

Outfall Catchment Mapping and Ranking

Last updated: April 6, 2017

Background

The federal Clean Water Act, passed in 1972, established regulation of pollutant discharges into “waters of the United States.”¹ This law requires municipalities to qualify for a permit under the National Pollutant Discharge Elimination System (NPDES) program in order to lawfully discharge stormwater into rivers, streams, and lakes. In Massachusetts, the 2003 Region 1 Final General Permit for Stormwater Discharges from Small Municipal Separate Storm Sewer Systems (MS4 permit hereafter) is in effect, although it expired in 2008, and a new permit was signed in April of 2016.² Once the new Massachusetts MS4 permit goes into effect on July 1, 2017, MS4 municipalities will be required to adopt stronger measures for minimizing the impact of pollutants from their stormwater on the cleanliness of the receiving waters.³

In 2013, the Neponset River Watershed Association (NepRWA) and MAPC secured a Community Innovation Challenge (CIC) grant from the state of Massachusetts to assist the Neponset Valley Watershed municipalities in collaborating to adopt a new approach to meet the new MS4 requirements. The CIC grant program promoted municipal efficiency through regional collaboration. In this case, the goal was to provide policy templates, recommendations, and technical tools that Neponset Valley municipalities could use to meet the new requirements of the MS4 permit. Representatives from conservation commissions and departments of public works who are both involved in the permitting or in operation and management of stormwater came together to create the Neponset Valley Regional Stormwater Collaborative. The collaborative includes representatives from Canton, Dedham, Foxborough, Medfield, Milton, Norwood, Randolph, Sharon, Stoughton, Walpole, Westwood, and the Boston Water and Sewer Commission, with a representative from Boston participating as a technical advisor.

In order for Massachusetts MS4 municipalities to meet the terms of the new permit, they must meet more stringent illicit discharge detection and elimination (IDDE) requirements. “Illicit Discharges” are any substances that enter the stormwater system other than stormwater, including chemicals, oils, gasoline, or waste.⁴ Such discharges are associated with auto or other industrial activities, older residences, and failing septic systems. According to the new MS4 permit, Massachusetts MS4

¹ United States Environmental Protection Agency. “Summary of the Clean Water Act.” <http://www2.epa.gov/laws-regulations/summary-clean-water-act> Last modified November 12, 2014

² Environmental Protection Agency. 2003. *National Pollutant Discharge Elimination System (NPDES) General Permit for Stormwater Discharges from Small Separate Storm Sewer System*.

http://www.epa.gov/region1/npdes/permits/permit_final_ms4.pdf

³ United States Environmental Protection Agency. 2014. *National Pollutant Discharge Elimination System (NPDES) General Permits for Stormwater Discharges from Small Municipal Separate Storm Sewer Systems in Massachusetts*.

<https://www3.epa.gov/region1/npdes/stormwater/ma/2016fpd/final-2016-ma-sms4-gp.pdf>

⁴ With some exceptions. United States Environmental Protection Agency. “Illicit Discharges.” <http://water.epa.gov/polwaste/nps/discharges.cfm> Last modified November 28, 2012.

municipalities will be required to a) delineate catchment areas draining to each outfall, b) identify the receiving waters associated with those outfalls, and c) rate the potential for illicit discharge of the outfall catchment areas as High or Low. This rating can be used as a tool to focus outreach, infrastructure, and enforcement campaigns to property owners or neighborhoods. Meeting this standard requires technical analysis of hydrology, topography, land use, and stormwater infrastructure.

Several public agencies have previously tackled the task of automatically delineating catchments using topographic data in cities such as San Francisco, Portland, and Tampa.⁵ By adopting these methods in Massachusetts, municipalities should be able to meet the requirements more cost-effectively. However, any attempt at standardization must contend with the highly varied quality and completeness of municipal stormwater infrastructure data and the often limited technical capacity available at the local level. To reduce redundancy of effort and account for the varied resources available in different cities and towns, MAPC built on previous examples by developing a regionally applicable method to conduct this analysis that requires a minimum of local stormwater infrastructure data in a standardized format. MAPC has published and maintains a set instructions and of ArcGIS tools that can be applied for any municipality in Massachusetts and potentially beyond. This document describes the method and provides instructions for implementing it using ArcGIS and CommunityViz, an ArcGIS add-in.

MAPC has applied this method in a number of municipalities, including the Towns of Milton, Westwood, Stoughton, and Medfield. Other consultants and GIS Analysts working throughout the state and beyond have also downloaded and applied this methodology.

Data and Software Requirements

Catchment delineation

- ArcGIS 10.2 or above
- Spatial Analyst extension

Catchment ranking

- ArcGIS 10.2 or above
- Community Viz

Stormwater Infrastructure Data

- Complete catch basin inventory
- Catch basins have an integer ID field that corresponds to outfall IDs (see “Creating Outfall Catchments” below)

⁵ “Urban Catchment Delineation Tool.” <https://code.google.com/p/besasm-toys/wiki/urbanCatchmentDelineationTool>. Last modified June 13, 2012; Nick Birth and Greg Braswell. 2011. “The ‘Urban Drainage’ Model: SF DPW uses Lidar DEM and Custom Algorithm for Delineating Drainage Catchments and Hydrologic Modelling.” *Bay Area Automated Mapping Association Journal* 5: 5-6. http://www.baama.org/Resources/Documents/BAAMA_Journal_V5I1_LoRes.pdf.

- Optional: “Owner” or other fields used to group catch basins into catchment areas.

Other Data Inputs

- Digital Elevation Model (DEM): for this analysis, we used the high resolution (1m) digital elevation models⁶ These models were created from point data captured by Lidar sensors in flights from 2002 to 2012, and processed by USGS.
- Vector feature classes to “etch” into DEM, such as:
 - Water features: MassDEP Hydrography⁷
 - Road center lines: MassDOT Road Inventory⁸
 - Gutters or edges of rights of way: MAPC Massachusetts Land Parcel Database.⁹

Delineating Outfall Catchments

The basic process for delineating the catchment areas for each outfall was to download, assemble, and enhance the Digital Elevation Model, then use it to define small catchments for each catch basin, and finally aggregate those smaller catchments into larger outfall catchment areas. In order to streamline the process for municipalities across Massachusetts, we created three custom ArcGIS tools: the Lidar Mosaic tool, the Create Burn Raster tool, and the Complete Watershed tool, packaged as the MAPC Catchment Delineation Toolbox. The tools are publicly available for download on Github.¹⁰

Preprocessing the DEM

First, we downloaded the relevant Lidar images from MassGIS and mosaicked them into a single DEM. We built this process into an ArcGIS script tool called the Lidar Mosaic Tool. To use this tool, download the relevant Lidar images from MassGIS. Then, unzip all the files and save them in a single folder. Finally, run the tool inputting the folder in the “workspace” box and the desired name of the output raster (without an extension) in the “output raster” box.¹¹

⁶ MassGIS. “LiDAR Terrain Data.” <http://www.mass.gov/anf/research-and-tech/it-serv-and-support/application-serv/office-of-geographic-information-massgis/datalayers/lidar.html>

⁷ Massachusetts Department of Environmental Protection. “MassDEP Hydrography (1:25,000).” March 2010. MassGIS. <http://www.mass.gov/anf/research-and-tech/it-serv-and-support/application-serv/office-of-geographic-information-massgis/datalayers/hd.html>

⁸ Massachusetts Department of Transportation. “MassDOT Roads.” June 2014. MassGIS. <http://www.mass.gov/anf/research-and-tech/it-serv-and-support/application-serv/office-of-geographic-information-massgis/datalayers/eotroads.html>

⁹ Metropolitan Area Planning Council. “MAPC Massachusetts Land Parcel Database.” 2012. MAPC.

¹⁰ Go to <https://github.com/MAPC/stormwater-toolkit> to download the toolbox.

¹¹ The tool is set to mosaic using the value of the first listed raster in the case of overlapping rasters. It is also set to pull the pixel type from the first raster listed, so please use caution when mosaicking rasters from different lidar runs. This may require additional processing.

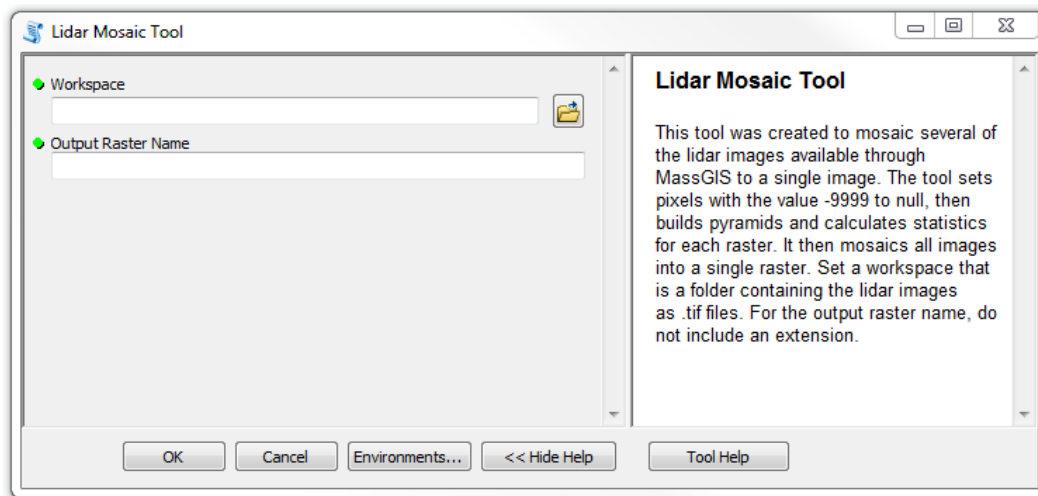


Figure 1. Lidar Mosaic script tool.

