



HRU Analysis for SNEP Region | HRU Mapping Approach

TO: Michelle Vuto, EPA Region 1

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SUBJECT: EPA Region 1 SNEP Hydrologic Response Unit (HRU) Mapping Approach

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1 INTRODUCTION

Horsley Witten Group, Inc. (HW) and FB Environmental Associates (FBE) were contracted by the United States Environmental Protection Agency (US EPA) to assist US EPA and SNEP in facilitating stormwater pollution control and tracking by mapping Hydrologic Response Units (HRUs) at a regional-scale for the [SNEP region](#), which covers the watersheds of Narragansett Bay, Buzzards Bay, Nantucket Sound (including Martha's Vineyard, Nantucket, and the south-draining portions of Cape Cod; see Figure 1). This is the final deliverable of the HRU Mapping Approach task, incorporating feedback from EPA and other project partners.

2 PROJECT OVERVIEW

Conducting this analysis at the regional level is intended to ensure source data and analytical consistency, provide an efficiency of scale, and facilitate and accelerate outreach and education to the many municipalities and subwatersheds encompassed by this region.

Hydrologic Response Units (HRUs) in this task will be created by integrating readily available geospatial datasets: land use, impervious cover, soils, and elevation (with derived slope). The resulting HRU map will then be used to develop runoff and pollutant load simulations based on local historical weather datasets. Each HRU is associated with specific stormwater pollutant loading characteristics as estimated in [EPA's Opti-Tool](#), based on EPA Stormwater Management Model (SWMM) (EPA, 2016). The HRU map, EPA's Opti-Tool, and historical weather data from the region will be used in Opti-Tool to estimate stormwater pollutant loading for each HRU in Task 4, *Watershed Stormwater Pollutant Loading Analysis*.

These mapped pollutant load estimates are intended to facilitate stormwater management efforts within the SNEP region. Beyond predicting current stormwater pollutant loads, Opti-Tool also is able to estimate cost and pollutant load reduction from a set of structural Stormwater Control Measures (SCMs) for stormwater remediation. Opti-Tool also incorporates a cost-per-load-reduction function so that proposed sets of location-specific SCMs may be evaluated for cost and effectiveness. HRU mapping and pollutant load estimations preceded site-scale stormwater management efforts in the Wading River (Taunton River) Flow Duration Curves projects, and the Tisbury Impervious Cover Disconnection (ICD) project. This project is expected to facilitate stormwater management in the many watersheds and municipalities within the SNEP region, with targeted outreach to those municipalities occurring in the final stages of this project.

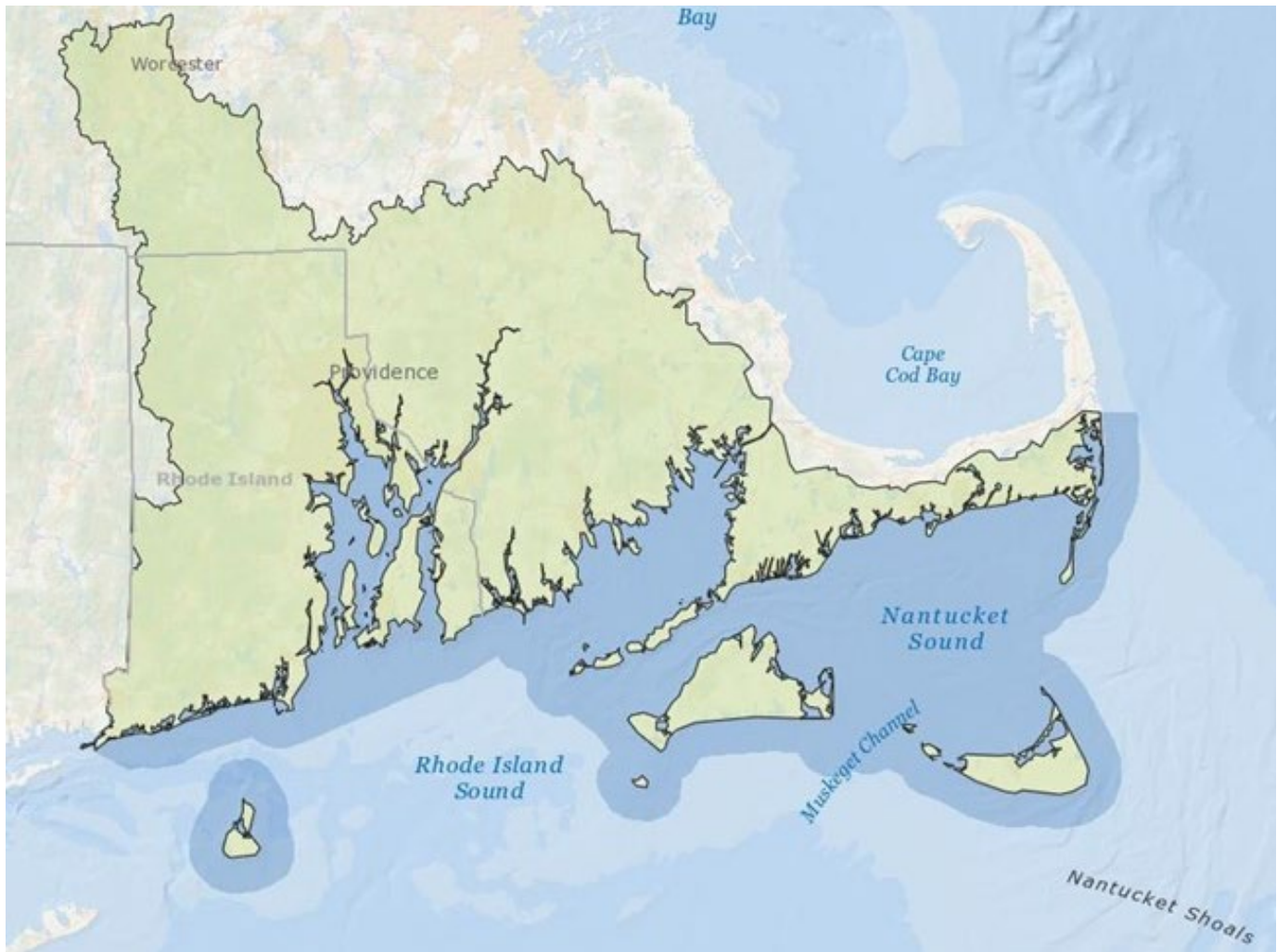


Figure 1: Southeast New England Program (SNEP) region. [Source EPA](#), accessed November 1, 2023.

3 OVERVIEW OF HRU MAPPING APPROACH

As mentioned in Section 2, HRU mapping integrates readily available geospatial datasets. These data layers provide inputs to the SWMM model as implemented in Opti-Tool and are thus standardized for all HRU analysis efforts. Opti-Tool is based on regionally calibrated stormwater pollutant loading data for the land use and impervious classes below. These specific geospatial data layers and feature classes have been used in previous efforts in the Taunton River watershed (Wading River); Tisbury ICD project; Great Bay, NH; and by the Cape Cod Commission in their HRU analyses.

