrial	Impervious
	11		Developed Pervious	Pervious
5	5	Low Density Residential	Low Density Residential	Impervious
	11		Developed Pervious	Pervious
6	6	Medium Density Residential	Medium Density Residential	Impervious
	11		Developed Pervious	Pervious
7	7	High Density Residential	High Density Residential	Impervious
	11		Developed Pervious	Pervious
8	8	Highway	Highway	Impervious
	11		Developed Pervious	Pervious
9	9	Open Space	Open Space	Impervious
	11		Developed Pervious	Pervious

Table 2-2. HRU Land Cover classification for Tisbury

Land Cover ID	Land Cover HRU Code	Land Cover HRU Group
1	0	Pervious
2	1	Impervious

Table 2-3. HRU Soil classification for Tisbury

Soil ID	Soil HRU Code	Soil (HSG)	Soil HRU Group
1	1	A	A
2	2	B	B
3	3	C	C
4	4	D	D

Table 2-4. HRU Slope classification for Tisbury

Slope ID	Slope HRU Code	Slope HRU Group
1	1	Low (<5%)
2	2	Medium (5% - 15%)
3	3	High (>15%)

Table 2-5. Final assignment of Tisbury HRU categories

HRU ID	HRU CODE	Land Use	Land Cover	Hydrologic Soil Group	Slope
1	13110	Agriculture	Pervious	A	Low
2	13120				Med
3	13130				High
4	13210			B	Low
5	13220				Med
6	13230				High
7	2001		Impervious	n/a	n/a
8	12110	Forest	Pervious	A	Low
9	12120				Med
10	12130				High
11	12210			B	Low
12	12220				Med
13	12230				High
14	1001		Impervious	n/a	n/a
15	11110	Developed	Pervious	A	Low
16	11120				Med
17	11130				High
18	11210			B	Low
19	11220				Med
20	11230				High
21	11310			C	Low
22	11320				Med
23	11330				High
24	11410			D	Low
25	11420				Med
26	11430				High
27	3001	Commercial	Impervious	n/a	n/a
28	4001	Industrial			
29	5001	Low Density Residential			
30	6001	Medium Density Residential			
31	7001	High Density Residential			
32	8001	Highway			
33	9001	Open Space			

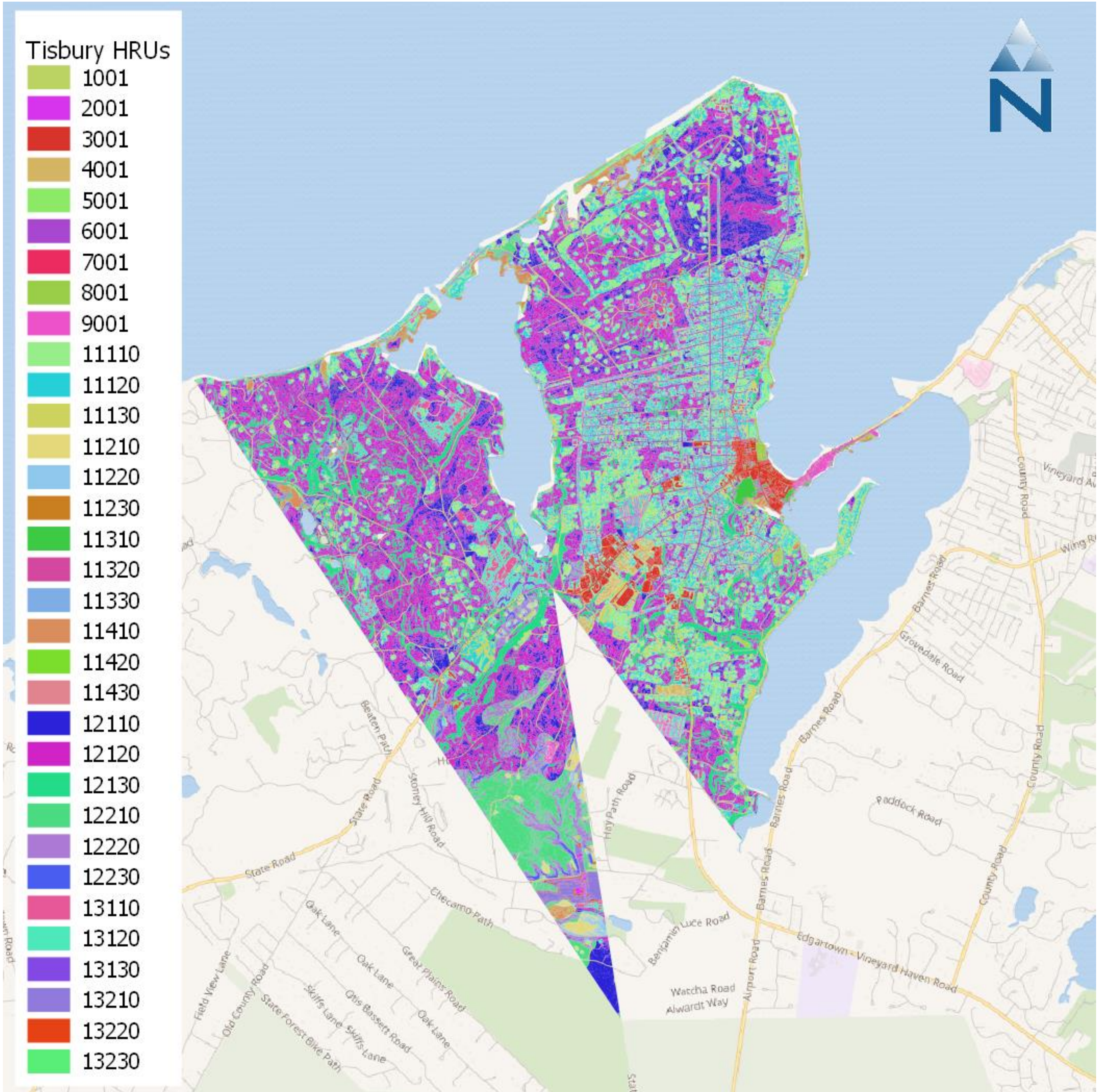

Figure 2-1. Tisbury HRU categories.

2.1 Zoning Districts

The zoning districts for the Town of Tisbury were overlaid with the HRUs presented in the previous section to organize the Opti-Tool model into functional groupings consistent with boundaries used for other town planning efforts (Tisbury 2003). Figure 2-2 presents a map of the 10 zoning districts which include three business/commercial districts, five residential districts, and the Lagoon Harbor Park district. Less than 0.1% of the area falls into the final "Not Zoned" category. These zoning districts are used in Section 3 and Appendix A to summarize the results of the existing runoff volume and total nitrogen loading.

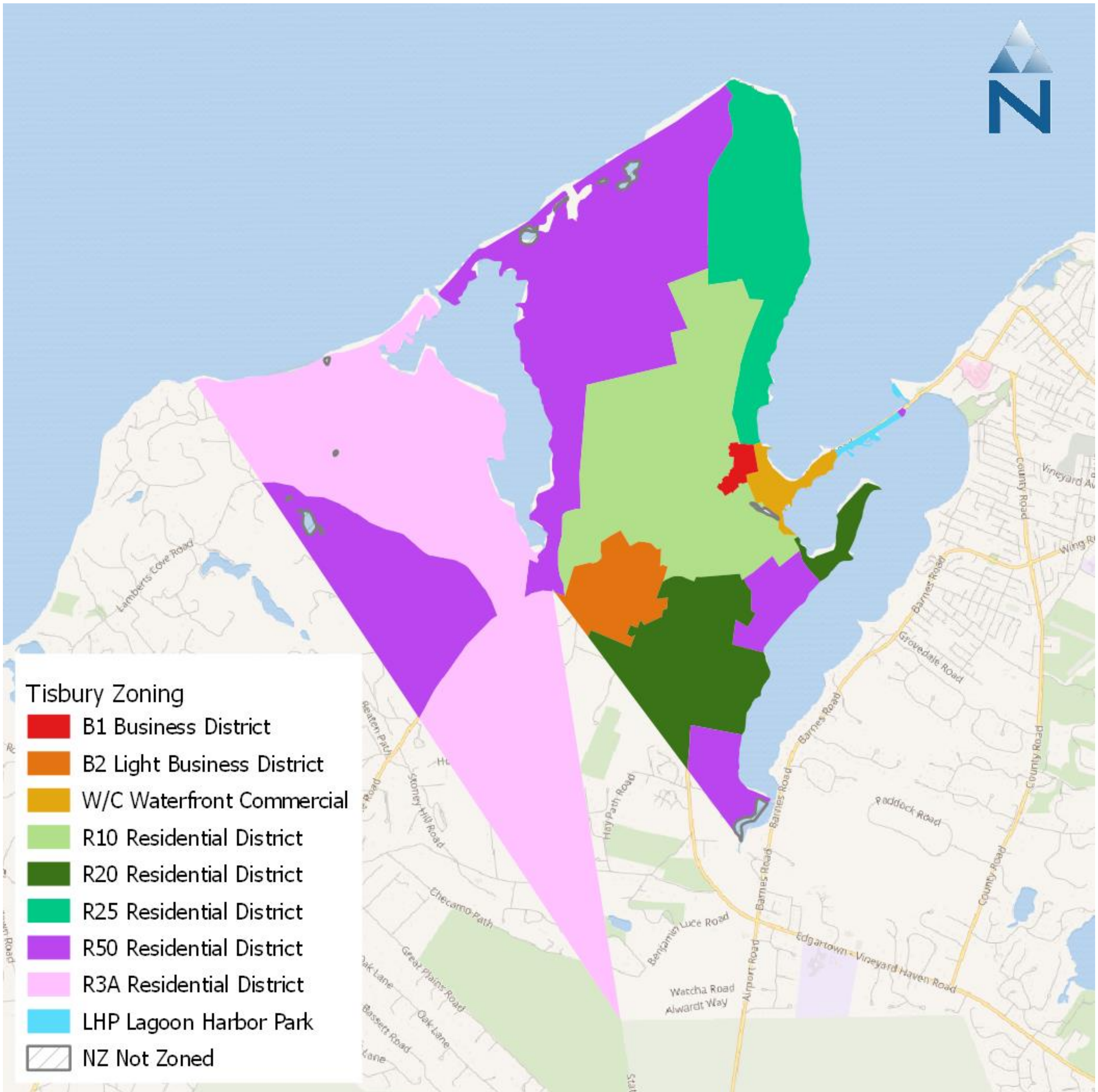

Figure 2-2. Tisbury zoning districts.