The Lidar Mosaic tool performs the following steps:

1. Sets Null value to <-400
2. Builds Pyramids and Calculates Statistics
3. Mosaics to New Raster

Enhancing the DEM

Although the lidar elevation model has a very high spatial resolution, it is still not precise enough to capture the relief and drainage patterns created by gutters, curbs, road crowns, or other features that are small but greatly impact stormwater runoff patterns. In order to take these important stormwater control features into account, we enhance the DEM to simulate these features by “burning” or etching them into the DEM. This process ensures that within an urban area, water is modeled as flowing off of properties and into roadways, where it cannot leave a gutter once it enters one, and does not cross the crown of the road. In addition to modeling features of the urban landscape more faithfully, we burned in the streambeds and other bodies of water because the DEM did not accurately capture the known streambed for smaller streams that lay in flat floodplains. The image on the lower left shows a hillshade of the Lidar DEM before features were burned into it. The flat area in the southeast actually contains a streambed with a flat floodplain, which does not appear on the DEM, which means that the watershed tool will not accurately map the flow accumulation in this area. The roads also appear completely flat, as the slight curve of the road crown is not represented in the DEM. The lower right image shows the area after gutters, road crowns, and water bodies have been burned into it, which corrects these flat areas by etching known features into the elevation model, making it more representative of the hydrologic conditions in the area.

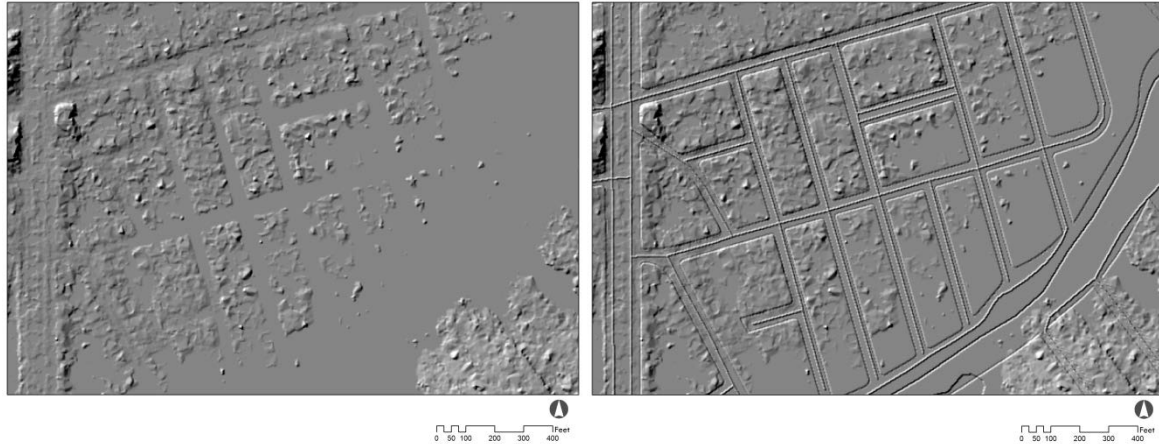


Figure 2. Hillshades before and after enhancement.

To enhance the DEM, we created several “burn” rasters, which are raster representations of features such as streams or gutters. The cells representing the feature are set to the “burn value,” or the value that will be added to the original DEM, and all other cells are set to zero. We created an ArcGIS script tool to create these rasters more easily (Figure 3).

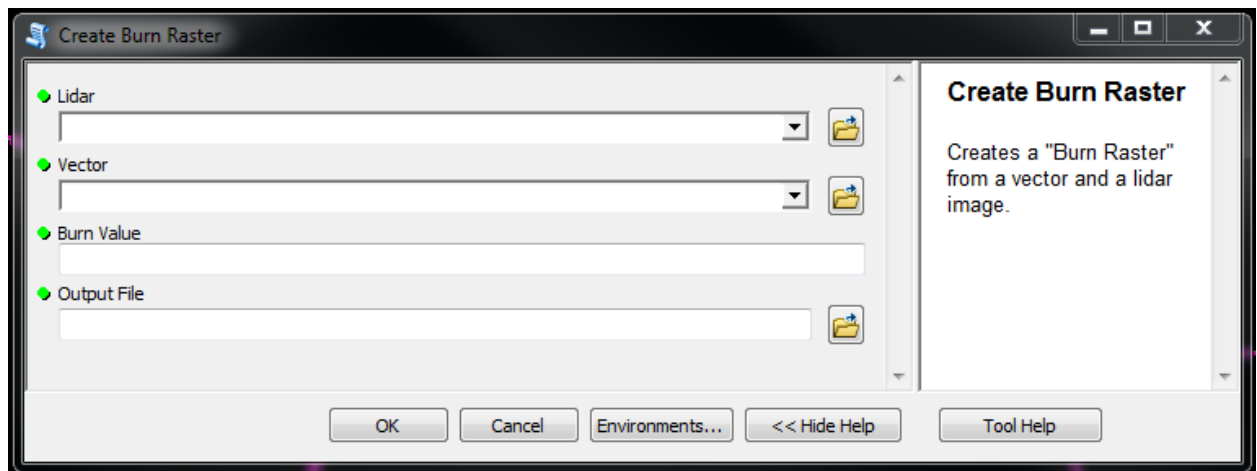


Figure 3. Create Burn Raster script tool.

This tool performs the following steps

1. Sets environments
 - A. Processing Extent > Snap Raster: select lidar mosaic
 - B. Processing Extent > Extent: same as lidar mosaic
 - C. Raster Analysis > Cell size: same as lidar mosaic
 - D. Raster Analysis > Mask: same as lidar mosaic
2. Creates an editable copy of the vector feature class
3. Adds a field to the vector's attribute table called “Burn_Val.”
4. Populates the new field with the burn value.
5. Converts the vector to a raster
6. Converts zeros to nulls

7. Saves results

For example, to create a burn raster for the road crown, a user inputs the DEM that will be enhanced with the burn raster, the road center line shapefile or feature class as the “Input Vector”, then enters .5 into the “Enter Burn Value” field, and finally names the output file. The user should repeat this process with any other variable. For gutters, stream channels, or other features that will be subtracted from the DEM rather than added, users can enter a negative number. This tool can be run in batch mode (right click > batch) to create several burn rasters at once. See table 1 for an example of values used for the Town of Milton.

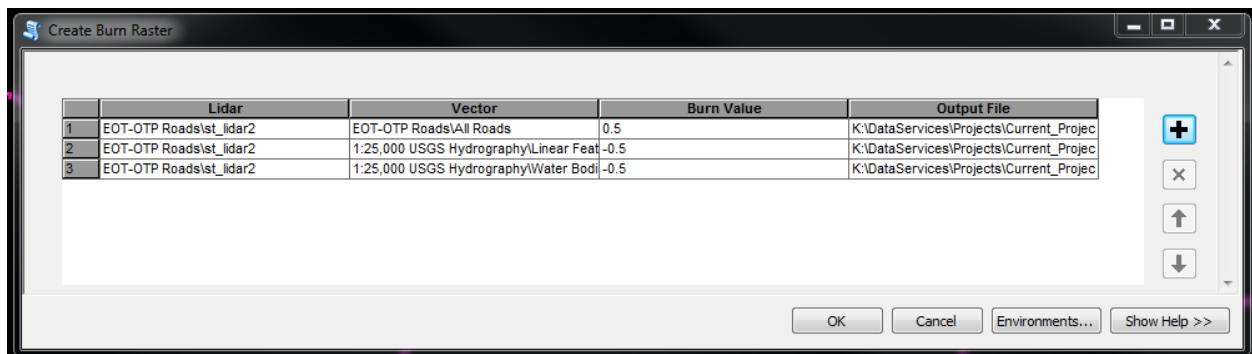


Figure 4. Create Burn Raster script tool in batch mode.

Table 1. Features and burn values.

Feature	Data Source	Burn value
Gutters	MAPC Statewide Parcel dataset, ROWs converted to polylines	-0.25m
Road Crowns	MassDOT Road centerlines	0.50m
Water Features	MassDEP	-0.25m

After creating the set of burn rasters, the user should add the burn rasters to the DEM using the Raster Calculator.

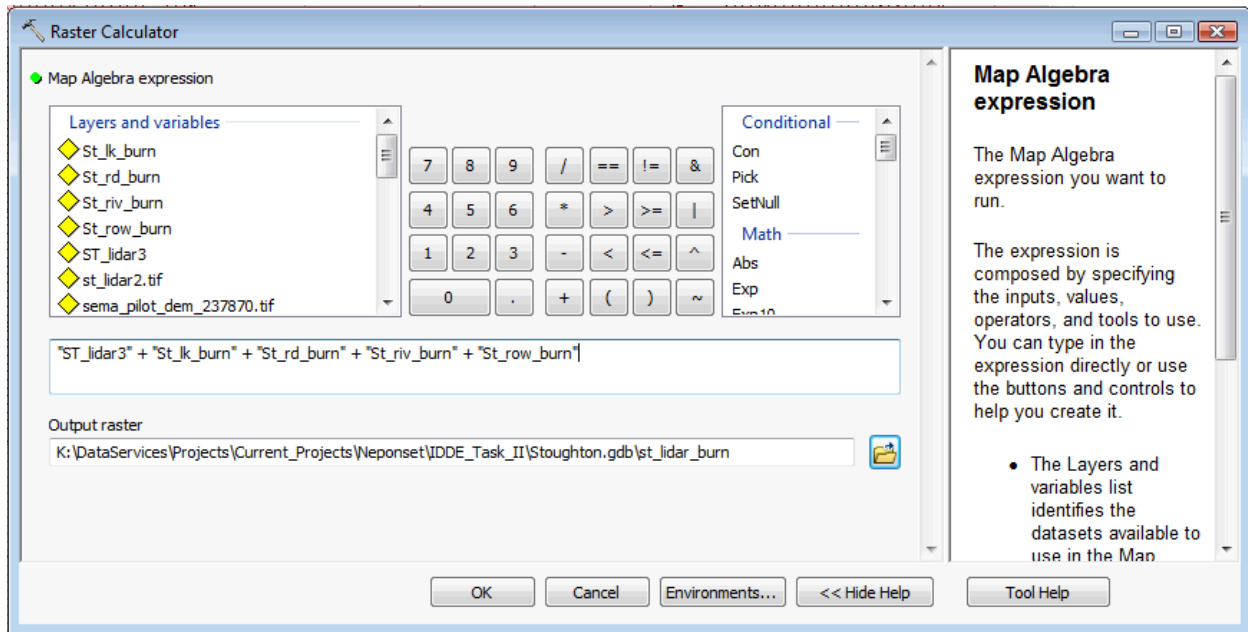


Figure 5. Using the Raster Calculator tool to enhance the DEM using the burn rasters.