- Land use (10 classes)
 - Agriculture
 - Commercial
 - Forest
 - Highway
 - Industrial
 - Low Density Residential
 - Medium Density Residential
 - High Density Residential
 - Open Land
 - Water
- Impervious cover (2 classes)
 - Impervious (e.g., roads, buildings)
 - Pervious
- Hydrologic soil group (4 classes)
 - A: least runoff when thoroughly wet, most transmissive of water (e.g., >90% sand or gravel)
 - B: moderately low runoff when thoroughly wet
 - C: moderately high runoff when thoroughly wet
 - D: most runoff when thoroughly wet, least transmissive of water (e.g., >40% clay)
- Slope of terrain (3 classes)
 - ≤5%
 - >5% to 15%
 - >15%

When these data layers are overlain, it creates HRU features, each of which contains one attribute from each of the four data layers. The number of unique combinations of these feature classes results in 240 possible unique HRUs, though not all combinations may be present in the SNEP region.

4 SELECTED INPUT DATASETS

HW and FBE have reviewed publicly available state GIS data for this project from the Massachusetts Bureau of Geographic Information (MassGIS), the Rhode Island Geographic Information System (RIGIS) and federal sources such as the EPA, National Oceanic and Atmospheric Administration (NOAA) and the United States Geological Survey (USGS). Team members have also consulted with US EPA and project partners on data used in previous HRU analyses. The selected input datasets which align with the watershed characterization layers noted in Section 1.1 were based on regional consistency, appropriate spatial resolution, data availability and adequate quality assurance. These datasets are discussed further within this subsection.

[SNEP's 2021-2025 Strategic Plan](#) describes the SNEP geographic area as follows:

"The Program covers Rhode Island and the southeastern coastal areas of Massachusetts including the southern facing watersheds of Cape Cod, Martha's Vineyard and Nantucket, Narragansett Bay, and Buzzards Bay." (SNEP, 2021)

The shapefile of the SNEP area (SNEP_Region_Boundary.shp) was provided by EPA, and are also shown in:

- Map of SNEP Study Area (image format). Source: SNEP.
https://snepnetwork.org/wp-content/uploads/2020/07/SNEP_RegionMap-1024x791-2.png
- Interactive map of study area. Source: EPA.
<https://epa.maps.arcgis.com/apps/webappviewer/index.html?id=596401a1439e48a8a02ce9473b453c41>

Using the above maps as guides, HW/FBE identified 39 Rhode Island and 95 Massachusetts municipalities (total of 134) entirely or partially in the SNEP area. The SNEP Strategic Plan instead states the SNEP region covers all or part of 133 municipalities (SNEP, 2021), one less than what HW/FBE identified. HW/FBE will work with EPA SNEP to review and confirm municipalities in the SNEP region. HW/FBE reviewed a recent map (Figure 2) from [SNEP's 2021-2025 Strategic Plan](#), and was not able to resolve the discrepancy. We anticipate that SNEP can provide a list of municipalities in their region or the shapefiles used to create the map in Figure 2 to resolve the issue.

4.1 WATERSHED BOUNDARIES

The SNEP geographic area definition mentions watersheds. The HW/FBE team will use the SNEP shapefile provided by EPA and available geospatial watershed datasets and features to define the watersheds in the region. Using the sources in Table 1, we found that the HUC 12 watersheds available in EPA's [Watershed Index Online](#) (WSIO) data library matched the published SNEP watershed map. We identified 83 HUC 12 watersheds in the SNEP region. We also used Massachusetts "subbasins" data layer to provide the dividing line between drainage to the bay and the ocean on Cape Cod (Figure 3).

We noted some minor misalignments along watershed boundaries when comparing EPA's HUC 12 watersheds and the respective state GIS agency data layers to the SNEP region maps (Figure 3). We intend to proceed using EPA's SNEP-area watershed and HUC12 boundaries, and the MassGIS "subbasins" data layer for Cape Cod.

Table 1: Watershed boundary datasets.

Data Layer	Shapefile Name and Link	Source Agency	Note
EPA's HUC 12	NHDplusV2_HUC12.shp, contained within WSIO Geodatabase with Hydrologic Unit Code (HUC12) polygons [zip archive]	EPA	Accessed via EPA's Watershed Index Online (WSIO). We intend to use this data layer.
MA HUC 12 watersheds	NRCSHUC_POLY	MassGIS	Minor boundary variations as compared to SNEP watershed map.
MA subbasins	SUBBASINS_POLY	MassGIS	This layer to be used to divide Cape Cod between the bay and ocean (not provided in other HUC12 data layers)
RI HUC 12 watersheds	Watershed Boundary Dataset HUC 12	RIGIS	The SNEP area is truncated at the RI-CT boundary. This data layer was inspected but will not be used.

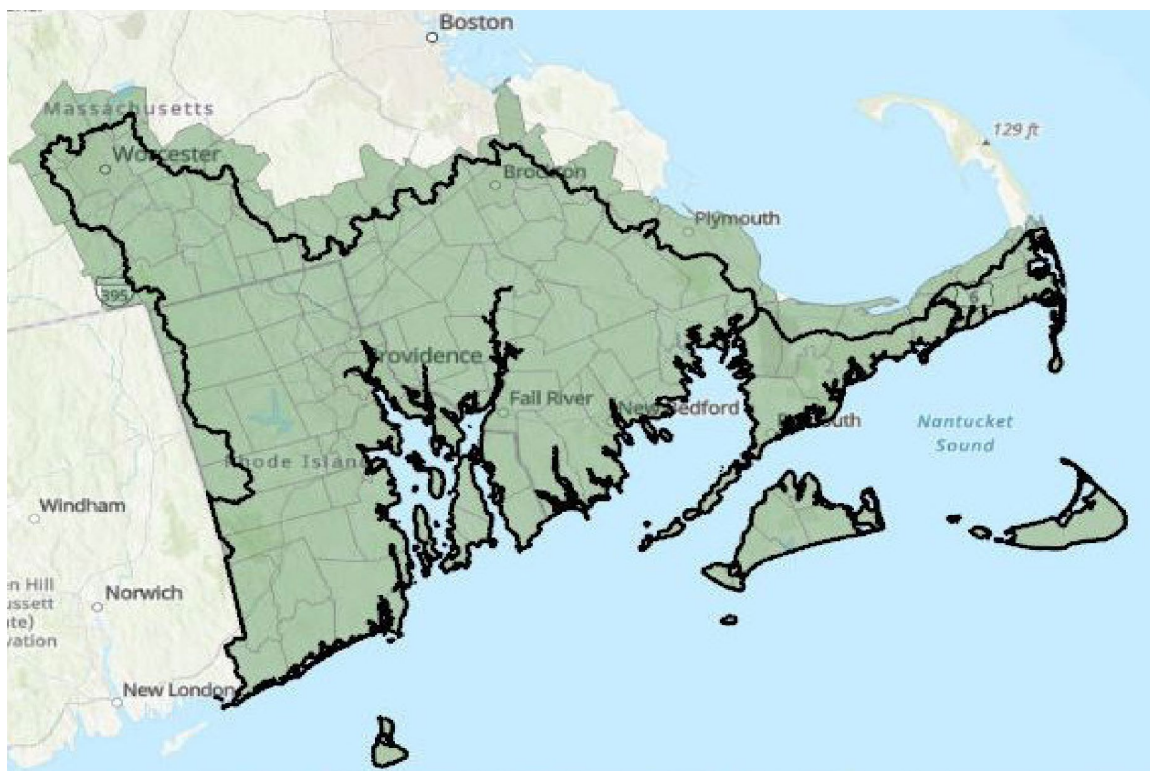


Figure 2: [SNEP's 2021-2025 Strategic Plan](#) includes this map of towns and watersheds (SNEP, 2021).