2.2 HRU Area Distribution

Figure 2-3 summarizes the HRU area distribution for Tisbury after performing the GIS overlay analysis described previously and presented in Table 2-5. This figure, called a *treemap*, uses proportionally sized rectangles to present hierarchical data in a way that highlights dominance and patterns. This example expresses the entire HRU distribution for Tisbury as a percent of total HRU area. The largest, most visually dominant rectangles highlight HRUs that represent the largest portion of Tisbury's area relative to the other categories.

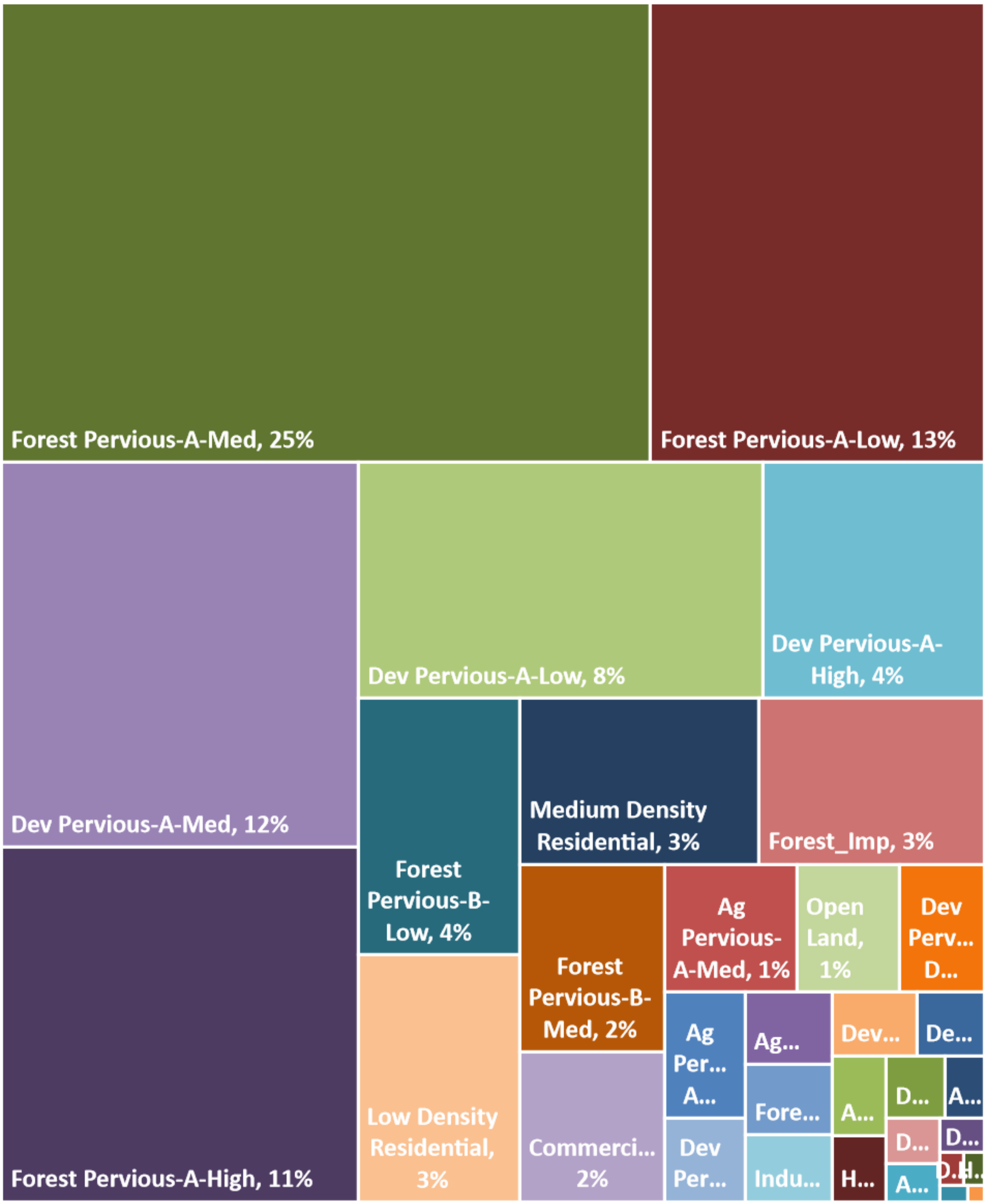

Figure 2-3. Summary of HRU distributions for Tisbury with emphasis on the largest categories.

Over 68% of the area in Tisbury is dominated by five of the 33 HRU categories, three categories of pervious forest (HSG-A with three different slopes) and two categories of developed pervious (HSG-A with two different slopes). All five of these HRUs, shown in Figure 2-3, are categorized as HSG-A with the highest infiltration potential. The three forested categories alone account for almost 50% of the total area. While these five HRUs dominate the area distribution, they all represent pervious land cover on HSG-A soils and may represent a disproportionately low contribution of runoff and total nitrogen loading. Section 3 further presents an analysis of annual runoff volume and total nitrogen loading by HRUs and zoning districts.

While Figure 2-3 shows the dominant HRU categories encompassing all of Tisbury, the HRU distribution of individual zoning districts shows variation in the HRU distribution across districts suggesting that the runoff and total nitrogen sources, and ultimately the management strategies, will also vary across zoning districts. Table A-1 in Appendix A presents the HRU area distribution for each of the 10 zoning districts separately, along with the overall HRU distribution for Tisbury.

3 DEVELOPMENT OF HRU TIMESERIES

One of the most important steps in stormwater management planning is establishing the baseline condition for runoff and pollutant loading. When performing simulation for BMP planning, the baseline condition becomes the basis for evaluating all management scenarios. The climate data discussed in Section 1 are the primary inputs to the SWMM-HRU model used by the Opti-Tool to simulate watershed hydrology and water quality processes. Using this climate data, the Opti-Tool generates hourly surface runoff volumes and concentrations for total nitrogen (TN), total phosphorous (TP), total zinc (Zn), and total suspended solids (TSS) based on hydrologic and water quality parameters. The Opti-Tool installation provides access to climate data from the Logan Airport gauge, and the model was previously calibrated using these timeseries along with New England's regional monitoring data and observed pollutant event mean concentrations (EMCs) in stormwater runoff (U.S. EPA, 2016). The SWMM-HRU model design accounts for processes that contribute to overland flow and associated water quality. The model is not designed to address mixing conditions between ground water and currents in marine environments. Also, the modeling focus for this study is the stormwater (wet weather condition) and does not include any wastewater sources (e.g., septic systems failure) for the pollutant load estimation.

This application applied the same calibrated model along with precipitation and temperature data from the Martha's Vineyard Airport (USAF-ID 725066) to account for locally distinct precipitation characteristics discussed in Section 1.1 and Section 1.2. Specifically, the general higher proportion of smaller storm depth events in the distribution at the Martha's Vineyard Airport gauge (Table 1-3) is expected to result in smaller, and possibly more frequent, storms as compared to the Logan gauge. The results of the SWMM model simulation, which include 20-year hourly runoff volume timeseries and total nitrogen loading timeseries, are shown in Table 3-1 and are further discussed in Section 3.1. Figure 3-1 and Figure 3-2 show the spatial distribution of annual average runoff depth (inches/year) and TN unit-area loading (pounds/acre/year) by HRU types for Tisbury. These timeseries and the HRU distribution for Tisbury (Section 2.2) form the foundation of the Opti-Tool analysis. The HRUs results highlight the critical areas (high runoff and pollutant loading) as shown in Figure 3-1 and Figure 3-2 and provide primary inputs to all management scenarios simulating BMPs.