Creating Catch Basin Catchments

To simplify the steps necessary to create catch basin watersheds, we created a “Complete Watershed” script tool. Tool inputs are the enhanced DEM, the pour point (catch basin) vector layer, the field to be used for catch basin IDs, the maximum snap distance, and finally a name for the output file. The inputs have the following requirements: 1) the workspace must be a geodatabase, 2) both the Lidar DEM and the catch basin file should be stored within the workspace geodatabase, 3) neither input file should be nested in a group layer in the map document, and 4) the “snap point field” should be an integer.

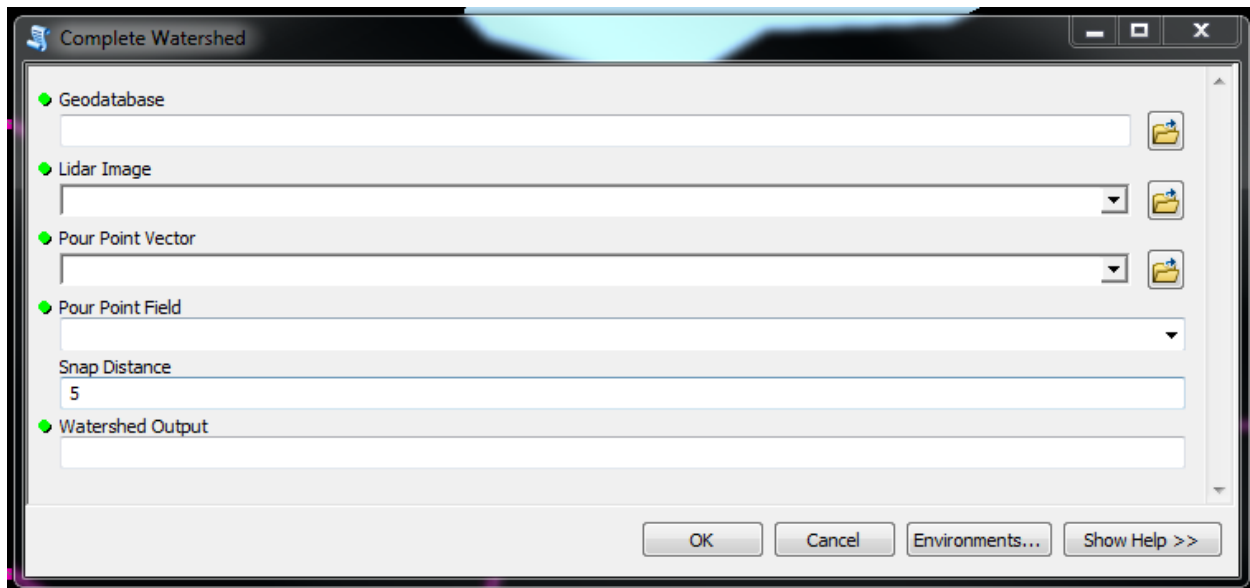


Figure 6. The Complete Watershed script tool.

The tool combines the following steps:

1. Fills any sinks in the enhanced DEM
2. Creates a flow direction raster from processed DEM
3. Creates a flow accumulation raster using flow direction raster
4. Snaps the pour points (catch basins) to pixels with high accumulated flow
5. Creates watersheds using the flow direction raster and snapped pour points as inputs
6. Converts the watershed raster to a vector

Snapping the pour points (step 4 above) is particularly important, since catch basins points may not coincide with the pixels where the gutters have been burned into the DEM. For this step, the inputs are the point feature class representing the catch basins, and a maximum snap distance.

The tool will shift the location of the catch basins to coincide with pixels of highest flow accumulation in the flow accumulation raster within the radius specified as the “snap distance.” If this step is skipped, water will be modeled as flowing past the catch basins. The default value in this field is 5 map units. For the Town of Milton, we evaluated a

range of radii and arrived at a maximum snap distance of 10 meters—the width of an average roadway—by visually assessing the distance between the catch basin points and the areas of high flow accumulation.

If catch basin catchments look “stringy” or extremely small, try adjusting the snap distance.

The output of this tool is a set of very small watersheds—one for each catch basin. The tool will also output a set of intermediate rasters that can be used for troubleshooting or for other analyses.

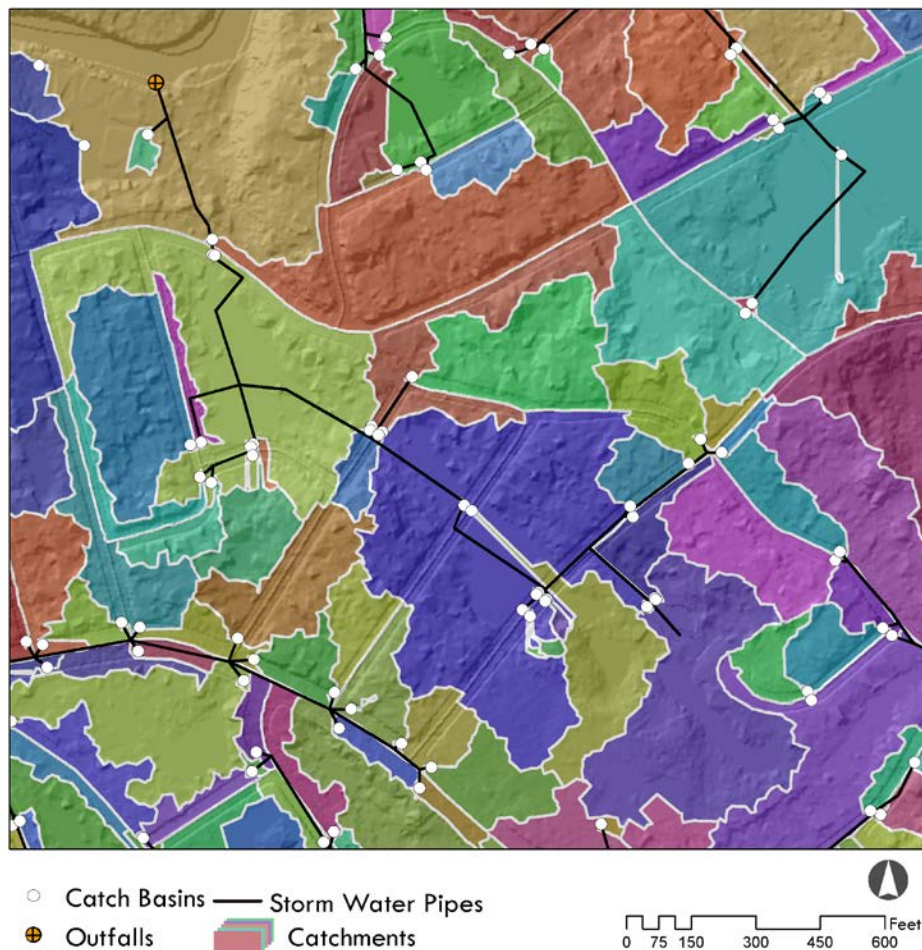


Figure 7. Catchments for each catch basin. The “streaky” catchments are in very flat areas with very low flow accumulation. Aggregating the catchments by outfall corrects for most of these issues.

The “gridcode” field in the output raster contains the “snap pour point values,” and can be used to join the original attribute table to the watershed layer. Most likely, the catch basin vector layer will have to be dissolved by gridcode value before the join will work properly.

Creating Outfall Catchments – An example from Milton, Massachusetts

The MS4 permit draft requires municipalities to delineate land areas that contribute rain water runoff to particular outfalls, so the small catch basin catchment areas must be “dissolved” into larger units based on their outfall. In order to achieve this, the catch basin feature class should contain a field that assigns each feature to an outfall. This way, catch basins catchment areas that drain to the same outfall can be grouped.

MAPC developed the following method to allow municipalities to link catch basins and their outfalls using a common ID given point feature classes for catch basins and outfalls, and a line feature class representing stormwater pipes. This method will not produce a perfect result, but will likely save municipal officials time by providing a preliminary result. Using the methods outlined here, municipalities will not need perfectly clean, accurate, and precise datasets in order to begin tracing evidence of illicit discharge discovered at an outfall back to the land area that contributed rain water to that outfall. The following sections describes how we conducted this analysis for the Town of Milton.

Creating “pipe system” IDs

To connect catch basins to their outfalls, we:

1. Buffered the pipe line features out according to the pipe diameter, then dissolve.
2. Created a “Pipesys_ID” field in the attribute table of the new pipe polygon feature class.
3. Populated the “Pipesys_ID” field with the OID number using the field calculator.
4. Performed a spatial join to link the original pipe line network to the pipe polygon feature class.
5. Performed additional spatial joins to link the pipe polygon feature class to both the catch basins and the outfalls.

At this point, all interconnected pipes shared a Pipesys_ID, and all associated outfalls and catch basins shared that ID. When selecting the buffer distance, we visually inspected the spatial relationship between a sample of the catch basins and outfalls and the pipe lines. Although in some cases the point features were not snapped to the line network precisely, in most cases they still intersected with the buffered pipe systems, so the imprecision did not affect the results. Another way to address snapping errors in the data would be to set a search distance when performing the spatial join.