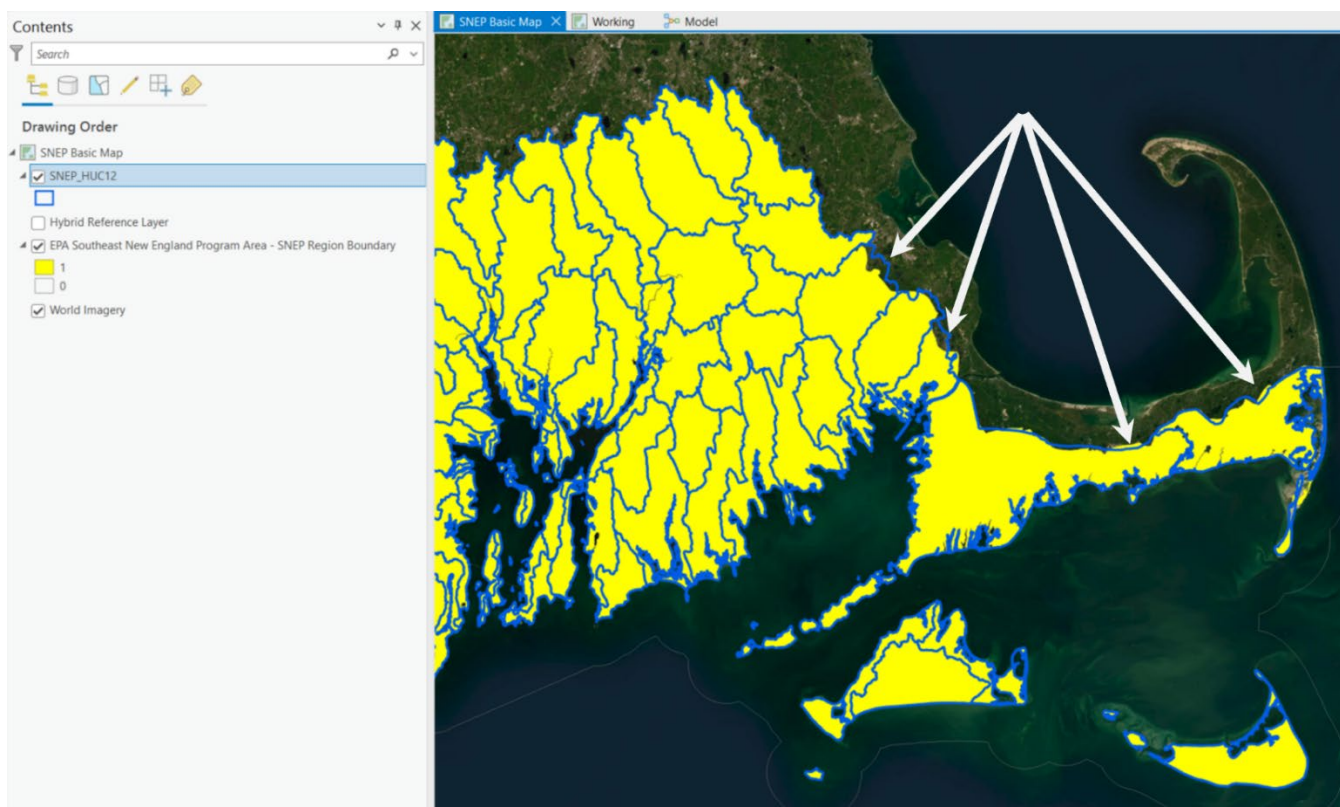


Figure 3: Minor misalignment between states' HUC12 watershed boundaries (blue) and EPA [SNEP's online interactive map](#) (yellow), which matches the Watershed Index Online (WSIO) shapefile. Arrows point to a few representative areas of misalignment.

4.2 MUNICIPAL BOUNDARIES

HW/FBE will use municipal boundaries as provided by the respective state GIS agencies (Table 2). Minor spatial adjustments may be necessary to ensure contiguous boundaries between the states.

Table 2: Municipal boundary datasets.

Data Layer	Shapefile Name and Link	Source Agency
MA Town Boundaries	CENSUS2020TOWNS_POLY	MassGIS
RI Town Boundaries	Municipalities_1997_project	RIGIS

4.3 HYDROLOGIC SOIL GROUP

Hydrologic soil groups (HSG) will be obtained from the USDA NRCS Web Soil Survey site, the originator of the dataset. HW/FBE has identified 39 shapefiles which cover the region. FBE will use this link to access this data source:

https://websoilsurvey.nrcs.usda.gov/app/HomePage.htm?TARGET_APP=Web_Soil_Survey_application_t2erfq3cdymiyoyk2clrhj2

Hydrologic soil group metadata provides the following descriptions of the feature classes (bold added). All dual HSG designations will be assigned to group “D.”

*“**Hydrologic soil groups** are based on estimates of runoff potential. Soils are assigned to one of four groups according to the rate of water infiltration when the soils are not protected by vegetation, are thoroughly wet, and receive precipitation from long-duration storms.*

The soils in the United States are assigned to four groups (A, B, C, and D) and three dual classes (A/D, B/D, and C/D). The groups are defined as follows:

***Group A.** Soils having a high infiltration rate (low runoff potential) when thoroughly wet. These consist mainly of deep, well drained to excessively drained sands or gravelly sands. These soils have a high rate of water transmission.*

***Group B.** Soils having a moderate infiltration rate when thoroughly wet. These consist chiefly of moderately deep or deep, moderately well drained or well drained soils that have moderately fine texture to moderately coarse texture. These soils have a moderate rate of water transmission.*

***Group C.** Soils having a slow infiltration rate when thoroughly wet. These consist chiefly of soils having a layer that impedes the downward movement of water or soils of moderately fine texture or fine texture. These soils have a slow rate of water transmission.*

***Group D.** Soils having a very slow infiltration rate (high runoff potential) when thoroughly wet. These consist chiefly of clays that have a high shrink-swell potential, soils that have a high water table, soils that have a claypan or clay layer at or near the surface, and soils that are shallow over nearly impervious material. These soils have a very slow rate of water transmission.*

*If a soil is assigned to a **dual hydrologic group (A/D, B/D, or C/D)**, the first letter is for drained areas and the second is for undrained areas. Only the soils that in their natural condition **are in group D** are assigned to dual classes.”*

4.4 SLOPE

HW/FBE will derive the slope of terrain from US Geological Survey (USGS) digital elevation models (DEMs), accessed through the National Map using this link: <https://apps.nationalmap.gov/downloader/>. See Table 3 for specific DEMs. See Section 5 Geospatial Workflow for how DEMs will be transformed into a slope data layer.

Table 3: USGS digital elevation models used to derive slope.

DEM Data Layer	USGS Name
Original DEM #1	USGS 1/3 Arc Second n42w070 20230117
Original DEM #2	USGS 1/3 Arc Second n42w071 20230117
Original DEM #3	USGS 1/3 Arc Second n42w072 20230117
Original DEM #4	USGS 1/3 Arc Second n43w071 20230117
Original DEM #5	USGS 1/3 Arc Second n43w072 20230117

4.5 LAND USE

Recent land use datasets will be sourced from the respective states as shown in Table 4.