Table 3-1. Tisbury HRUs unit-area based annual average runoff volume (in/yr) and TN loading (lb/ac/yr)

HRU ID	HRU CODE	HRU Description	Flow (in/yr)	TN (lb/ac/yr)
1	13110	Agriculture Pervious-A-Low	0.72	0.92
2	13120	Agriculture Pervious-A-Med	0.90	1.44
3	13130	Agriculture Pervious-A-High	0.97	1.66
4	13210	Agriculture Pervious-B-Low	2.30	2.82
5	13220	Agriculture Pervious-B-Med	2.70	3.77
6	13230	Agriculture Pervious-B-High	2.84	4.02
7	2001	Agriculture Impervious	37.53	10.65
8	12110	Forest Pervious-A-Low	0.72	0.19
9	12120	Forest Pervious-A-Med	0.90	0.28
10	12130	Forest Pervious-A-High	0.97	0.32
11	12210	Forest Pervious-B-Low	2.30	0.58
12	12220	Forest Pervious-B-Med	2.70	0.76
13	12230	Forest Pervious-B-High	2.84	0.81
14	1001	Forest Impervious	37.53	10.65
15	11110	Developed Pervious-A-Low	0.31	0.15
16	11120	Developed Pervious-A-Med	0.40	0.22
17	11130	Developed Pervious-A-High	0.44	0.25
18	11210	Developed Pervious-B-Low	2.30	1.23
19	11220	Developed Pervious-B-Med	2.70	1.63
20	11230	Developed Pervious-B-High	2.84	1.74
21	11310	Developed Pervious-C-Low	5.41	2.54
22	11320	Developed Pervious-C-Med	6.11	3.07
23	11330	Developed Pervious-C-High	6.39	3.23
24	11410	Developed Pervious-D-Low	10.25	3.94
25	11420	Developed Pervious-D-Med	11.15	4.56
26	11430	Developed Pervious-D-High	11.48	4.71
27	3001	Commercial	37.53	14.19
28	4001	Industrial	37.53	14.19
29	5001	Low Density Residential	37.53	13.26
30	6001	Medium Density Residential	37.53	13.26
31	7001	High Density Residential	37.53	13.26
32	8001	Highway	37.53	9.55
33	9001	Open Space	37.53	10.65

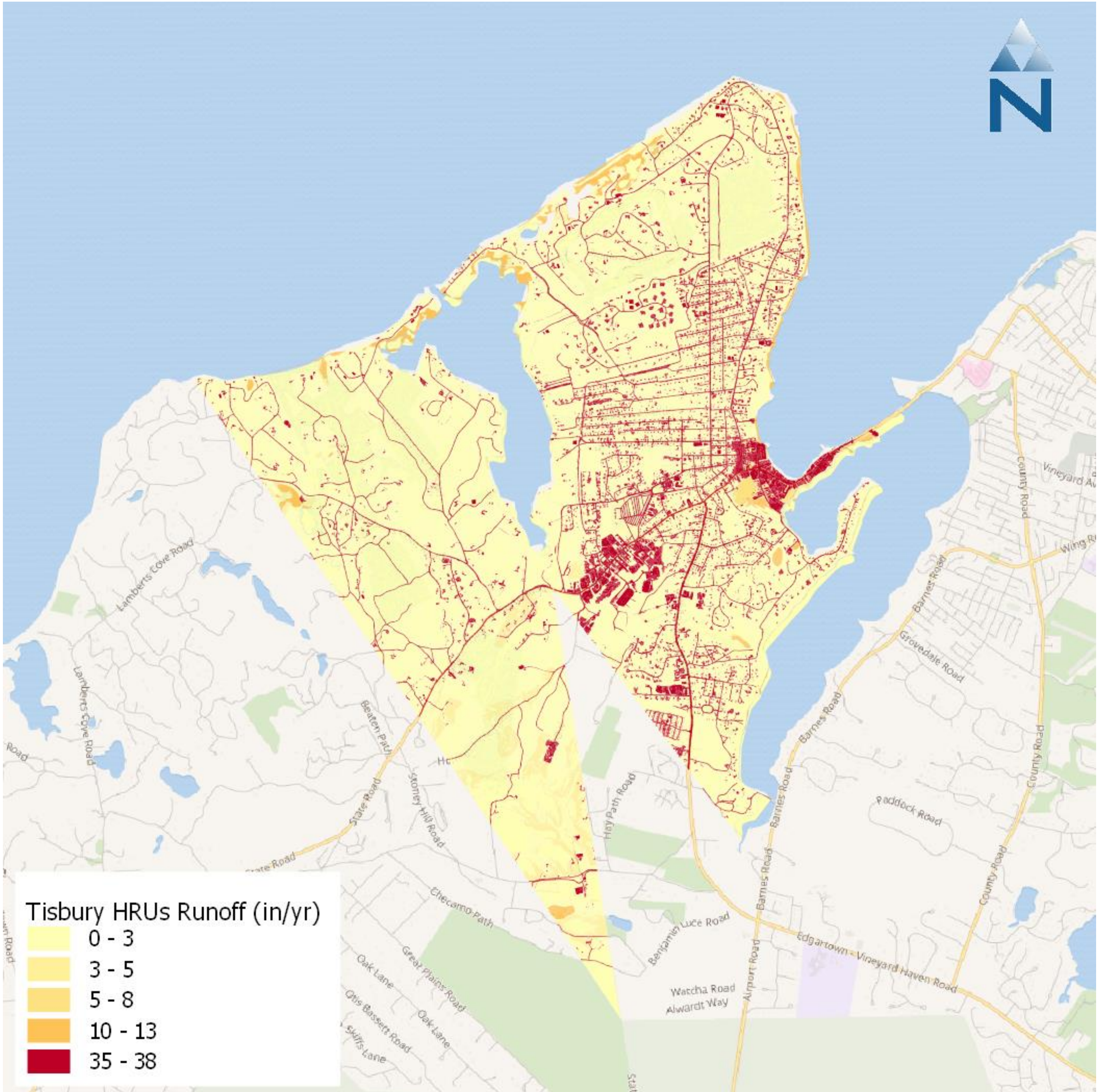

Figure 3-1. Tisbury HRUs unit-area based annual average runoff volume (inches/year).

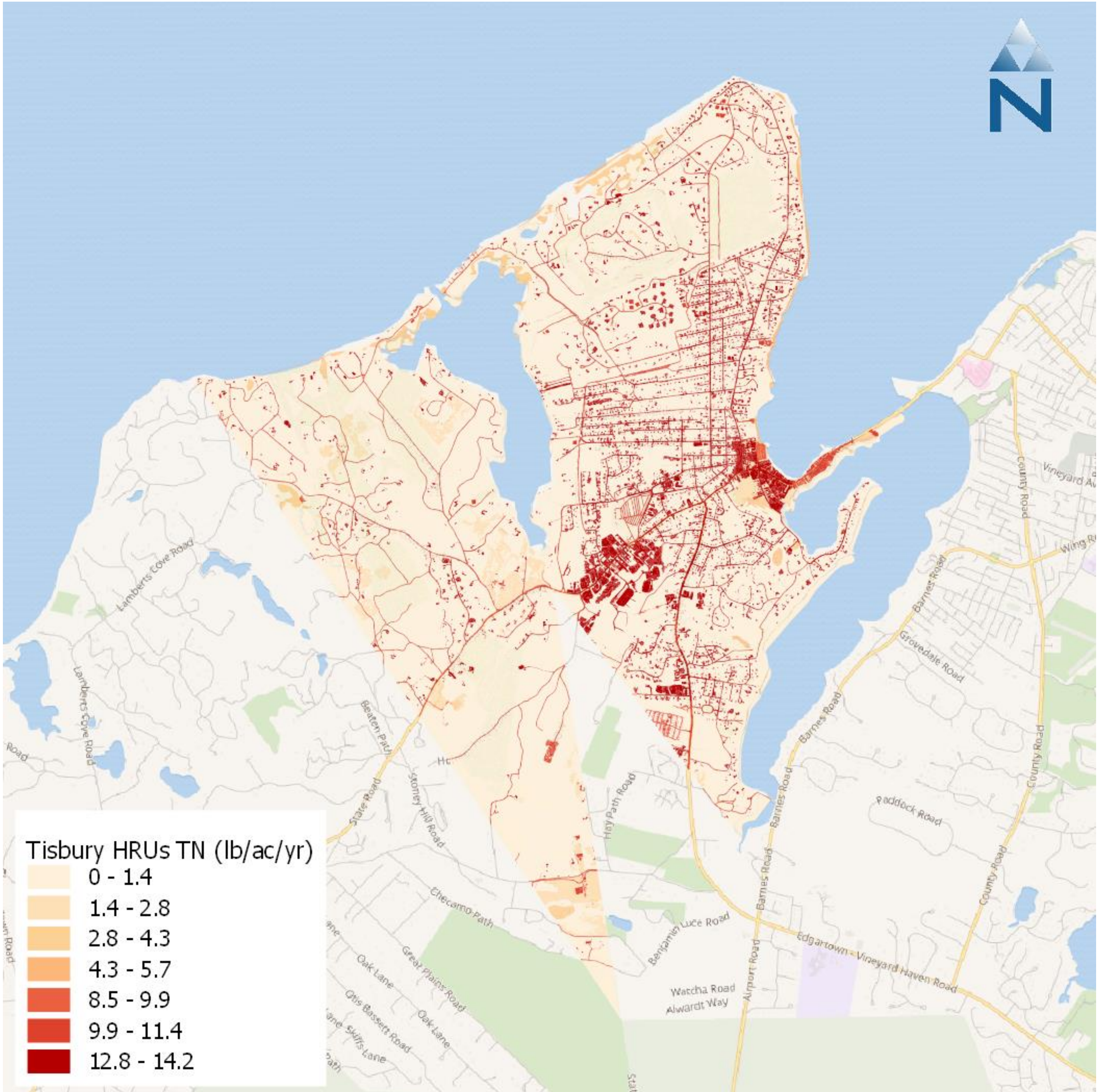

Figure 3-2. Tisbury HRUs unit-area based annual average total nitrogen load (pounds/acre/year).