Checking the data

After applying the automated method above to Milton’s data, we noticed several inconsistencies in the infrastructure data. Common errors include pipe systems without associated outfalls, catch basins with no associated pipe networks, interconnected pipe networks, and outfalls with no associated pipe network or “uphill” outfalls. We met with officials from Milton’s Department of Public Works to correct some of these areas based on their local knowledge. The local DPW staff informed us of some of the most common sources for these errors. The Milton DPW has a very complete dataset recording the location of every catch basin in the municipality. Because those features are easily visible from the surface, and their locations are relatively predictable, they were able to perform a survey recording each catch basin location in the town with a GPS. The underground components of the infrastructure were much more difficult for them to survey, because the pipe networks may be very old in some parts of town, or are not owned or

operated by the municipality, and they do not have access to the plans for those segments of pipes and their associated outfalls.

Table 2. Common problems with municipal stormwater data.

Data Problem	Common Causes	Solution
Pipe Systems with no associated outfall	The outfall may belong to DCR, MassDOT, or a private system, or the system may be so old that no plans exist	Outfall imputed based on local knowledge, owner recorded in a separate “owner” field
Catch basins with no associated pipe networks	Most catch basins were recorded in a survey of the entire town, so even though the catch basin was visible to the surveyor, the town may not own the catch basin, or the catch basin may be in a development that has not submitted their stormwater infrastructure plans to the town.	Catch basins are assigned a new pipe system ID, and an outfall is imputed based on local knowledge. If the catch basins are not owned by the town, the owner is recorded in the “owner” field.
Interconnected Pipe networks	Pipe networks may be interconnected, but for this method, each catch basin may be assigned to only one outfall, so the Town DPW stormwater experts were able to assess which outfall was most likely associated with each catch basin.	Pipe networks split by assigning certain segments distinct pipe system IDs based on local knowledge. Catch basin and outfall IDs changed to match associated pipes.
Outfalls with no associated pipe network or outfalls that appear in unlikely positions, such as on hilltops	Could be a pipe end erroneously recorded as an outfall	Do not assign catch basins to these outfalls. No additional solution needed. Could flag for field investigation.

In order to resolve these issues enough to aggregate the catchments by outfall, we made manual adjustments to the network based on the DPW staff’s extensive experience and personal knowledge of the stormwater system. In instances where a pipe network may be interconnected and could outfall to more than one place, for example, we adjusted the data based on information from the DPW staff.

We initially identified instances where more than one outfall was associated with an interconnected pipe network by using the “find identical” tool, then joining the output table back to the outfall table. In the image below, for example, the automated method assigned a single ID to outfalls 1, 2, and 3, because they are associated with a single interconnected pipe network. In order to assign only one outfall to each catch basin, we assigned new unique IDs to each outfall and manually assigned them to appropriate pipes and catch basins.

Catch basin 4 in the image below is an example of a catch basin that was missed by the automated method of ID assignment, since the small joining pipe segment is missing from the dataset. Such catch basins were assigned manually whenever possible.

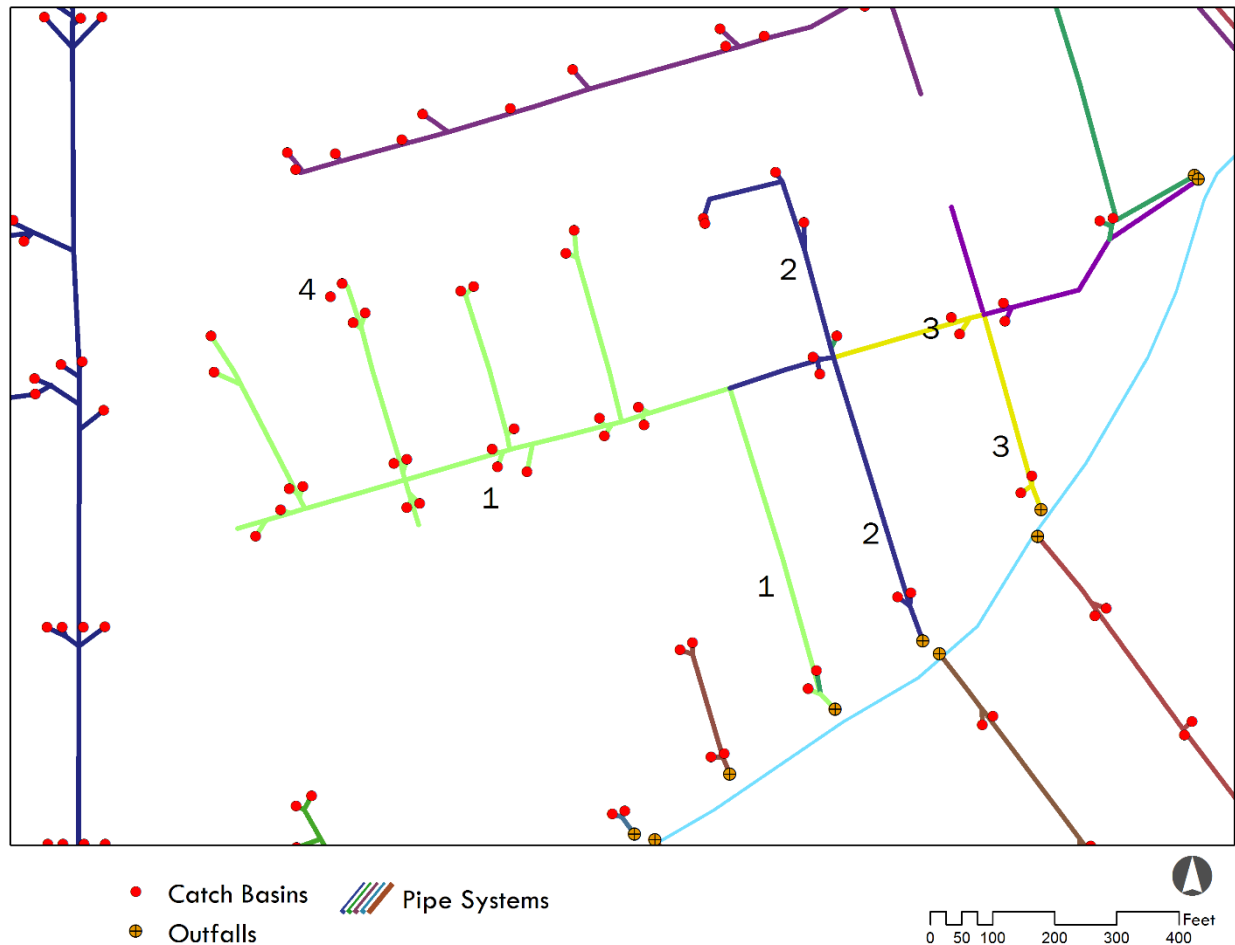


Figure 5. Splitting pipe systems by outfall.

We also added an “owner” field to account for interconnections in the infrastructure. According to the permit, municipalities must monitor not only their own outfalls, but also interconnections with other systems. For the purposes of the new MS4 permit, an interconnection is “the point where the permittee’s MS4 discharges to another MS4 or other storm sewer system, through which the discharge is conveyed to waters of the United States.”¹² The town of Milton is responsible for monitoring the stormwater at the point of the interconnection, not at the outfall belonging to another municipality or public agency.¹³ Additionally, some areas that do not have much potential for illicit discharge, such as “roadway drainage in undeveloped areas with no dwellings and no sanitary sewers, drainage for athletic fields, parks, and associated parking without services, cross country drainage alignments,” may be excluded from regulation by the permit.¹⁴ There is a cemetery in Milton, for example, that is on a private stormwater pipe system, and may also be excluded since it would be considered an undeveloped area with no dwellings under the terms of the permit. Drainage along roadways in the Blue Hills would also be excluded for the same reason.

¹² United States Environmental Protection Agency. 2014: 27

¹³ United States Environmental Protection Agency. 2014: 32

¹⁴ United States Environmental Protection Agency. 2014: 29

After each catch basin was assigned to a pipe system, which was in turn associated with a single outfall, we merged the smaller catch basin catchments into larger catchments based on outfall and owner. Merging on owner as well as outfall allows municipalities to distinguish between MS4 regulated areas and areas that would be exempt because of a private system or another exemption. See the image below for the resulting output:

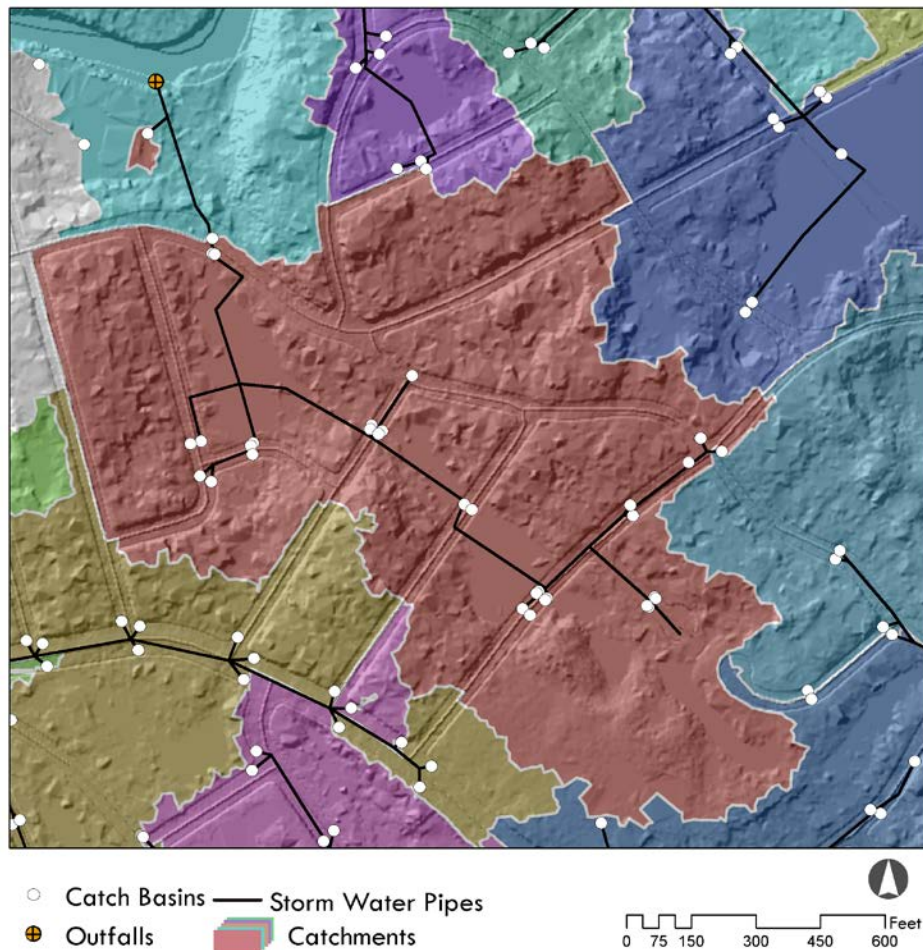


Figure 6. Outfall Catchments.