Table 4: Land use datasets.

Data Layer	Shapefile Name and Link	Source Agency	Year, Ground Conditions	Year, Data Published
MA land use original	LANDCOVER LANDUSE POLY	MassGIS	2016	2019
RI land use original	PLAN Land Cover Use 2020	RIGIS	2020	2022

4.6 IMPERVIOUS AREA

National Oceanic & Atmospheric Administration’s (NOAA) C-CAP High-Resolution Land Cover dataset provides recent, high resolution (1 m) data for both RI and MA. The “Version 2” subset contains an extract of impervious cover from the landcover data, reflecting 2019-2021 conditions. The datasets will be accessed through:

<https://coast.noaa.gov/digitalcoast/data/ccaphighres.html>

Direct links to the datasets are:

- [2021 NOAA C-CAP Version 2 Impervious Cover: Massachusetts](#)
- [2021 NOAA C-CAP Version 2 Impervious Cover: Rhode Island](#)

5 GEOSPATIAL WORKFLOW

5.1 PREPARING INPUT DATA LAYERS

The primary process for preparing the data involves combining the selected datasets in mapping software (GIS) and using the “union” tool. However, additional steps are necessary to ensure consistency, compatibility, data quality, and workflow efficiency. A geospatial workflow using the selected data layers has been reviewed in detail and is presented below. All work will occur in ArcMap Pro version 3.1.1 or newer.

Generally, the GIS project will use the standard **MassGIS projection** (NAD 1983 StatePlane Massachusetts FIPS 2001 (Meters)). Data layers may be (re-)projected as needed to ensure compatibility. Any areas of missing data will be resolved to ensure continuous data coverage. Minor data gaps will be addressed by adjustments to GIS data where necessary, such as realignment of watershed and municipal boundaries, and will be documented by the HW/FBE team. Resolution of more significant data gaps, if found, will be coordinated with SNEP and/or state GIS staff to determine the optimal approach. Data layers containing fully contiguous features covering the entire SNEP region are required to conduct a complete HRU analysis of the region.

5.1.1 Soils

The 39 soil hydrologic shapefiles will be processed into a single soils data layer as follows (bold text indicates GIS process step):

1. **Merge** 39 shapefiles into one shapefile
2. **Dissolve** by MUSYM (map unit symbol)
3. **Join** to the hydrologic soil group (HSG) ratings per MUSYM
4. **Project** to common projection (that used by MassGIS, see above)
5. **Union** to AOI (boundary box), correct slivers related to small gaps in the dataset
6. **Reclassify** the HSG ratings to the HRU ratings, then inspect results
7. **Dissolve** by HRU hydrologic soil group

5.1.2 Slope

DEMs (raster) will be processed into a slope shapefile (vector) as follows:

1. **Mosaic** DEMs into single raster
2. **Clip** DEM to the AOI (boundary box)
3. **Calculate % slope** for the DEM
4. Convert raster to integer type raster (**remap** slope to integer)
5. **Convert raster to polygon** version of slope, **classify** into three bins ($\leq 5\%$, 5-15% $> 15\%$)

5.1.3 Land Use

Both land use data layers have more (and different) feature classes than are used in HRU mapping. The project team will reclassify each data layer's features into the ten classes required by HRU mapping.

The Massachusetts land use and land cover data layer will be reclassified following the MassDEP land use / land cover "crosswalk" (2016 Massachusetts Small MS4 Permit Pollutant Loading Export Rates applied to the 2016 Massachusetts Land Use/Land Cover GIS Dataset, MassDEP, undated ca. 2020). The MassGIS land use / land cover data layer contains separate attribute fields for land use and land cover. Combined, they provide an analog to HRU categories (Table 5), including designating pervious/impervious categories. Note that the crosswalk does not fully align with HRU categories, as follows:

- **HRU Highway** appears to correspond to a **MassDEP weighted average pollutant load export rate** ("Weighted AvgPLER") based on Charles River watershed data.
- **HRU Low Density Residential** is missing in the MassDEP crosswalk.
- **MassDEP "PerviousHSG"** does not directly correspond to an HRU category.

Table 5: Massachusetts land use reclassification, as presented in the “2016 Massachusetts Small MS4 Permit Pollutant Loading Export Rates applied to the 2016 Massachusetts Land Use/Land Cover GIS Dataset” document (MassDEP undated, ca. 2020). Data are presented in a flat table (GIS) format in Table 7.