3.1 Runoff Volume & Total Nitrogen

Using the HRU land use distribution by zoning district presented in Section 2, the HRU timeseries developed with the SWMM model were summarized to evaluate annual average runoff volume and annual average total nitrogen load over the full 20-year simulation period. The results of this summary are presented in Figure 3-3 and Figure 3-4 summarized by HRU category, in Figure 3-5 summarized by zoning district, and in Figure 3-6 summarized by zoning district on a normalized area basis. Note the HRU categories shown in the figures are generalized fromforms the full set of 33 HRU developed in Section 2 for presentation purposes. Hydrologic soil group and slope were excluded, and the results were grouped by combinations of land use and land cover (i.e., either pervious or impervious). The following broad observations are seen within these four figures:

- Low density residential and medium density residential impervious areas are the largest sources of runoff and total nitrogen within Tisbury. These two HRUs had the largest area of all the impervious HRU categories. Impervious forest cover which includes roadways and possible recreational use parking areas adjacent to forest areas had the third highest area and consequently, the third highest runoff and pollutant load.
- Pervious forest HRUs were the fifth largest source of both runoff volume and total nitrogen. While pervious areas generally contribute less runoff and pollutant load on a normalized-area basis, pervious forest HRUs accounted for almost 50% of the entire Tisbury area.
- The higher density residential districts have higher runoff and total nitrogen loading areas than the lower density residential districts. Despite having lower per-acre runoff and total nitrogen loading rates, the residential districts *R50* and *R3A* have the second and third highest runoff volume and total nitrogen load because of their large area. Combined, these two zoning districts account for just over 62% of the area in Tisbury.

Because of recent flooding concerns in the downtown area, the three commercial districts *Business District (B1), Light Business District (B2), and Waterfront Commercial (W/C)* were compared separately to identify and target source areas with the potential to generate the highest runoff volume and total nitrogen loading. Figure 3-7 and Figure 3-8 present the subset of results for these three zoning districts. Like the plots showing land use area, runoff volume, and total nitrogen load for all of Tisbury, the HRU categories presented in these three figures have been generalized for presentation purposes. The following observations were made from examining these summaries:

- Commercial impervious area dominates as the major source of runoff and total nitrogen within all three of the zoning districts. Industrial impervious area also shows a relatively large contribution of both runoff and total nitrogen within the *Light Business District (B2)*.
- Residential areas do not appear to be major sources in these districts which is consistent with the expected programmatic uses designated by commercial zoning.

Figure 3-9 and Figure 3-10 show the area-normalized (i.e., per acre) annual average runoff depth and annual average total nitrogen load from the zonal districts in Tisbury. The trends for both runoff volume and total nitrogen loading are consistent between these two figures which show the following:

- The three commercial districts *Business District (B1), Light Business District (B2), and Waterfront Commercial (W/C)* have the highest per-acre runoff and total nitrogen loading rates of any of the ten districts. In most cases, these rates are more than double the rates seen for any of the residential districts.
- Similar to the trend described in Figure 3-6, the higher density residential districts have higher runoff and total nitrogen loading areas than the lower density residential districts.

Appendix A presents the HRU distribution for each of the 10 zoning districts separately, along with the overall HRU distribution for Tisbury.

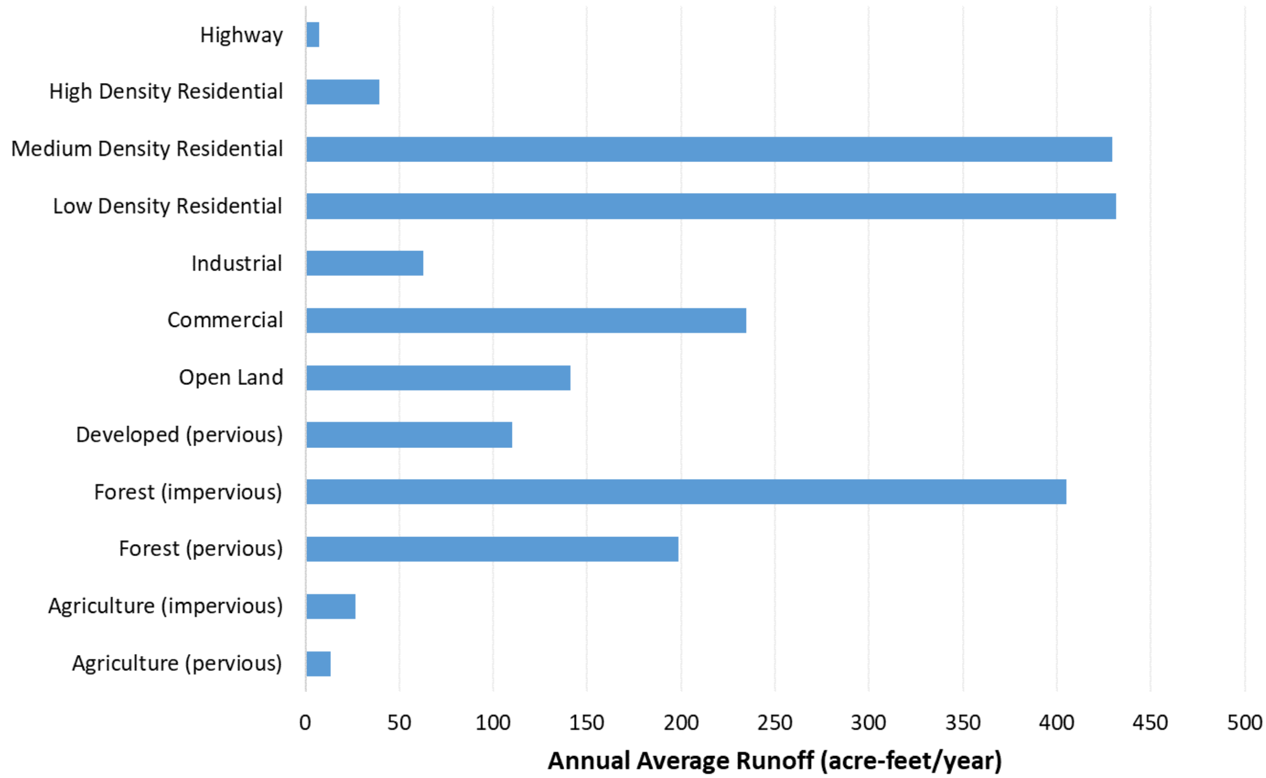

Figure 3-3. Summary of annual average runoff by generalized HRU category for Tisbury.

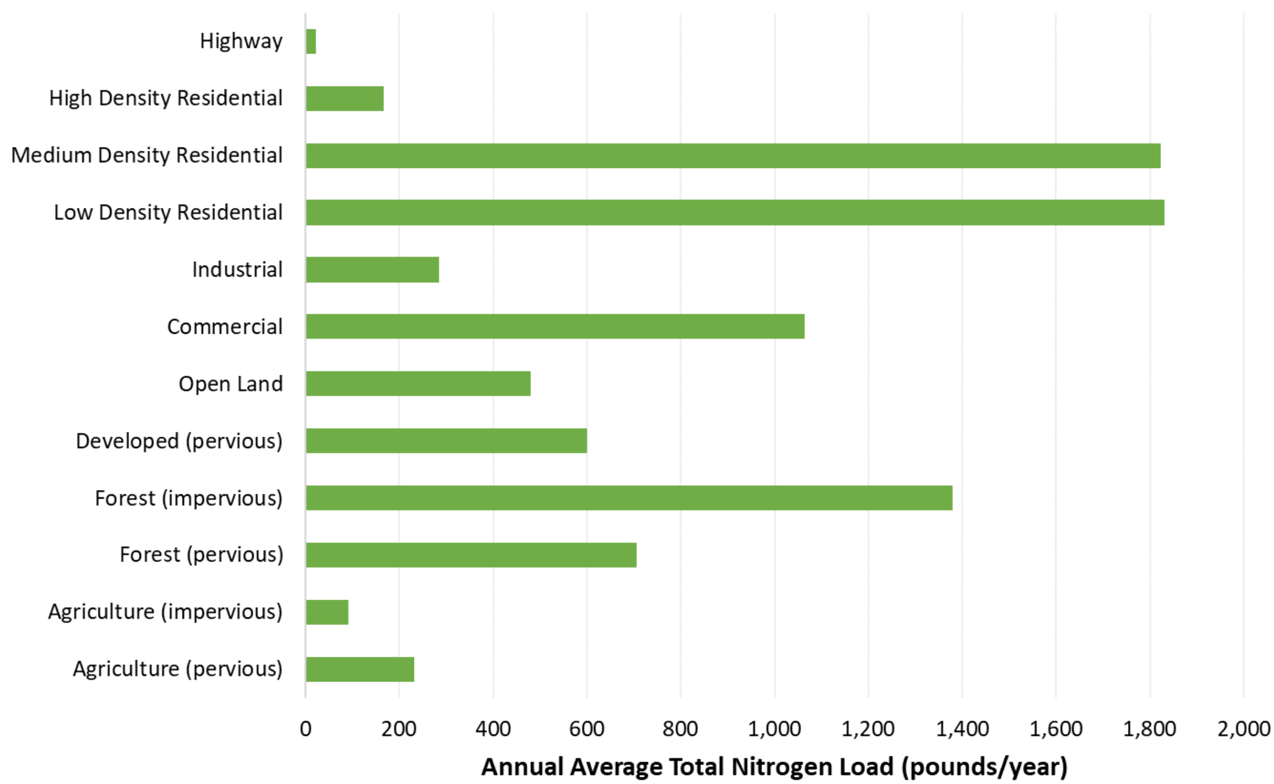

Figure 3-4. Summary of annual average total nitrogen by generalized HRU category for Tisbury.