Assigning Outfalls to Receiving Waters

Once catchment areas were defined for each outfall, we assigned those outfalls to receiving waters, so that the quality of the water can be considered when the catchment areas are ranked by inspection priority. This step is required for the new MS4 permit's Notice of Intent. We associated each outfall in the Neponset Watershed with a body of water from the MassDEP

Impaired Waters dataset, or the 303(d) waters, named for section 303(d) of the Federal Clean Water Act.¹⁵ Section 303(d) requires each state to monitor the quality of its bodies of water. This dataset includes both a line and polygon feature class representing the bodies of water that MassDEP monitors according to the requirements of section 303(d).¹⁶ Each stream segment or lake has a unique identifier, or “AU ID”, which allows the user to link the spatial data to either of the two data tables, described below. The new MS4 permit will most likely require municipalities to be able to identify which properties will produce runoff that will feed into a catch basin, which will ultimately outfall to each body of water in the 303(d) dataset. Our methodology so far has made the connection between an area of land, or catchment, through the stormwater drainage system to the outfall. The next section describes the connection between the outfalls and the receiving waters that they feed.

The first step of this process was to associate each outfall with a body of water from the 303(d) Integrated List of Waters (IL Waters) dataset, maintained by MassDEP and available through MassGIS. Because the 303(d) dataset does not include smaller streams, it was often difficult to tell which was the receiving water. To deal with this challenge with the Milton dataset, since we had already downloaded, processed, and mosaicked a high-resolution DEM, we created a custom stream network using the hydrology toolset and the pre-processed DEM to identify the much smaller streams and brooks including intermittent drainage that connect outfalls to larger bodies of water.

Using a flow accumulation raster created using a raw DEM we used the Con tool to create a raster with a value of 1 for pixels with a flow accumulation value above 20,000. Then, we converted this raster dataset into a vector using the Stream to Feature tool. Using this custom stream network, we were able to assign each outfall to a downstream body of water with an impairment classification.

For the other municipalities, for which we had not downloaded and mosaicked lidar DEMs, we used pre-existing datasets to determine which 303(d) water a particular outfall discharges to. The general process was straight-forward, and done manually, by visually assessing which 303(d) water body an outfall was associated with, and assigning the corresponding AU ID to the outfall. Because each city and town records its stormwater data differently, we added several fields to each outfall layer to aid in standardizing the outfall datasets. Many municipalities did not have unique identifiers for their outfalls, or were inconsistent in filling in a value for that field, so we added an “OF_ID” field as a unique identifier. The unique identifier we assigned has the prefix of the municipal ID number, a value from 1 to 351 assigned by the Massachusetts Department of Revenue, followed by a hyphen and an integer starting with 1. We also added the latitude and longitude in decimal degrees, so that the outfalls could be mapped from the exported table if

¹⁵ Visit <http://www.mass.gov/anf/research-and-tech/it-serv-and-support/application-serv/office-of-geographic-information-massgis/datalayers/wbs2012.html> for details and metadata.

¹⁶ Massachusetts Department of Environmental Protection. “MassDEP 2012 Integrated List of Waters (305(b)/303(d)).” May 2013. MassGIS. <http://www.mass.gov/anf/research-and-tech/it-serv-and-support/application-serv/office-of-geographic-information-massgis/datalayers/wbs2012.html>

necessary. Finally, we added an “AU_ID” (Assessment Unit ID) field that would contain the ID of the associated impaired body of water from the Impaired Waters dataset, described below.

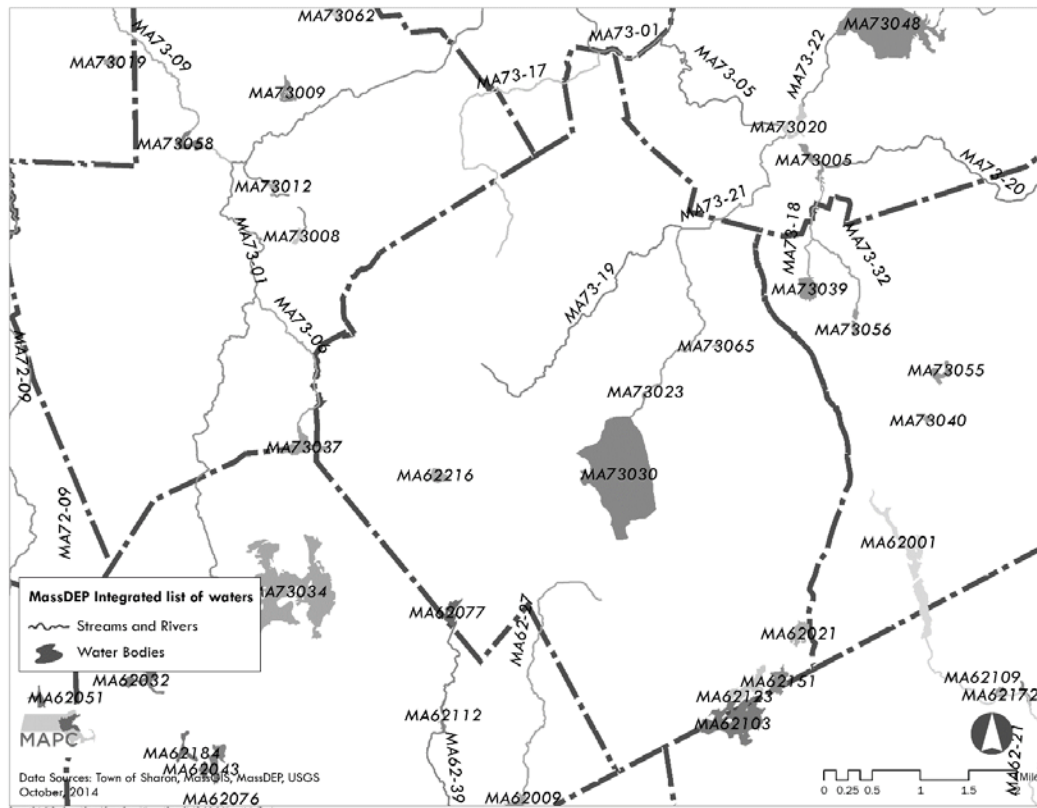


Fig 1. Mass DEP Impaired Waters dataset, available through MassGIS. Labels are AU_IDs

Our general strategy was to select outfalls within 100 m of a particular feature, and then use the field calculator to assign the appropriate AU ID. Figure 2 illustrates how few outfalls can be assigned AU IDs based only on the Impaired Waters dataset. Fortunately, many finer-grained datasets are available to supplement this dataset.