			LAND COVER CLASSES																		
			IMPERVIOUS	DEVELOPED SPACE OPEN	CULTIVATED	PASTURE/HAY	GRASSLAND	DECIDUOUS	EVERGREEN	SHRUB/SCRUB	FORESTED PALUSTRINE	SHRUB/SCRUB PALUSTRINE	EMERGENT PALUSTRINE	FORESTED ESTUARINE	SHRUB/SCRUB ESTUARINE	EMERGENT ESTUARINE	UNCONSOLIDATE	BARE	WATER	BED AQUATIC PALUSTRINE	BED AQUATIC ESTUARINE
			2	5	6	7	8	9	10	12	13	14	15	16	17	18	19	20	21	22	23
			DEV	DEV	UND	UND	UND	UND	UND	UND	UND	UND	UND	UND	UND	UND	UND	UND	UND	UND	UND
LAND USE CLASSES	UNKNOWN	0	-	Open Land	Pervious HSG	Agriculture Pervious	Agriculture Pervious	Pervious HSG	Forest Pervious	Forest Pervious	Forest Pervious	Pervious HSG	Pervious HSG	Pervious HSG	Pervious HSG	Pervious HSG	Pervious HSG	Pervious HSG	Water	Water	Water
	OPEN LAND	2	UND	Open Land	Pervious HSG	Agriculture Pervious	Agriculture Pervious	Pervious HSG	Forest Pervious	Forest Pervious	Forest Pervious	Pervious HSG	Pervious HSG	Pervious HSG	Pervious HSG	Pervious HSG	Pervious HSG	Pervious HSG	Water	Water	Water
	COMMERCIAL	3	DEV	Commercial and Industrial	Pervious HSG	Agriculture Pervious	Agriculture Pervious	Pervious HSG	Forest Pervious	Forest Pervious	Forest Pervious	Pervious HSG	Pervious HSG	Pervious HSG	Pervious HSG	Pervious HSG	Pervious HSG	Pervious HSG	Water	Water	Water
	INDUSTRIAL	4	DEV	Commercial and Industrial	Pervious HSG	Agriculture Pervious	Agriculture Pervious	Pervious HSG	Forest Pervious	Forest Pervious	Forest Pervious	Pervious HSG	Pervious HSG	Pervious HSG	Pervious HSG	Pervious HSG	Pervious HSG	Pervious HSG	Water	Water	Water
	FOREST	6	UND	Forest	Forest Pervious	Forest Pervious	Agriculture Pervious	Forest Pervious	Forest Pervious	Forest Pervious	Forest Pervious	Forest Pervious	Forest Pervious	Forest Pervious	Forest Pervious	Forest Pervious	Pervious HSG	Pervious HSG	Water	Water	Water
	AGRICULTURAL	7	UND	Agriculture	Agriculture Pervious	Agriculture Pervious	Agriculture Pervious	Agriculture Pervious	Forest Pervious	Forest Pervious	Forest Pervious	Pervious HSG	Pervious HSG	Pervious HSG	Pervious HSG	Pervious HSG	Pervious HSG	Pervious HSG	Water	Water	Water
	RECREATIONAL	8	DEV	Open Land	Pervious HSG	Agriculture Pervious	Agriculture Pervious	Pervious HSG	Forest Pervious	Forest Pervious	Forest Pervious	Pervious HSG	Pervious HSG	Pervious HSG	Pervious HSG	Pervious HSG	Pervious HSG	Pervious HSG	Water	Water	Water
	TAX EXEMPT	9	-	Commercial and Industrial	Pervious HSG	Agriculture Pervious	Agriculture Pervious	Pervious HSG	Forest Pervious	Forest Pervious	Forest Pervious	Pervious HSG	Pervious HSG	Pervious HSG	Pervious HSG	Pervious HSG	Pervious HSG	Pervious HSG	Water	Water	Water
	MIXED-PRIMARILY RESIDENTIAL	10	DEV	Multi-Family and High-Density Residential	Pervious HSG	Agriculture Pervious	Agriculture Pervious	Pervious HSG	Forest Pervious	Forest Pervious	Forest Pervious	Pervious HSG	Pervious HSG	Pervious HSG	Pervious HSG	Pervious HSG	Pervious HSG	Pervious HSG	Water	Water	Water
	SINGLE FAMILY RESIDENTIAL	11	DEV	Medium-Density Residential	Pervious HSG	Agriculture Pervious	Agriculture Pervious	Pervious HSG	Forest Pervious	Forest Pervious	Forest Pervious	Pervious HSG	Pervious HSG	Pervious HSG	Pervious HSG	Pervious HSG	Pervious HSG	Pervious HSG	Water	Water	Water
	MULTI-FAMILY RESIDENTIAL	12	DEV	Multi-Family and High-Density Residential	Pervious HSG	Agriculture Pervious	Agriculture Pervious	Pervious HSG	Forest Pervious	Forest Pervious	Forest Pervious	Pervious HSG	Pervious HSG	Pervious HSG	Pervious HSG	Pervious HSG	Pervious HSG	Pervious HSG	Water	Water	Water
	OTHER RESIDENTIAL	13	DEV	Medium-Density Residential	Pervious HSG	Agriculture Pervious	Agriculture Pervious	Pervious HSG	Forest Pervious	Forest Pervious	Forest Pervious	Pervious HSG	Pervious HSG	Pervious HSG	Pervious HSG	Pervious HSG	Pervious HSG	Pervious HSG	Water	Water	Water
	MIXED OTHER	20	-	Commercial and Industrial	Pervious HSG	Agriculture Pervious	Agriculture Pervious	Pervious HSG	Forest Pervious	Forest Pervious	Forest Pervious	Pervious HSG	Pervious HSG	Pervious HSG	Pervious HSG	Pervious HSG	Pervious HSG	Pervious HSG	Water	Water	Water
	MIXED COMMERCIAL	30	DEV	Commercial and Industrial	Pervious HSG	Agriculture Pervious	Agriculture Pervious	Pervious HSG	Forest Pervious	Forest Pervious	Forest Pervious	Pervious HSG	Pervious HSG	Pervious HSG	Pervious HSG	Pervious HSG	Pervious HSG	Pervious HSG	Water	Water	Water
	RIGHT OF WAY	55	DEV	Weighted Avg PLER	Pervious HSG	Agriculture Pervious	Agriculture Pervious	Pervious HSG	Forest Pervious	Forest Pervious	Forest Pervious	Pervious HSG	Pervious HSG	Pervious HSG	Pervious HSG	Pervious HSG	Pervious HSG	Pervious HSG	Water	Water	Water
	WATER	88	UND	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water

Rhode Island land uses will be reclassified as shown in Table 6. This approach (and the approach used in the past in Massachusetts in the Tisbury ICD project; Alvi and Murphy, 2018) is based on a land use / land cover data layer contains only a single attribute field, and thus no crosswalk is involved.

Table 6: Rhode Island land use reclassification for HRU purposes.

LULC 2020 Identifier	[Rhode Island] Class Name/Description	HRU Land Use
111	High Density Residential (<1/8 acre lots)	High Density Residential
112	Medium High Density Residential (1/4 to 1/8 acre lots)	Medium Density Residential
113	Medium Density Residential (1 to 1/4 acre lots)	Medium Density Residential
114	Medium Low Density Residential (1 to 2 acre lots)	Medium Density Residential
115	Low Density Residential (>2 acre lots)	Low Density Residential
120	Commercial (sale of products and services)	Commercial
130	Industrial (manufacturing, design, assembly, etc.)	Industrial
141	Roads (divided highways >200' plus related facilities)	Highway
142	Airports (and associated facilities)	Commercial
143	Railroads (and associated facilities)	Highway
144	Water and Sewage Treatment	Industrial
145	Waste Disposal (landfills, junkyards, etc.)	Industrial
146	Power Lines (100' or more width)	Open Land
151	Commercial/Residential Mixed	Commercial
161	Developed Recreation (all recreation)	Open Land
162	Vacant Land	Open Land
163	Cemeteries	Open Land
170	Institutional (schools, hospitals, churches, etc.)	Commercial
210	Pasture (agricultural not suitable for tillage)	Agriculture
220	Cropland (tillable)	Agriculture
230	Orchards, Groves, Nurseries	Agriculture
250	Idle Agriculture (abandoned fields and orchards)	Agriculture
300	Brushland (shrub and brush areas, reforestation)	Agriculture
410	Deciduous Forest (>80% hardwood)	Forest
420	Softwood Forest (>80% softwood)	Forest
430	Mixed Forest	Forest
500	Water	Water
600	Wetland	Open Land
720	Sandy Areas (not beaches)	Open Land
730	Rock Outcrops	Open Land
740	Mines, Quarries and Gravel Pits	Industrial
750	Transitional Areas (urban open)	Open Land
147	Other Transportation (terminals, docks, etc.)	Highway
148	Ground-mounted Solar Energy Systems	Commercial
710	Beaches	Open Land
149	Wind Energy Systems	Commercial
152	Commercial/Industrial Mixed	Industrial
240	Confined Feeding Operations	Agriculture
760	Mixed Barren Areas	Open Land
760	Mixed Barren Areas	Open Land

5.1.4 Impervious Area

Impervious area contains two feature classes, impervious and pervious, which will be **reprojected** into the common MassGIS projection and **clipped** to the project boundary. These may optionally be converted to polygon and merged into one file prior to further geospatial processing. Otherwise, the information in the two data layers will be combined (**dissolved**) subsequently.

5.2 GENERATING THE HRU MAP

Input data layers are a mix of **raster** and **vector** type. The project team intends to convert rasters to vectors (as described above in *Preparing Input Data Layers*) and produce a **vector (polygon) HRU map**. Pixelated vector shapefiles (e.g., due to raster to polygon conversion) may be compressed in size via the “**simplify polygon**” tool, which transforms pixelated edges to smooth edges without changing feature area.