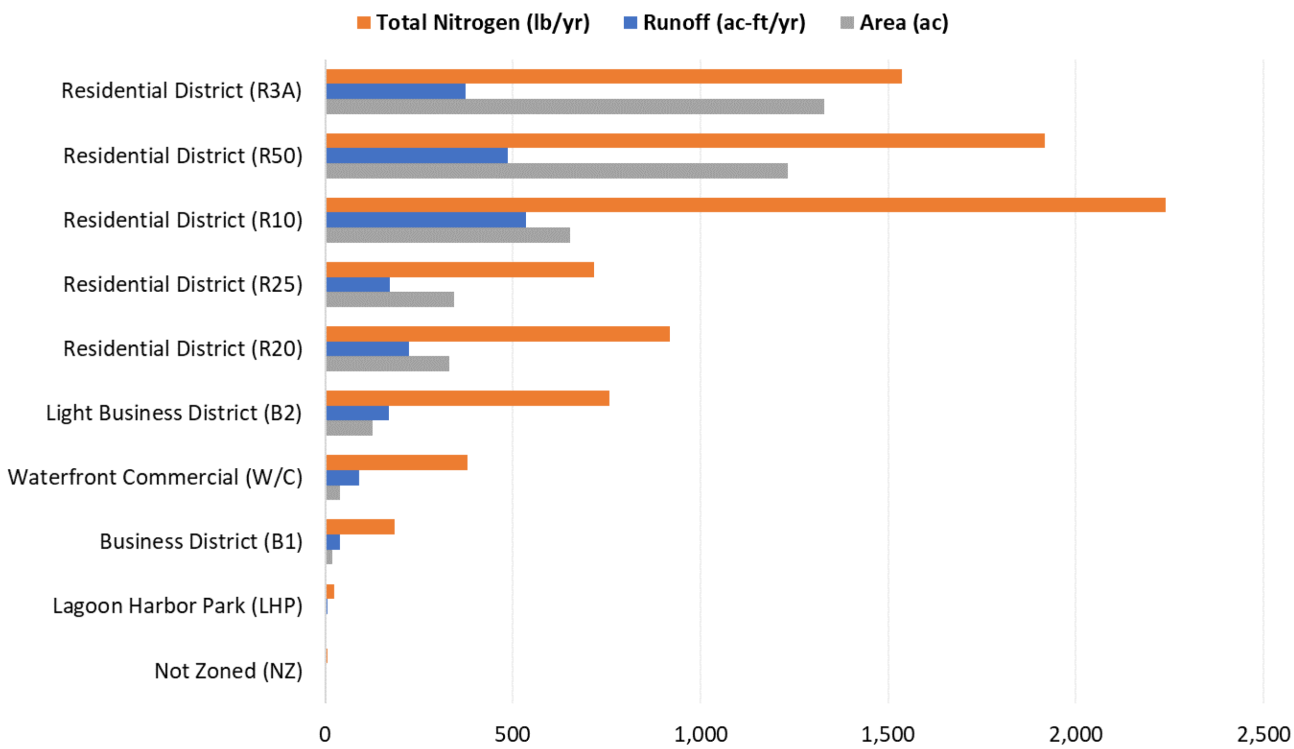

Figure 3-5. Summary of total area, runoff volume, and total nitrogen load by zoning district.

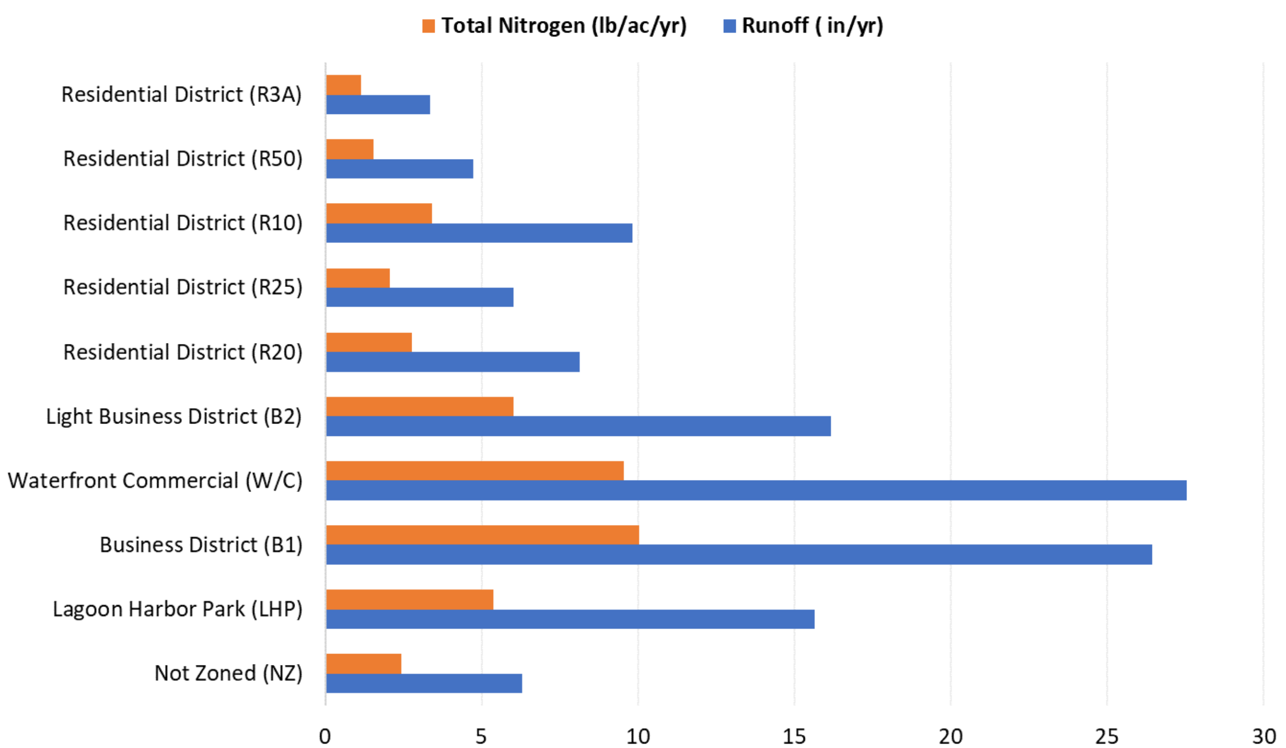

Figure 3-6. Summary of normalized runoff volume and total nitrogen load by zoning district.

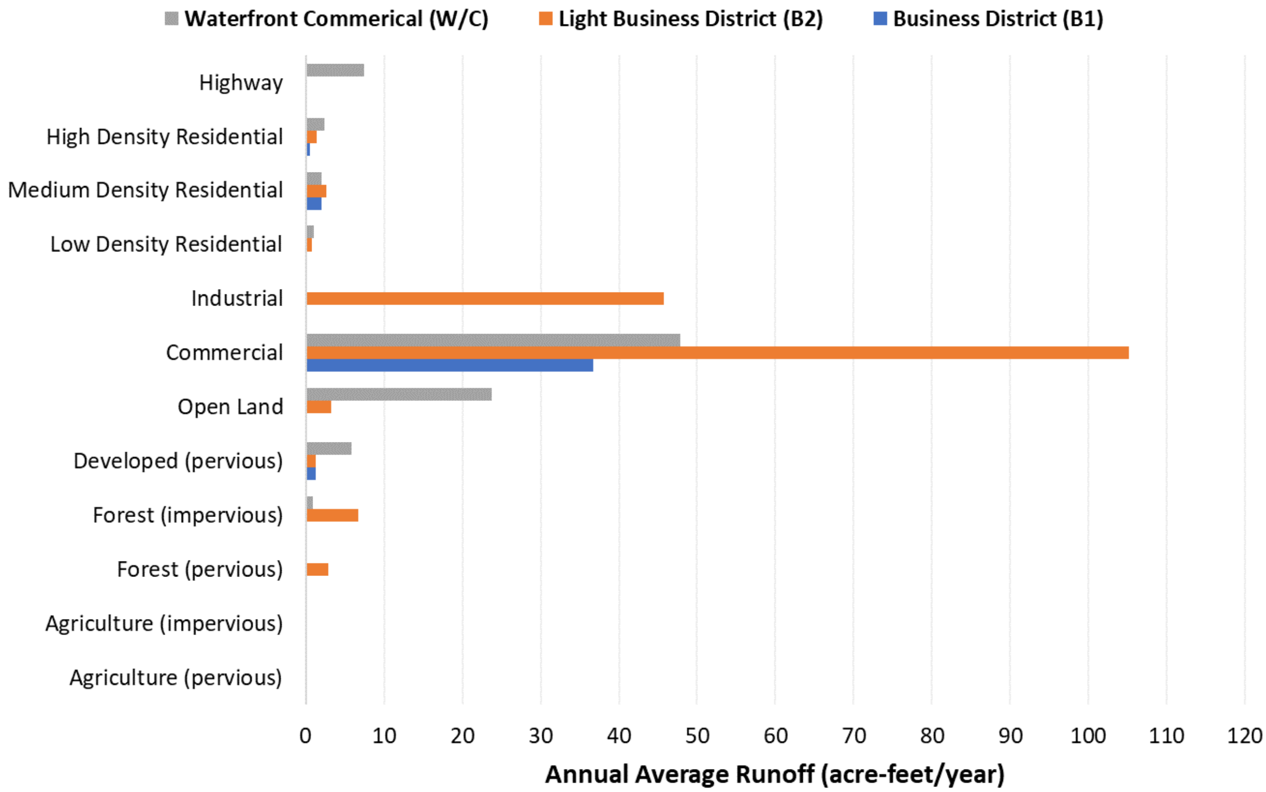

Figure 3-7. Summary of annual average runoff by generalized HRU category for commercial zoning districts.