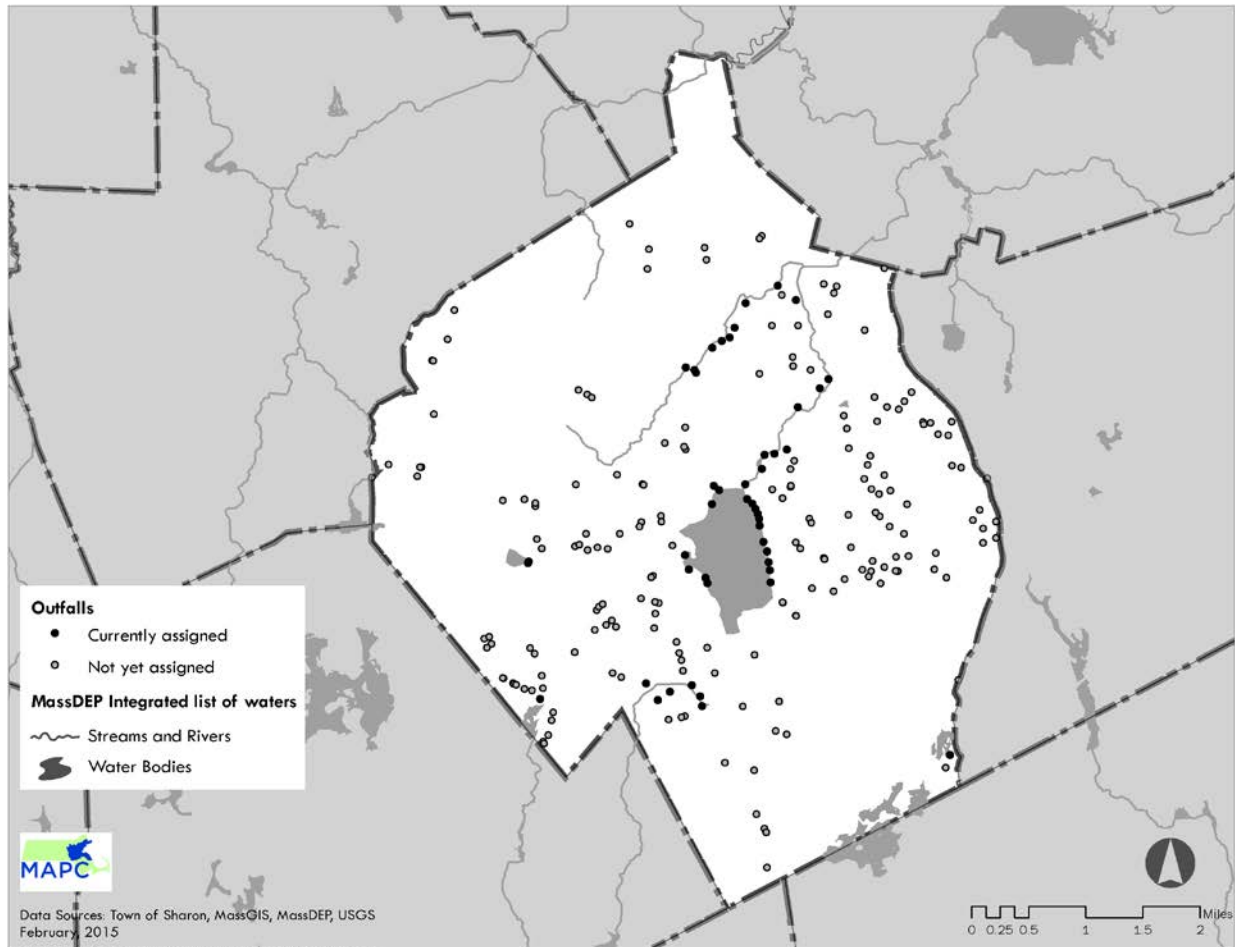


Figure 2. The Impaired Waters (Integrated list of waters) dataset. Red outfalls outfall directly to an impaired water. Gray outfalls cannot be assigned based on this dataset alone.

Adding the USGS Hydrography layer allows us to assign more outfalls to impaired waters.¹⁷ Using this dataset, we selected outfalls within around 100 m of the streams and bodies of water from this dataset, and assigned them the AU ID of the impaired water that these smaller streams feed into (See Figure 3). Although this allowed us to assign many more outfalls to impaired waters, it was no means exhaustive, so we repeated the process with the Mass DEP wetlands layer.

¹⁷ United States Geological Survey. "Hydrography (1:100,000)". February 2013. MassGIS. <http://www.mass.gov/anf/research-and-tech/it-serv-and-support/application-serv/office-of-geographic-information-massgis/datalayers/hd100.html>

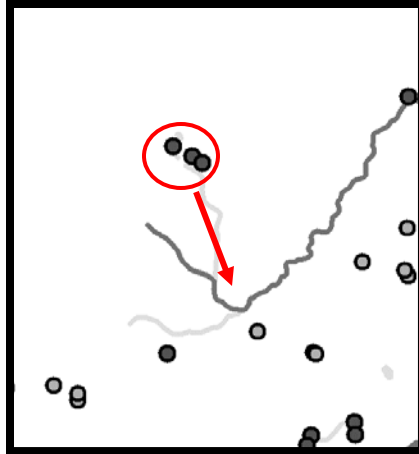


Figure 3. Using the USGS Hydrography dataset to associate the outfall to the Impaired Water.

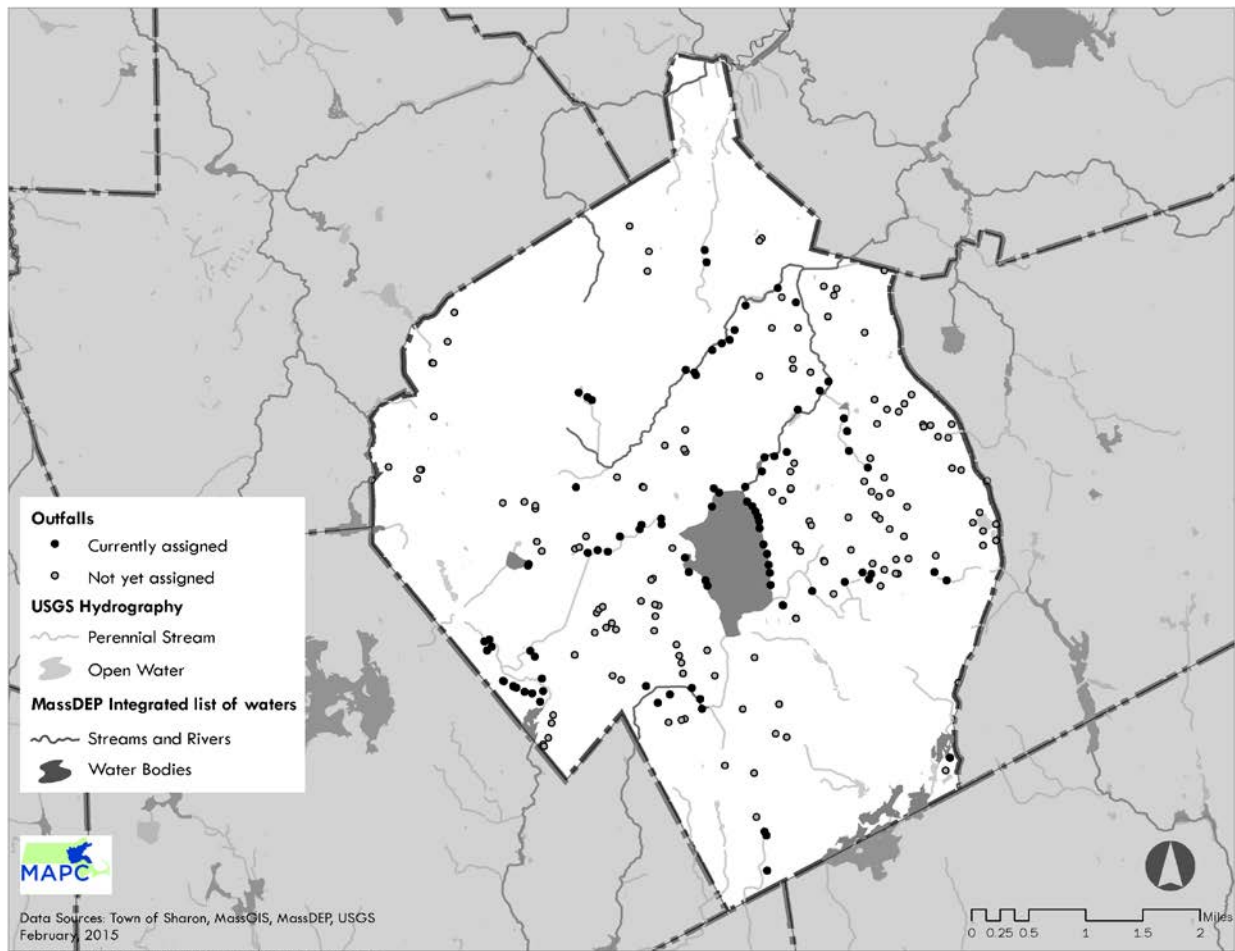


Figure 4. Using the USGS Hydrography dataset to assign an AU ID to additional outfalls.

Many drainage systems in the Neponset watershed outfall to the wetland areas that surround streams, rivers, ponds, and lakes. Using the MassDEP wetlands dataset, we assigned AU IDs to outfalls based on which impaired waters were associated with those outfalls.¹⁸

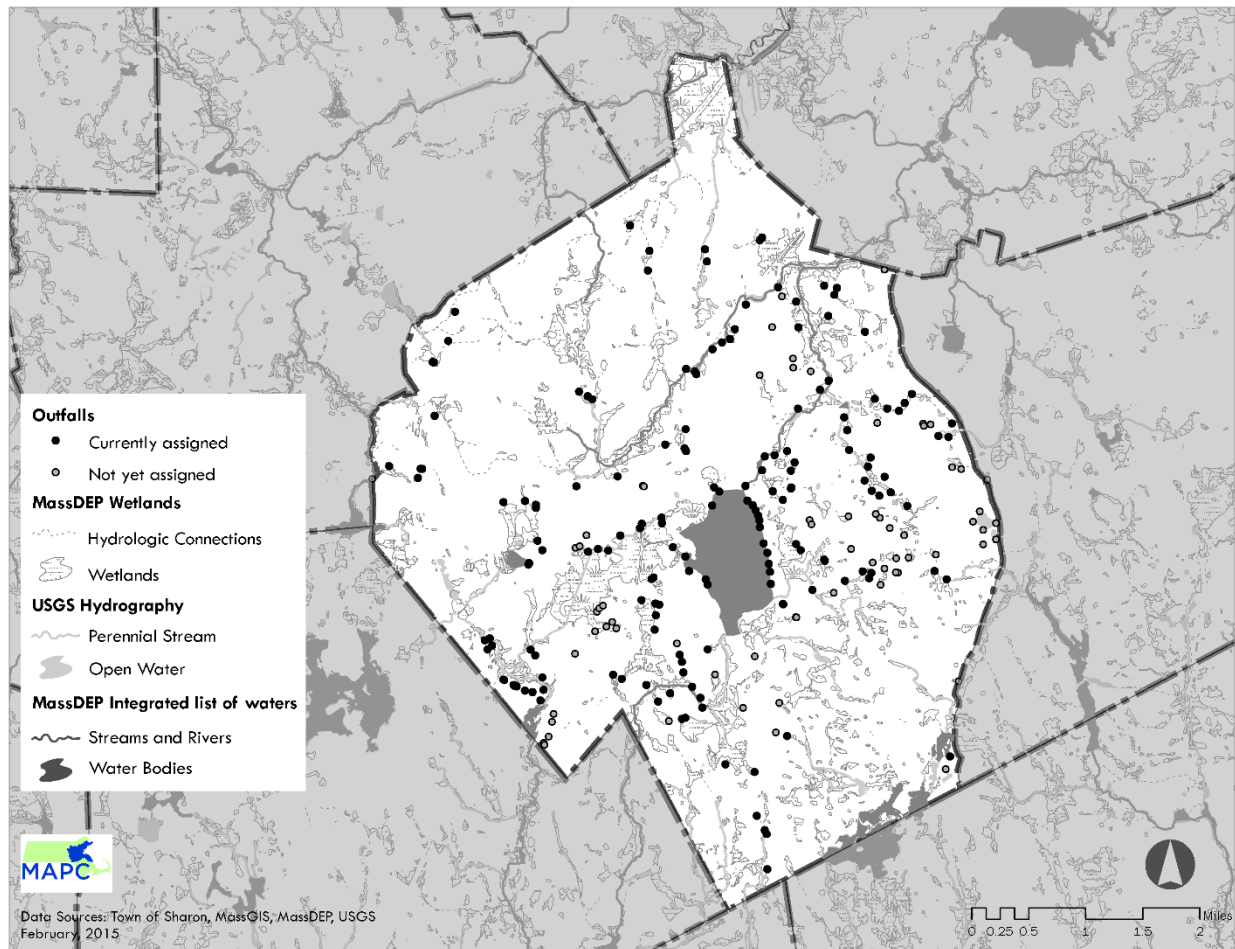


Figure 5. Using the MassDEP wetlands dataset to assign more outfalls to AU IDs.