If file sizes result in excessive memory or processing time usage, input data layers may be clipped to smaller units (e.g., five sub-areas called **groups**) and the HRU map may be generated in batches. Example groups of towns and watersheds are shown in Figure 4. Alternately, HRU maps may be generated individually by town and by watershed (thus facilitating Task 4). In either case, basic scripting (e.g., using a text editor and publicly available Python repositories) may be used to iterate through groups, if doing so will be more time efficient.

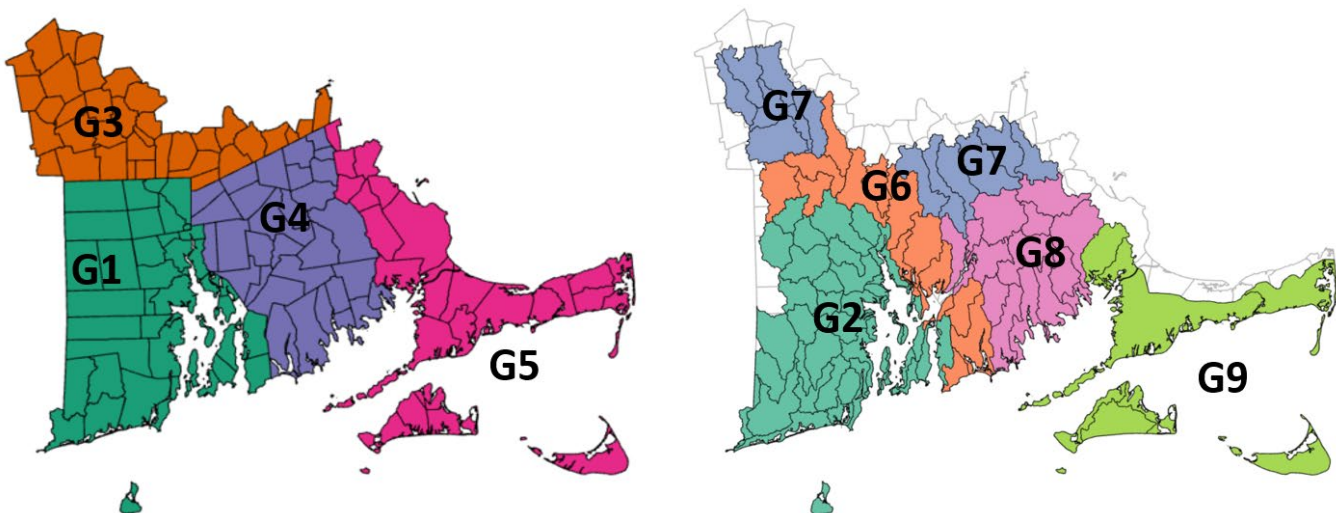


Figure 4: Example grouping if HRU mapping is conducted in batches. Groups G1, G3-G5 (left) are by municipal boundaries, while G2, G6-G9 are by HUC 12 watersheds.

HW/FBE will union each of the four input data layers in series (hydrologic soil group, slope, land use, impervious area), then the resulting HRU map will be dissolved by HRU, and calculate geometry will be performed to generate a summary results table for the entire SNEP region. Four summary tables will show areas and percentages of each data layers for the entire SNEP region. More detailed summary results tables (e.g., by town and by watershed) will be produced under Task 4. The ArcGIS Model Builder (i.e., workflow) was developed based on a grouped-batch approach (shown in Figure 4), with “G#” indicating a group (Figure 5). ArcGIS Model Builder automatically generates a Python script. That script may optionally be used to iterate through input and output files (e.g., municipalities and/or watersheds) in Task 4, Watershed Stormwater Pollutant Loading Analysis.



Figure 5: ArcGIS Model Builder example geospatial processing workflow to create the SNEP area HRU map.

Table 7: MassDEP “crosswalk” of MassGIS land cover / land use into HRU categories (see also Table 5) in flat table format for GIS import.

MassGIS Land Use	MassGIS Land Cover	2016 Small MS4 Pollutant Loading Export Rate Category (Crosswalk)
Unknown	Developed Space Open	Pervious HSG
Unknown	Cultivated	Agriculture Pervious
Unknown	Pasture/ Hay	Agriculture Pervious
Unknown	Grassland	Pervious HSG
Unknown	Deciduous	Forest Pervious
Unknown	Evergreen	Forest Pervious
Unknown	Shrub/ Scrub	Forest Pervious
Unknown	Forested Palustrine	Pervious HSG
Unknown	Shrub/Scrub Palustrine	Pervious HSG
Unknown	Emergent Palustrine	Pervious HSG
Unknown	Forested Estuarine	Pervious HSG
Unknown	Shrub/Scrub Estuarine	Pervious HSG
Unknown	Emergent Estuarine	Pervious HSG
Unknown	Shored Unconsolidate	Pervious HSG
Unknown	Bare	Pervious HSG
Unknown	Water	Water
Unknown	Bed Aquatic Palustrine	Water
Unknown	Bed Aquatic Estuarine	Water
Open Land	Impervious	Open Land
Open Land	Developed Space Open	Pervious HSG
Open Land	Cultivated	Agriculture Pervious
Open Land	Pasture/ Hay	Agriculture Pervious
Open Land	Grassland	Pervious HSG
Open Land	Deciduous	Forest Pervious
Open Land	Evergreen	Forest Pervious
Open Land	Shrub/ Scrub	Forest Pervious
Open Land	Forested Palustrine	Pervious HSG
Open Land	Shrub/Scrub Palustrine	Pervious HSG
Open Land	Emergent Palustrine	Pervious HSG
Open Land	Forested Estuarine	Pervious HSG
Open Land	Shrub/Scrub Estuarine	Pervious HSG
Open Land	Emergent Estuarine	Pervious HSG
Open Land	Shored Unconsolidate	Pervious HSG
Open Land	Bare	Pervious HSG
Open Land	Water	Water
Open Land	Bed Aquatic Palustrine	Water
Open Land	Bed Aquatic Estuarine	Water
Commercial	Impervious	Commercial and Industrial
Commercial	Developed Space Open	Pervious HSG
Commercial	Cultivated	Agriculture Pervious
Commercial	Pasture/ Hay	Agriculture Pervious
Commercial	Grassland	Pervious HSG