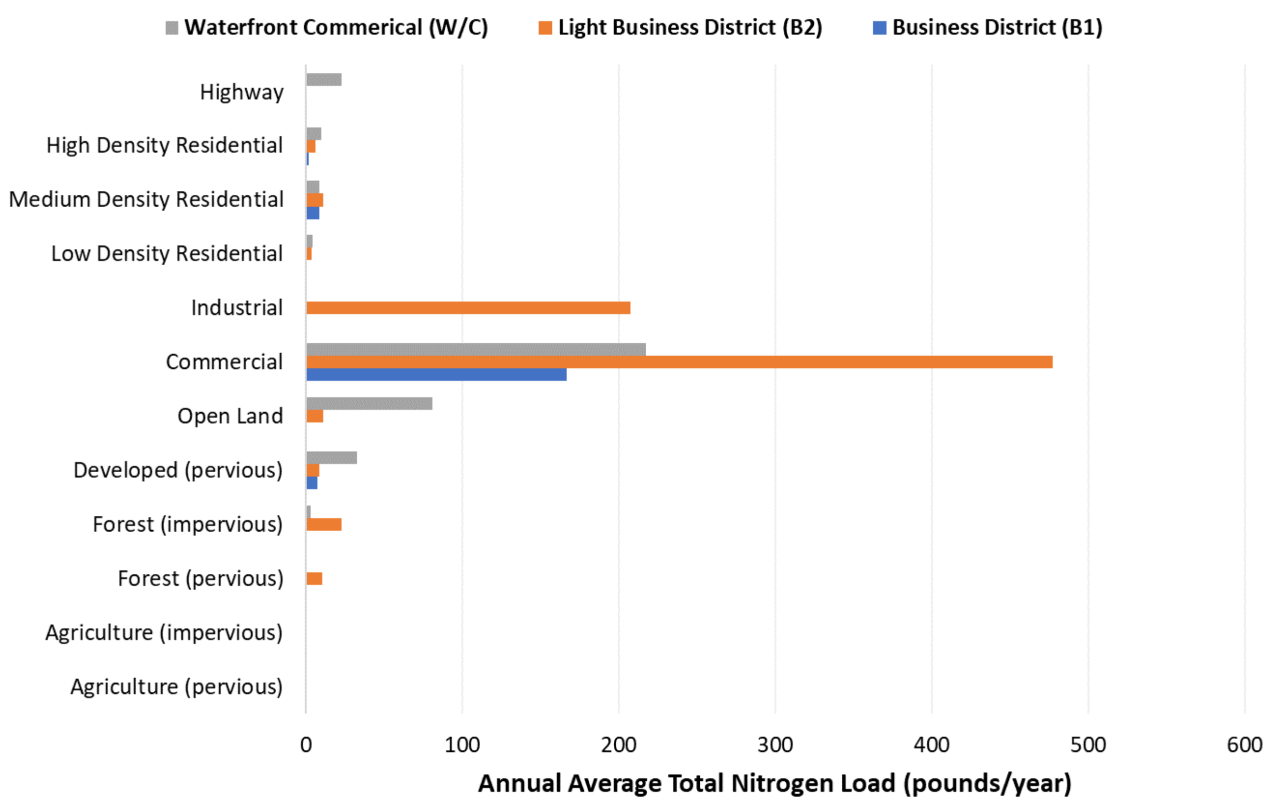

Figure 3-8. Summary of annual average total nitrogen by generalized HRU category for commercial zoning districts.

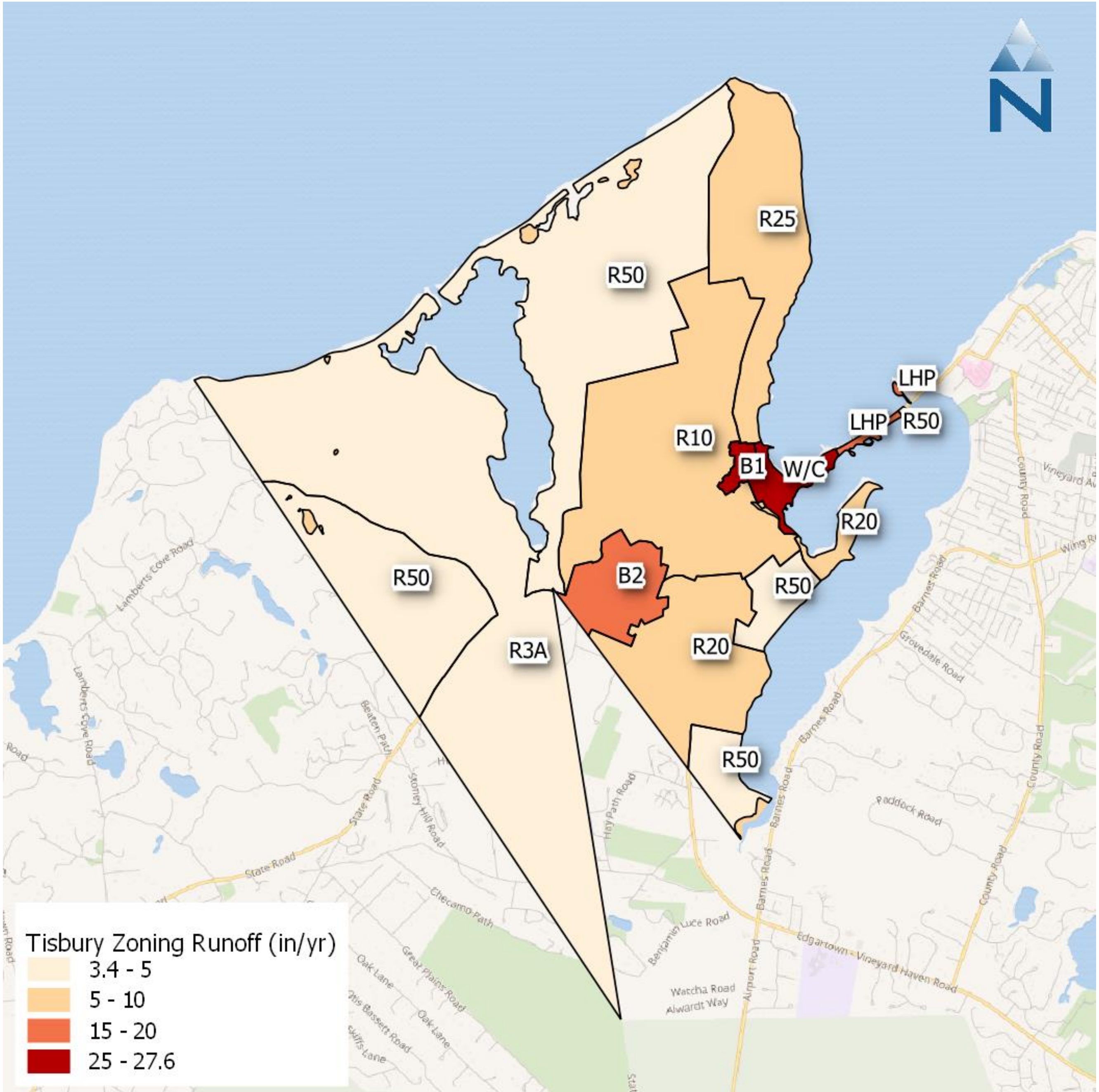

Figure 3-9. Tisbury annual average runoff volume (inches/year) normalized for zoning districts.