In some cases, an outfall may be situated on a rivulet that is too small to be depicted in any of the three hydrological datasets described above. In those cases, the topographic contours can help assign these outfalls AU IDs (Figure 6).¹⁹ The contours show areas where higher hills and ridges separate riverbeds into distinct basins.

¹⁸ Massachusetts Department of Environmental Protection. "MassDEP Wetlands (1:12,000)." January 2009. MassGIS. <http://www.mass.gov/anf/research-and-tech/it-serv-and-support/application-serv/office-of-geographic-information-massgis/datalayers/depwetlands112000.html>

¹⁹ Massachusetts Geographic Information Systems. "Elevation Contours (1:5,000)." June 2003. MassGIS. <http://www.mass.gov/anf/research-and-tech/it-serv-and-support/application-serv/office-of-geographic-information-massgis/datalayers/hp.html>

Finally, the last few ambiguous outfalls can be assigned using the MassGIS drainage sub-basins layer.²⁰

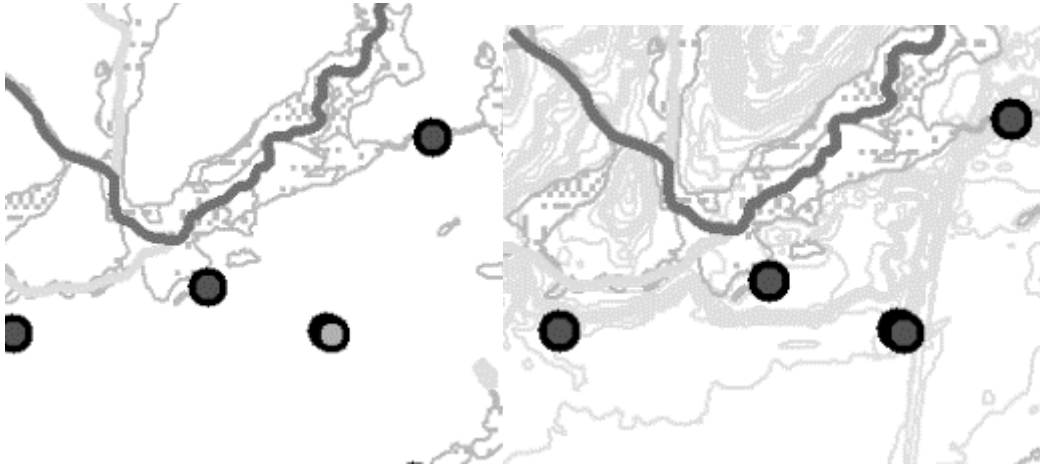
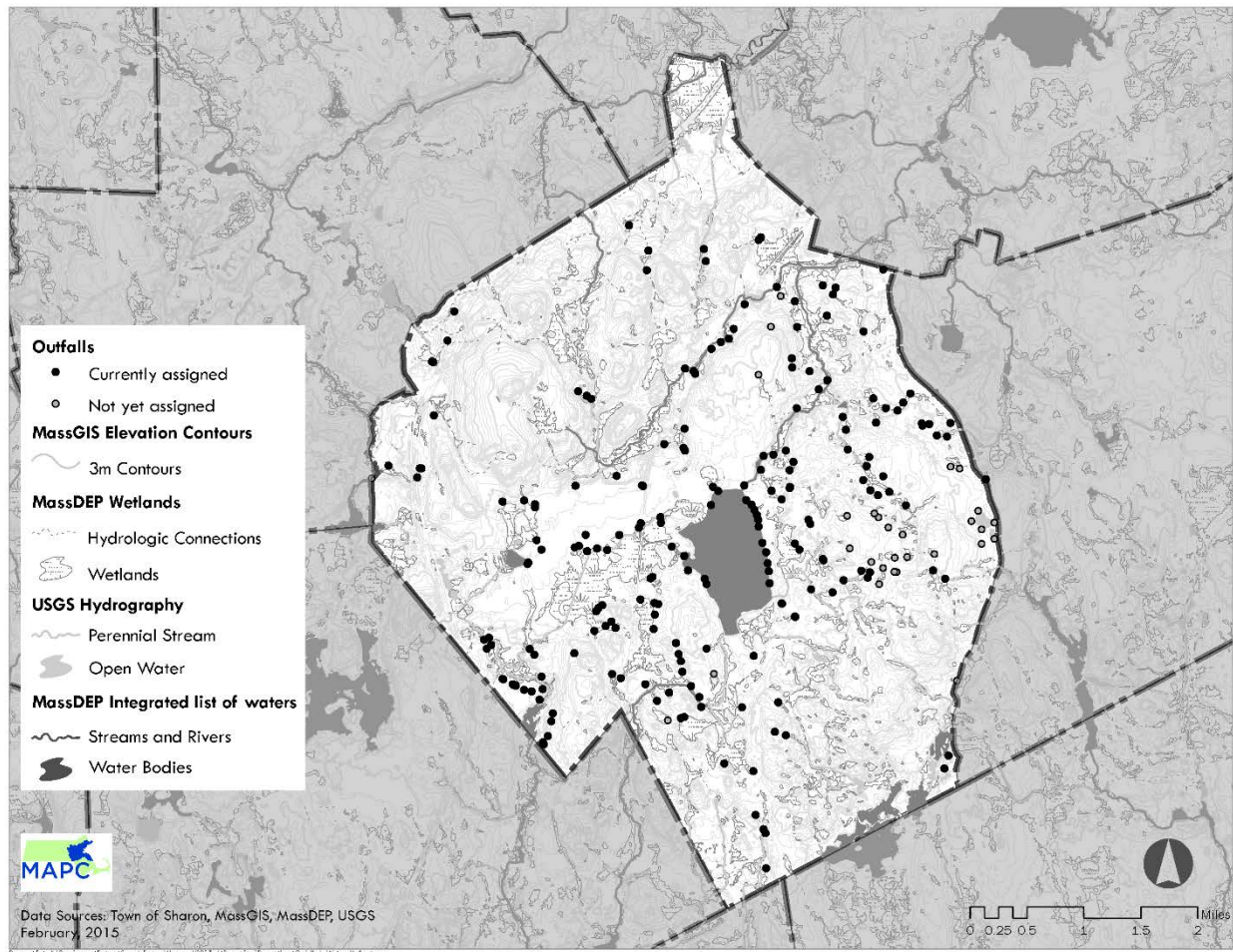


Figure 6. Using topographic contours to associate outfalls with Impaired Waters



²⁰ Massachusetts Geographic Information Systems. "Drainage Sub-basins." December 2007. MassGIS. <http://www.mass.gov/anf/research-and-tech/it-serv-and-support/application-serv/office-of-geographic-information-massgis/datalayers/subbas.html>

Figure 7. Topographic Contours in Sharon.