MassGIS Land Use	MassGIS Land Cover	2016 Small MS4 Pollutant Loading Export Rate Category (Crosswalk)
Commercial	Deciduous	Forest Pervious
Commercial	Evergreen	Forest Pervious
Commercial	Shrub/ Scrub	Forest Pervious
Commercial	Forested Palustrine	Pervious HSG
Commercial	Shrub/Scrub Palustrine	Pervious HSG
Commercial	Emergent Palustrine	Pervious HSG
Commercial	Forested Estuarine	Pervious HSG
Commercial	Shrub/Scrub Estuarine	Pervious HSG
Commercial	Emergent Estuarine	Pervious HSG
Commercial	Shored Unconsolidate	Pervious HSG
Commercial	Bare	Pervious HSG
Commercial	Water	Water
Commercial	Bed Aquatic Palustrine	Water
Commercial	Bed Aquatic Estuarine	Water
Industrial	Impervious	Commercial and Industrial
Industrial	Developed Space Open	Pervious HSG
Industrial	Cultivated	Agriculture Pervious
Industrial	Pasture/ Hay	Agriculture Pervious
Industrial	Grassland	Pervious HSG
Industrial	Deciduous	Forest Pervious
Industrial	Evergreen	Forest Pervious
Industrial	Shrub/ Scrub	Forest Pervious
Industrial	Forested Palustrine	Pervious HSG
Industrial	Shrub/Scrub Palustrine	Pervious HSG
Industrial	Emergent Palustrine	Pervious HSG
Industrial	Forested Estuarine	Pervious HSG
Industrial	Shrub/Scrub Estuarine	Pervious HSG
Industrial	Emergent Estuarine	Pervious HSG
Industrial	Shored Unconsolidate	Pervious HSG
Industrial	Bare	Pervious HSG
Industrial	Water	Water
Industrial	Bed Aquatic Palustrine	Water
Industrial	Bed Aquatic Estuarine	Water
Forest	Impervious	Forest
Forest	Developed Space Open	Forest Pervious
Forest	Cultivated	Forest Pervious
Forest	Pasture/ Hay	Agriculture Pervious
Forest	Grassland	Forest Pervious
Forest	Deciduous	Forest Pervious
Forest	Evergreen	Forest Pervious
Forest	Shrub/ Scrub	Forest Pervious
Forest	Forested Palustrine	Forest Pervious
Forest	Shrub/Scrub Palustrine	Forest Pervious
Forest	Emergent Palustrine	Forest Pervious
Forest	Forested Estuarine	Forest Pervious

MassGIS Land Use	MassGIS Land Cover	2016 Small MS4 Pollutant Loading Export Rate Category (Crosswalk)
Forest	Shrub/Scrub Estuarine	Forest Pervious
Forest	Emergent Estuarine	Forest Pervious
Forest	Shored Unconsolidate	Pervious HSG
Forest	Bare	Pervious HSG
Forest	Water	Water
Forest	Bed Aquatic Palustrine	Water
Forest	Bed Aquatic Estuarine	Water
Agricultural	Impervious	Agriculture
Agricultural	Developed Space Open	Agriculture Pervious
Agricultural	Cultivated	Agriculture Pervious
Agricultural	Pasture/ Hay	Agriculture Pervious
Agricultural	Grassland	Agriculture Pervious
Agricultural	Deciduous	Forest Pervious
Agricultural	Evergreen	Forest Pervious
Agricultural	Shrub/ Scrub	Forest Pervious
Agricultural	Forested Palustrine	Pervious HSG
Agricultural	Shrub/Scrub Palustrine	Pervious HSG
Agricultural	Emergent Palustrine	Pervious HSG
Agricultural	Forested Estuarine	Pervious HSG
Agricultural	Shrub/Scrub Estuarine	Pervious HSG
Agricultural	Emergent Estuarine	Pervious HSG
Agricultural	Shored Unconsolidate	Pervious HSG
Agricultural	Bare	Pervious HSG
Agricultural	Water	Water
Agricultural	Bed Aquatic Palustrine	Water
Agricultural	Bed Aquatic Estuarine	Water
Recreational	Impervious	Open Land
Recreational	Developed Space Open	Pervious HSG
Recreational	Cultivated	Agriculture Pervious
Recreational	Pasture/ Hay	Agriculture Pervious
Recreational	Grassland	Pervious HSG
Recreational	Deciduous	Forest Pervious
Recreational	Evergreen	Forest Pervious
Recreational	Shrub/ Scrub	Forest Pervious
Recreational	Forested Palustrine	Pervious HSG
Recreational	Shrub/Scrub Palustrine	Pervious HSG
Recreational	Emergent Palustrine	Pervious HSG
Recreational	Forested Estuarine	Pervious HSG
Recreational	Shrub/Scrub Estuarine	Pervious HSG
Recreational	Emergent Estuarine	Pervious HSG
Recreational	Shored Unconsolidate	Pervious HSG
Recreational	Bare	Pervious HSG
Recreational	Water	Water
Recreational	Bed Aquatic Palustrine	Water
Recreational	Bed Aquatic Estuarine	Water

MassGIS Land Use	MassGIS Land Cover	2016 Small MS4 Pollutant Loading Export Rate Category (Crosswalk)
Tax Exempt	Impervious	Commercial and Industrial
Tax Exempt	Developed Space Open	Pervious HSG
Tax Exempt	Cultivated	Agriculture Pervious
Tax Exempt	Pasture/ Hay	Agriculture Pervious
Tax Exempt	Grassland	Pervious HSG
Tax Exempt	Deciduous	Forest Pervious
Tax Exempt	Evergreen	Forest Pervious
Tax Exempt	Shrub/ Scrub	Forest Pervious
Tax Exempt	Forested Palustrine	Pervious HSG
Tax Exempt	Shrub/Scrub Palustrine	Pervious HSG
Tax Exempt	Emergent Palustrine	Pervious HSG
Tax Exempt	Forested Estuarine	Pervious HSG
Tax Exempt	Shrub/Scrub Estuarine	Pervious HSG
Tax Exempt	Emergent Estuarine	Pervious HSG
Tax Exempt	Shored Unconsolidate	Pervious HSG
Tax Exempt	Bare	Pervious HSG
Tax Exempt	Water	Water
Tax Exempt	Bed Aquatic Palustrine	Water
Tax Exempt	Bed Aquatic Estuarine	Water
Mixed-Primarily Residential	Impervious	Multi-Family and High-Density Residential
Mixed-Primarily Residential	Developed Space Open	Pervious HSG
Mixed-Primarily Residential	Cultivated	Agriculture Pervious
Mixed-Primarily Residential	Pasture/ Hay	Agriculture Pervious
Mixed-Primarily Residential	Grassland	Pervious HSG
Mixed-Primarily Residential	Deciduous	Forest Pervious
Mixed-Primarily Residential	Evergreen	Forest Pervious
Mixed-Primarily Residential	Shrub/ Scrub	Forest Pervious
Mixed-Primarily Residential	Forested Palustrine	Pervious HSG
Mixed-Primarily Residential	Shrub/Scrub Palustrine	Pervious HSG
Mixed-Primarily Residential	Emergent Palustrine	Pervious HSG
Mixed-Primarily Residential	Forested Estuarine	Pervious HSG
Mixed-Primarily Residential	Shrub/Scrub Estuarine	Pervious HSG
Mixed-Primarily Residential	Emergent Estuarine	Pervious HSG
Mixed-Primarily Residential	Shored Unconsolidate	Pervious HSG
Mixed-Primarily Residential	Bare	Pervious HSG
Mixed-Primarily Residential	Water	Water
Mixed-Primarily Residential	Bed Aquatic Palustrine	Water
Mixed-Primarily Residential	Bed Aquatic Estuarine	Water
Single Family Residential	Impervious	Medium -Density Residential
Single Family Residential	Developed Space Open	Pervious HSG
Single Family Residential	Cultivated	Agriculture Pervious
Single Family Residential	Pasture/ Hay	Agriculture Pervious
Single Family Residential	Grassland	Pervious HSG
Single Family Residential	Deciduous	Forest Pervious
Single Family Residential	Evergreen	Forest Pervious