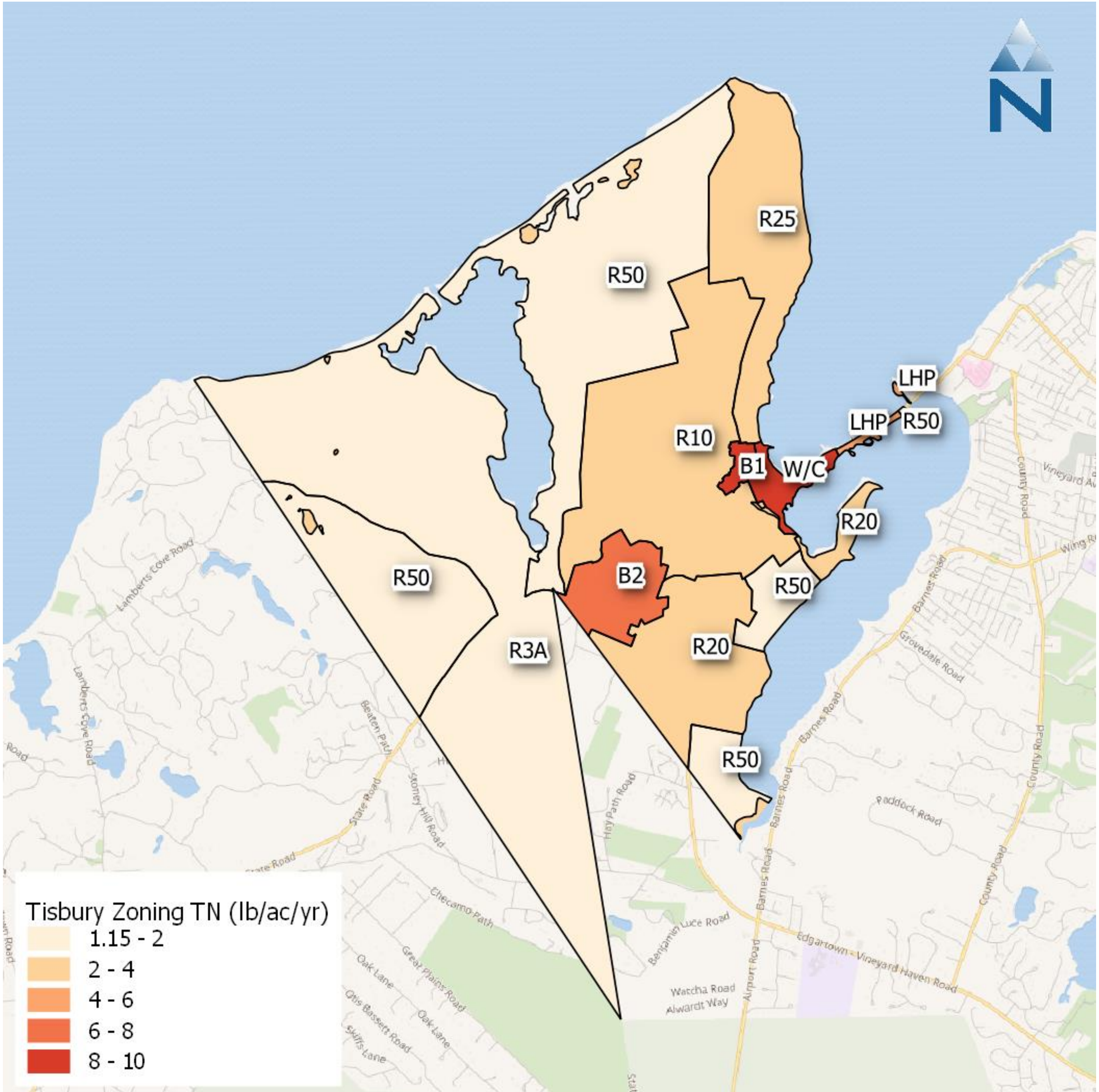

Figure 3-10. Tisbury annual average total nitrogen load (pounds/acre/year) normalized for zoning districts.

4 SUMMARY

This technical memorandum described the development of Hydrologic Response Units (HRUs), reviewed available climate data for characterizing conditions representative of Tisbury and Martha's Vineyard, discussed the setup of the SWMM-HRU model in Opti-Tool and concluded by presenting results of existing condition runoff volume and total nitrogen loading from the source areas in Tisbury. This existing condition, or baseline, will be the reference condition upon which the performance of different management strategies will be evaluated.

Weather data from the Martha's Vineyard Airport gauge provided both precipitation and daily temperature timeseries that were used as inputs to the SWMM-HRU model. The model development process also built upon the previous work presented in the Task 4A watershed characterization technical memorandum by leveraging GIS layers which described landscape characteristics most influential for runoff and pollutant generation, including slope, hydrologic soil group, and land cover type to build model HRUs. The area within Tisbury was also categorized by zoning district to better align with other planning efforts. Once the HRU were developed, SWMM-HRU model simulation was performed to develop timeseries and to quantify the volume of stormwater runoff and mass of total nitrogen generated over the 20-year simulation period.

The results of these summary level analyses show that runoff and total nitrogen loading were highest in the commercial and higher-density residential districts on a normalized area basis; however, pervious forested areas and lower density residential areas make up a large portion of Tisbury's area, and also a proportionally large portion of the runoff volume and total nitrogen load. The three commercial districts, which have been the focus of recent flooding concerns, showed the highest normalized area loading rates of all the zoning districts making these areas a focal point when considering future management strategies.

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APPENDIX A: SUMMARY OF HRU AREA, RUNOFF, AND TOTAL NITROGEN LOADS

Table A-1. Distribution of area by HRU and zoning district (acres). Darker shades represent higher values within each column.

HRU Categories	Area Distribution by Zoning District (acres)										All Zoning
	B1	B2	R10	R20	R25	R50	R3A	LHP	W/C	NZ	
Agriculture Pervious-A-Low	0.00	0.00	0.78	0.00	0.26	6.98	27.31	0.00	0.00	0.04	35.4
Agriculture Pervious-A-Med	0.00	0.00	0.26	0.00	0.48	15.44	42.44	0.00	0.00	0.04	58.7
Agriculture Pervious-A-High	0.00	0.00	0.02	0.00	0.05	3.73	11.14	0.00	0.00	0.01	14.9
Agriculture Pervious-B-Low	0.00	0.00	0.00	0.00	0.00	0.00	21.51	0.00	0.00	0.01	21.5
Agriculture Pervious-B-Med	0.00	0.00	0.00	0.00	0.00	0.02	6.94	0.00	0.00	0.03	7.0
Agriculture Pervious-B-High	0.00	0.00	0.00	0.00	0.00	0.02	0.96	0.00	0.00	0.01	1.0
Agriculture Impervious	0.00	0.00	0.00	0.00	0.11	1.96	6.46	0.00	0.00	0.01	8.6
Forest Pervious-A-Low	0.08	5.83	30.47	27.39	67.47	204.02	196.77	0.00	0.04	0.20	532.3
Forest Pervious-A-Med	0.20	15.06	74.27	59.44	75.41	409.03	399.89	0.00	0.13	0.26	1,033.7
Forest Pervious-A-High	0.17	10.60	40.56	46.77	10.23	158.61	171.07	0.00	0.24	0.23	438.5
Forest Pervious-B-Low	0.02	0.81	0.75	0.05	0.00	11.40	130.10	0.00	0.02	0.17	143.3
Forest Pervious-B-Med	0.02	1.47	1.14	0.09	0.00	9.53	81.76	0.00	0.02	0.08	94.1
Forest Pervious-B-High	0.00	0.13	0.41	0.15	0.00	2.24	18.16	0.00	0.01	0.06	21.2
Forest Impervious	0.06	2.14	10.12	12.04	7.38	54.60	42.86	0.00	0.29	0.01	129.5
Developed Pervious-A-Low	0.62	12.07	110.62	33.67	52.03	92.17	28.66	0.00	0.14	0.03	330.0
Developed Pervious-A-Med	1.46	14.20	166.49	61.59	62.20	119.98	47.85	0.00	0.44	0.06	474.3
Developed Pervious-A-High	0.95	12.66	55.95	33.03	16.95	39.26	22.21	0.00	0.34	0.04	181.4
Developed Pervious-B-Low	0.00	0.07	0.17	0.00	0.00	1.49	17.16	0.00	0.00	0.00	18.9
Developed Pervious-B-Med	0.00	0.06	0.06	0.00	0.00	1.11	13.89	0.00	0.00	0.00	15.1
Developed Pervious-B-High	0.00	0.06	0.01	0.00	0.00	0.12	2.56	0.00	0.00	0.00	2.8
Developed Pervious-C-Low	1.19	0.00	4.59	0.00	0.17	0.00	0.00	0.60	5.93	0.00	12.5
Developed Pervious-C-Med	0.90	0.00	0.38	0.00	0.21	0.00	0.00	0.77	3.08	0.00	5.3
Developed Pervious-C-High	0.30	0.00	0.08	0.00	0.04	0.00	0.00	0.42	0.77	0.00	1.6
Developed Pervious-D-Low	0.00	0.00	2.05	0.43	1.60	21.63	10.37	0.58	0.62	0.61	37.9
Developed Pervious-D-Med	0.00	0.00	1.67	0.57	6.50	9.24	4.19	0.64	0.42	0.33	23.5
Developed Pervious-D-High	0.00	0.00	0.35	0.39	3.45	2.58	0.89	0.36	0.26	0.11	8.4
Open Space	0.04	1.04	11.24	5.07	3.52	9.56	5.82	1.14	7.61	0.00	45.0
Commercial	11.74	33.63	8.01	2.85	1.82	1.11	0.55	0.00	15.31	0.00	75.0
Industrial	0.00	14.61	0.53	4.91	0.00	0.00	0.00	0.00	0.00	0.00	20.0
Low Density Residential	0.00	0.26	22.66	37.75	9.96	47.77	19.26	0.00	0.31	0.04	138.0
Medium Density Residential	0.63	0.84	107.36	1.32	23.75	2.83	0.00	0.00	0.65	0.00	137.4
High Density Residential	0.16	0.45	1.92	2.88	0.65	5.71	0.00	0.00	0.76	0.00	12.5
Highway	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	2.36	0.00	2.4
Total	**18.5**	**126.0**	**652.9**	**330.4**	**344.3**	**1,232.1**	**1,330.8**	**4.5**	**39.8**	**2.4**	**4,081.7**

Table A-2. Distribution of annual average runoff volume by HRU and zoning district (acre-feet/year). Darker shades represent higher values within each column.

HRU Categories	Annual Average Runoff Volume by Zoning District (acre-feet/year)										All Zoning
	B1	B2	R10	R20	R25	R50	R3A	LHP	W/C	NZ	
Agriculture Pervious-A-Low	0.0	0.0	0.6	0.0	0.2	5.0	19.6	0.0	0.0	0.0	25.4
Agriculture Pervious-A-Med	0.0	0.0	0.2	0.0	0.4	13.9	38.3	0.0	0.0	0.0	52.9
Agriculture Pervious-A-High	0.0	0.0	0.0	0.0	0.0	3.6	10.8	0.0	0.0	0.0	14.5
Agriculture Pervious-B-Low	0.0	0.0	0.0	0.0	0.0	0.0	49.4	0.0	0.0	0.0	49.4
Agriculture Pervious-B-Med	0.0	0.0	0.0	0.0	0.0	0.1	18.8	0.0	0.0	0.1	18.9
Agriculture Pervious-B-High	0.0	0.0	0.0	0.0	0.0	0.1	2.7	0.0	0.0	0.0	2.8
Agriculture Impervious	0.0	0.0	0.0	0.0	4.3	73.7	242.6	0.0	0.0	0.3	320.9
Forest Pervious-A-Low	0.1	4.2	21.9	19.7	48.4	146.4	141.2	0.0	0.0	0.1	381.9
Forest Pervious-A-Med	0.2	13.6	67.0	53.6	68.0	368.9	360.7	0.0	0.1	0.2	932.4
Forest Pervious-A-High	0.2	10.3	39.3	45.3	9.9	153.6	165.6	0.0	0.2	0.2	424.6
Forest Pervious-B-Low	0.0	1.9	1.7	0.1	0.0	26.2	298.9	0.0	0.0	0.4	329.2
Forest Pervious-B-Med	0.0	4.0	3.1	0.2	0.0	25.7	220.8	0.0	0.1	0.2	254.2
Forest Pervious-B-High	0.0	0.4	1.2	0.4	0.0	6.4	51.5	0.0	0.0	0.2	60.0
Forest Impervious	2.2	80.2	379.9	452.0	277.1	2,049.1	1,608.5	0.0	11.0	0.3	4,860.2
Developed Pervious-A-Low	0.2	3.7	34.2	10.4	16.1	28.5	8.9	0.0	0.0	0.0	102.1
Developed Pervious-A-Med	0.6	5.7	66.9	24.7	25.0	48.2	19.2	0.0	0.2	0.0	190.6
Developed Pervious-A-High	0.4	5.6	24.8	14.6	7.5	17.4	9.8	0.0	0.1	0.0	80.4
Developed Pervious-B-Low	0.0	0.2	0.4	0.0	0.0	3.4	39.4	0.0	0.0	0.0	43.4
Developed Pervious-B-Med	0.0	0.2	0.2	0.0	0.0	3.0	37.5	0.0	0.0	0.0	40.9
Developed Pervious-B-High	0.0	0.2	0.0	0.0	0.0	0.3	7.3	0.0	0.0	0.0	7.8
Developed Pervious-C-Low	6.4	0.0	24.8	0.0	0.9	0.0	0.0	3.3	32.1	0.0	67.6
Developed Pervious-C-Med	5.5	0.0	2.3	0.0	1.3	0.0	0.0	4.7	18.8	0.0	32.6
Developed Pervious-C-High	1.9	0.0	0.5	0.0	0.3	0.0	0.0	2.7	4.9	0.0	10.3
Developed Pervious-D-Low	0.0	0.0	21.0	4.4	16.4	221.6	106.3	6.0	6.3	6.2	388.2
Developed Pervious-D-Med	0.0	0.0	18.6	6.3	72.4	103.0	46.7	7.1	4.7	3.6	262.5
Developed Pervious-D-High	0.0	0.0	4.0	4.5	39.6	29.6	10.2	4.1	3.0	1.3	96.4
Open Space	1.5	38.9	422.0	190.1	132.2	358.8	218.2	42.9	285.8	0.0	1,690.5
Commercial	440.7	1,262.0	300.7	107.0	68.4	41.7	20.7	0.0	574.4	0.0	2,815.6
Industrial	0.0	548.4	19.8	184.2	0.0	0.0	0.0	0.0	0.0	0.0	752.3
Low Density Residential	0.0	9.6	850.5	1,416.8	373.9	1,792.7	722.9	0.0	11.7	1.5	5,179.7
Medium Density Residential	23.8	31.4	4,029.0	49.7	891.1	106.1	0.0	0.0	24.5	0.0	5,155.5
High Density Residential	5.9	17.1	71.9	108.1	24.4	214.4	0.0	0.0	28.3	0.0	470.1
Highway	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	88.7	0.0	89.2
Total	**489.6**	**2,037.3**	**6,406.4**	**2,692.3**	**2,078.4**	**5,841.5**	**4,476.6**	**70.9**	**1,095.1**	**14.9**	**25,203.0**

Table A-3. Distribution of annual average total nitrogen load by HRU and zoning district (lbs/year). Darker shades represent higher values within each column.

HRU Categories	Annual Average Total Nitrogen Load by Zoning District (pounds/year)										All Zoninc
	B1	B2	R10	R20	R25	R50	R3A	LHP	W/C	NZ	
Agriculture Pervious-A-Low	0.0	0.0	0.7	0.0	0.2	6.4	25.1	0.0	0.0	0.0	32.5
Agriculture Pervious-A-Med	0.0	0.0	0.4	0.0	0.7	22.3	61.3	0.0	0.0	0.1	84.7
Agriculture Pervious-A-High	0.0	0.0	0.0	0.0	0.1	6.2	18.5	0.0	0.0	0.0	24.8
Agriculture Pervious-B-Low	0.0	0.0	0.0	0.0	0.0	0.0	60.6	0.0	0.0	0.0	60.7
Agriculture Pervious-B-Med	0.0	0.0	0.0	0.0	0.0	0.1	26.1	0.0	0.0	0.1	26.3
Agriculture Pervious-B-High	0.0	0.0	0.0	0.0	0.0	0.1	3.8	0.0	0.0	0.0	4.0
Agriculture Impervious	0.0	0.0	0.0	0.0	1.2	20.9	68.8	0.0	0.0	0.1	91.1
Forest Pervious-A-Low	0.0	1.1	5.7	5.2	12.7	38.5	37.1	0.0	0.0	0.0	100.4
Forest Pervious-A-Med	0.1	4.3	21.1	16.8	21.4	115.9	113.3	0.0	0.0	0.1	293.0
Forest Pervious-A-High	0.1	3.4	13.0	15.0	3.3	51.0	55.0	0.0	0.1	0.1	140.9
Forest Pervious-B-Low	0.0	0.5	0.4	0.0	0.0	6.7	76.1	0.0	0.0	0.1	83.8
Forest Pervious-B-Med	0.0	1.1	0.9	0.1	0.0	7.2	62.1	0.0	0.0	0.1	71.5
Forest Pervious-B-High	0.0	0.1	0.3	0.1	0.0	1.8	14.7	0.0	0.0	0.0	17.1
Forest Impervious	0.6	22.8	107.8	128.2	78.6	581.4	456.4	0.0	3.1	0.1	1,379.0
Developed Pervious-A-Low	0.1	1.8	16.7	5.1	7.9	13.9	4.3	0.0	0.0	0.0	49.9
Developed Pervious-A-Med	0.3	3.1	36.4	13.5	13.6	26.2	10.5	0.0	0.1	0.0	103.7
Developed Pervious-A-High	0.2	3.2	14.0	8.2	4.2	9.8	5.5	0.0	0.1	0.0	45.3
Developed Pervious-B-Low	0.0	0.1	0.2	0.0	0.0	1.8	21.1	0.0	0.0	0.0	23.2
Developed Pervious-B-Med	0.0	0.1	0.1	0.0	0.0	1.8	22.6	0.0	0.0	0.0	24.7
Developed Pervious-B-High	0.0	0.1	0.0	0.0	0.0	0.2	4.4	0.0	0.0	0.0	4.8
Developed Pervious-C-Low	3.0	0.0	11.7	0.0	0.4	0.0	0.0	1.5	15.1	0.0	31.8
Developed Pervious-C-Med	2.7	0.0	1.2	0.0	0.6	0.0	0.0	2.4	9.5	0.0	16.4
Developed Pervious-C-High	1.0	0.0	0.2	0.0	0.1	0.0	0.0	1.4	2.5	0.0	5.2
Developed Pervious-D-Low	0.0	0.0	8.1	1.7	6.3	85.2	40.8	2.3	2.4	2.4	149.2
Developed Pervious-D-Med	0.0	0.0	7.6	2.6	29.6	42.1	19.1	2.9	1.9	1.5	107.4
Developed Pervious-D-High	0.0	0.0	1.6	1.9	16.2	12.1	4.2	1.7	1.2	0.5	39.5
Open Space	0.4	11.0	119.7	54.0	37.5	101.8	61.9	12.2	81.1	0.0	479.7
Commercial	166.6	477.1	113.7	40.4	25.9	15.8	7.8	0.0	217.2	0.0	1,064.5
Industrial	0.0	207.3	7.5	69.6	0.0	0.0	0.0	0.0	0.0	0.0	284.4
Low Density Residential	0.0	3.4	300.6	500.8	132.2	633.6	255.5	0.0	4.1	0.5	1,830.7
Medium Density Residential	8.4	11.1	1,424.0	17.5	315.0	37.5	0.0	0.0	8.6	0.0	1,822.2
High Density Residential	2.1	6.0	25.4	38.2	8.6	75.8	0.0	0.0	10.0	0.0	166.2
Highway	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	22.6	0.0	22.7
Total	**185.7**	**757.7**	**2,239.2**	**919.0**	**716.6**	**1,916.3**	**1,537.0**	**24.4**	**379.7**	**5.8**	**8,681.3**