MassGIS Land Use	MassGIS Land Cover	2016 Small MS4 Pollutant Loading Export Rate Category (Crosswalk)
Single Family Residential	Shrub/ Scrub	Forest Pervious
Single Family Residential	Forested Palustrine	Pervious HSG
Single Family Residential	Shrub/Scrub Palustrine	Pervious HSG
Single Family Residential	Emergent Palustrine	Pervious HSG
Single Family Residential	Forested Estuarine	Pervious HSG
Single Family Residential	Shrub/Scrub Estuarine	Pervious HSG
Single Family Residential	Emergent Estuarine	Pervious HSG
Single Family Residential	Shored Unconsolidate	Pervious HSG
Single Family Residential	Bare	Pervious HSG
Single Family Residential	Water	Water
Single Family Residential	Bed Aquatic Palustrine	Water
Single Family Residential	Bed Aquatic Estuarine	Water
Multi-Family Residential	Impervious	Multi-Family and High-Density Residential
Multi-Family Residential	Developed Space Open	Pervious HSG
Multi-Family Residential	Cultivated	Agriculture Pervious
Multi-Family Residential	Pasture/ Hay	Agriculture Pervious
Multi-Family Residential	Grassland	Pervious HSG
Multi-Family Residential	Deciduous	Forest Pervious
Multi-Family Residential	Evergreen	Forest Pervious
Multi-Family Residential	Shrub/ Scrub	Forest Pervious
Multi-Family Residential	Forested Palustrine	Pervious HSG
Multi-Family Residential	Shrub/Scrub Palustrine	Pervious HSG
Multi-Family Residential	Emergent Palustrine	Pervious HSG
Multi-Family Residential	Forested Estuarine	Pervious HSG
Multi-Family Residential	Shrub/Scrub Estuarine	Pervious HSG
Multi-Family Residential	Emergent Estuarine	Pervious HSG
Multi-Family Residential	Shored Unconsolidate	Pervious HSG
Multi-Family Residential	Bare	Pervious HSG
Multi-Family Residential	Water	Water
Multi-Family Residential	Bed Aquatic Palustrine	Water
Multi-Family Residential	Bed Aquatic Estuarine	Water
Other Residential	Impervious	Medium -Density Residential
Other Residential	Developed Space Open	Pervious HSG
Other Residential	Cultivated	Agriculture Pervious
Other Residential	Pasture/ Hay	Agriculture Pervious
Other Residential	Grassland	Pervious HSG
Other Residential	Deciduous	Forest Pervious
Other Residential	Evergreen	Forest Pervious
Other Residential	Shrub/ Scrub	Forest Pervious
Other Residential	Forested Palustrine	Pervious HSG
Other Residential	Shrub/Scrub Palustrine	Pervious HSG
Other Residential	Emergent Palustrine	Pervious HSG
Other Residential	Forested Estuarine	Pervious HSG
Other Residential	Shrub/Scrub Estuarine	Pervious HSG
Other Residential	Emergent Estuarine	Pervious HSG

MassGIS Land Use	MassGIS Land Cover	2016 Small MS4 Pollutant Loading Export Rate Category (Crosswalk)
Other Residential	Shored Unconsolidate	Pervious HSG
Other Residential	Bare	Pervious HSG
Other Residential	Water	Water
Other Residential	Bed Aquatic Palustrine	Water
Other Residential	Bed Aquatic Estuarine	Water
Mixed Other	Impervious	Commercial and Industrial
Mixed Other	Developed Space Open	Pervious HSG
Mixed Other	Cultivated	Agriculture Pervious
Mixed Other	Pasture/ Hay	Agriculture Pervious
Mixed Other	Grassland	Pervious HSG
Mixed Other	Deciduous	Forest Pervious
Mixed Other	Evergreen	Forest Pervious
Mixed Other	Shrub/ Scrub	Forest Pervious
Mixed Other	Forested Palustrine	Pervious HSG
Mixed Other	Shrub/Scrub Palustrine	Pervious HSG
Mixed Other	Emergent Palustrine	Pervious HSG
Mixed Other	Forested Estuarine	Pervious HSG
Mixed Other	Shrub/Scrub Estuarine	Pervious HSG
Mixed Other	Emergent Estuarine	Pervious HSG
Mixed Other	Shored Unconsolidate	Pervious HSG
Mixed Other	Bare	Pervious HSG
Mixed Other	Water	Water
Mixed Other	Bed Aquatic Palustrine	Water
Mixed Other	Bed Aquatic Estuarine	Water
Mixed Commercial	Impervious	Commercial and Industrial
Mixed Commercial	Developed Space Open	Pervious HSG
Mixed Commercial	Cultivated	Agriculture Pervious
Mixed Commercial	Pasture/ Hay	Agriculture Pervious
Mixed Commercial	Grassland	Pervious HSG
Mixed Commercial	Deciduous	Forest Pervious
Mixed Commercial	Evergreen	Forest Pervious
Mixed Commercial	Shrub/ Scrub	Forest Pervious
Mixed Commercial	Forested Palustrine	Pervious HSG
Mixed Commercial	Shrub/Scrub Palustrine	Pervious HSG
Mixed Commercial	Emergent Palustrine	Pervious HSG
Mixed Commercial	Forested Estuarine	Pervious HSG
Mixed Commercial	Shrub/Scrub Estuarine	Pervious HSG
Mixed Commercial	Emergent Estuarine	Pervious HSG
Mixed Commercial	Shored Unconsolidate	Pervious HSG
Mixed Commercial	Bare	Pervious HSG
Mixed Commercial	Water	Water
Mixed Commercial	Bed Aquatic Palustrine	Water
Mixed Commercial	Bed Aquatic Estuarine	Water
Right Of Way	Impervious	Weighted Avg PLER
Right Of Way	Developed Space Open	Pervious HSG

MassGIS Land Use	MassGIS Land Cover	2016 Small MS4 Pollutant Loading Export Rate Category (Crosswalk)
Right Of Way	Cultivated	Agriculture Pervious
Right Of Way	Pasture/ Hay	Agriculture Pervious
Right Of Way	Grassland	Pervious HSG
Right Of Way	Deciduous	Forest Pervious
Right Of Way	Evergreen	Forest Pervious
Right Of Way	Shrub/ Scrub	Forest Pervious
Right Of Way	Forested Palustrine	Pervious HSG
Right Of Way	Shrub/Scrub Palustrine	Pervious HSG
Right Of Way	Emergent Palustrine	Pervious HSG
Right Of Way	Forested Estuarine	Pervious HSG
Right Of Way	Shrub/Scrub Estuarine	Pervious HSG
Right Of Way	Emergent Estuarine	Pervious HSG
Right Of Way	Shored Unconsolidate	Pervious HSG
Right Of Way	Bare	Pervious HSG
Right Of Way	Water	Water
Right Of Way	Bed Aquatic Palustrine	Water
Right Of Way	Bed Aquatic Estuarine	Water
Water	Impervious	Water
Water	Developed Space Open	Water
Water	Cultivated	Water
Water	Pasture/ Hay	Water
Water	Grassland	Water
Water	Deciduous	Water
Water	Evergreen	Water
Water	Shrub/ Scrub	Water
Water	Forested Palustrine	Water
Water	Shrub/Scrub Palustrine	Water
Water	Emergent Palustrine	Water
Water	Forested Estuarine	Water
Water	Shrub/Scrub Estuarine	Water
Water	Emergent Estuarine	Water
Water	Shored Unconsolidate	Water
Water	Bare	Water
Water	Water	Water
Water	Bed Aquatic Palustrine	Water
Water	Bed Aquatic Estuarine	Water

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