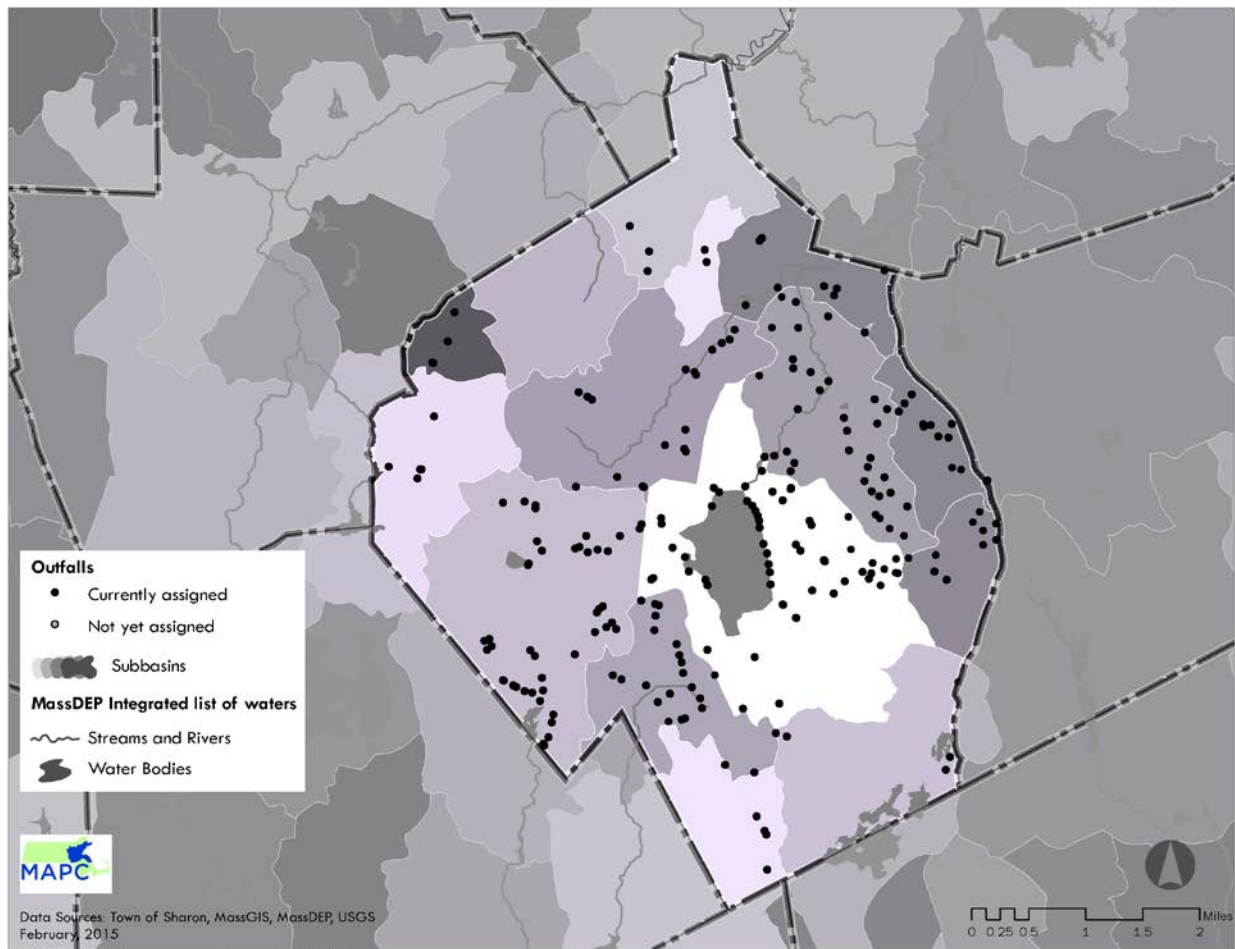


Figure 8. Drainage Sub-basins.

Ranking Catchments

Once we delineated outfall catchments for Milton and linked outfalls with Impaired Waters in Milton and all other Neponset Watershed Municipalities, we ranked Milton's outfall catchments according to how likely they were to contribute illicit discharges to the receiving waters. We used CommunityViz, a GIS-based assessment tool for planning, to prioritize outfalls and catchments using the program's suitability wizard. This suitability analysis evaluates sites based on a set of specified quantitative criteria. In this case, the presence of older homes, industrial uses, septic systems, and other physical features were summarized into a composite score from 0 to 100. Catchments with a median score or below were considered low priority, catchments within the third quartile were considered medium, and those within the top quartile were considered high priority, or most likely to contribute illicit discharges to impaired waters.

Land use codes were designated as medium or high potential for illicit discharges using information found in the 2004 manual from Center for Watershed Protection, titled "Illicit

Discharge Detection and Elimination: a guidance manual for program development and technical assessments”.²¹ The guidance manual provided illicit discharge pollution potential for a variety of land uses and included their SIC codes in Attachment A, which were compared to and converted to NAICS codes during this process.

We used the following criteria for the analysis:

Generating sites, Businesses

We used two data sources to capture information on businesses that are at high or medium risk for illicit discharge into the stormwater system, and used these two datasets to create lists of high and medium risk businesses, which we then combined to create an index of generating businesses. One dataset is the Massachusetts Land Parcel Database, which summarizes the assessor’s records associated with each parcel. This dataset contains a land use code assigned by the assessor. These codes can be very specific—gas stations are distinguished from automobile repair shops, for example. The other dataset is establishment listings published by InfoGroup. Each business in this dataset has an associated classification code as well. These codes, called North American Industry Classification System (NAICS) codes are the standardized codes used by the US Census Bureau and other federal agencies for collecting economic data. These codes are even more specific than those from the parcel dataset. See the tables below for descriptions of the business types that we classified into high and medium risk businesses. See the appendix for the list of Assessor’s and NAICS codes included in each category.

High Potential businesses:	
<ul style="list-style-type: none"> • Heavy Construction equipment rental and leasing • Building and heavy construction (for land disturbing activities) • Buildings for manufacturing operations • Apparel and other fabrics • Auto recyclers and scrap yards • Boat building and repair • Chemical products • Food processing • Garbage truck washout activities • Leather tanners • Metal production, plating, and engraving operations • Facilities providing building materials, hardware, and farm equipment, heating, hardware, plumbing, lumber supplies and 	<ul style="list-style-type: none"> • Paper and wood products • Petroleum storage and refining/ gas production plants • Tanks holding fuel and oil for retail distribution • Natural or manufactured gas storage • Textile mills • Transportation equipment • Landfills and hazardous waste material disposal • Maintenance depots • Streets and highways construction • Ports • Railroads • Petroleum bulk stations or terminals • Research and development facilities

²¹ Environmental Protection Agency. “Illicit Discharge Detection and Elimination: A Guidance Manual for Program Development and Technical Assessments.”
http://cfpub2.epa.gov/npdes/docs.cfm?program_id=6&view=allprog&sort=name#iddmanual Last Updated on October 1, 2004.

equipment	
-----------	--

Medium Potential businesses:	
<ul style="list-style-type: none"> • Auto repair facilities/ automotive vehicles or supplies sales and service • Automobile parking lots or garages • Bus transportation facilities and related properties • Campgrounds/RV parks • Car dealers • Car washes • Food stores and wholesale beverage/ supermarkets • Small retail and services stores • Eating and drinking establishments 	<ul style="list-style-type: none"> • Gasoline stations/ fuel service areas • Marinas • Nurseries and garden centers • Oil change shops • Restaurants • Chemical products • Food processing • Rubber and plastics • Colleges and universities • Airports • Rental car lots • US postal service • Trucking companies and distribution centers

Figure 7. Lists of commercial potential illicit discharge generating sites.

To create the Business Generator Index, we multiplied the count of medium risk businesses from both datasets within each catchment by five, and added the result to the count of high risk businesses multiplied by ten (medium risk businesses * 5 + high risk businesses * 10). Next, we divided this index by the acreage of the catchment to produce a density index. We used the generating site index density value as a criterion for the suitability analysis.

Generating sites, Residential

For residential properties, the age of the house contributes to its risk for contributing illicit discharge to the stormwater system. The draft Massachusetts MS4 permit states that one of the ranking factors that MS4 municipalities are to consider is “Age of surrounding development and infrastructure – Industrial areas greater than 40 years old and areas where the sanitary sewer system is more than 40 years old will probably have a high illicit discharge potential. Developments 20 years or younger will probably have a low illicit discharge potential.”²² We created a residential index similar to that of the business index. In this case, we used the same parcel database, this time using the “last built date.” We used this category based on the assumption that new construction or drastic rebuilding would be required to follow the building codes in effect at the date of construction.

Again, we created two categories of residential risk: high, for the count of houses in a catchment built more than 40 years ago, and medium, for the count of houses in the catchment built 20 to 40 years ago. We created an index using the same formula as that for the business index (count of

²² United States Environmental Protection Agency. 2014. *National Pollutant Discharge Elimination System (NPDES) General Permits for Stormwater Discharges from Small Municipal Separate Storm Sewer Systems in Massachusetts*. <http://www.epa.gov/region1/npdes/stormwater/ma/2014DraftMASmallMS4GeneralPermit.pdf>, pg. 31.

medium risk *5 + count of high risk *10), and divided the result by the acreage of the catchment. We used this housing index per acre value as a criterion for the suitability model.

Sewer and Septic

We also created criteria reflecting the density of sewer lines and the concentration of septic systems within each catchment. Based on the line shapefiles we got from the GIS Analyst at Milton's DPW sent us, we calculated the length of sewer pipe within each catchment divided by the total area of that catchment. Milton also provided us with a shapefile representing each parcel that has a septic system. For the "septic" criterion, we simply divided the number of septic systems in each catchment by the acreage of that catchment.

Quality of Receiving Waters

As described above, each catchment was associated with a single receiving water in the Integrated List of Waters created and maintained by MassDEP and published by MassGIS. We used the category of the associated receiving waters as a criterion within the suitability analysis. Categories of Impaired waters range from 1 to 5, with 5 being the most impaired, and 1 being unimpaired. Category 2 and 3 waters may be unimpaired for some uses and not assessed for others, or there may not be enough information available to make an assessment. Within Milton, all waters were rated a category 5, but elsewhere in the Neponset Watershed, some of the waters rank in a lower category, so we included the receiving water criterion even though it makes no difference in the rankings of the catchments for Milton.

The suitability analysis

After defining the five criteria described above, we ran a suitability analysis that ranked each catchment from 0 (least problematic) to 100 (most problematic) for each catchment. To create this ranking, each criterion was assigned a weight, based on how much that criterion should impact the resulting ranking (Table 3). The weights can be changed easily within CommunityViz, and should be decided upon based on the data specific to that town. If the entire town is on septic systems rather than town sewer lines, for example, it will not make sense to use the density of sewer lines as a criterion, since all catchments would have a value of 0, so this criterion would not change the overall score. Based on the weights above, the results for Milton are summarized in the map below:

Table 3. Ranking criteria and weights

Criterion	Description		Dataset	Weight
Business Generating Site Index Density	Count of businesses of specified types divided by catchment area (in acres)		MAPC Massachusetts Land Parcel Database, InfoGroup	8
House Age Index Density	Summary index, weighted count of		MAPC Massachusetts Land Parcel	6

	houses older than 40 and 20 years.		Database	
Density of sewer pipes	Length of sewer pipes per acre		municipal infrastructure data	2
Density of septic systems	Number of septic systems per acre		municipal data	7
Quality of receiving waters	Category of water, 3, 4, or 5		303(d) Integrated List of Waters dataset from MassDEP, available through MassGIS	2

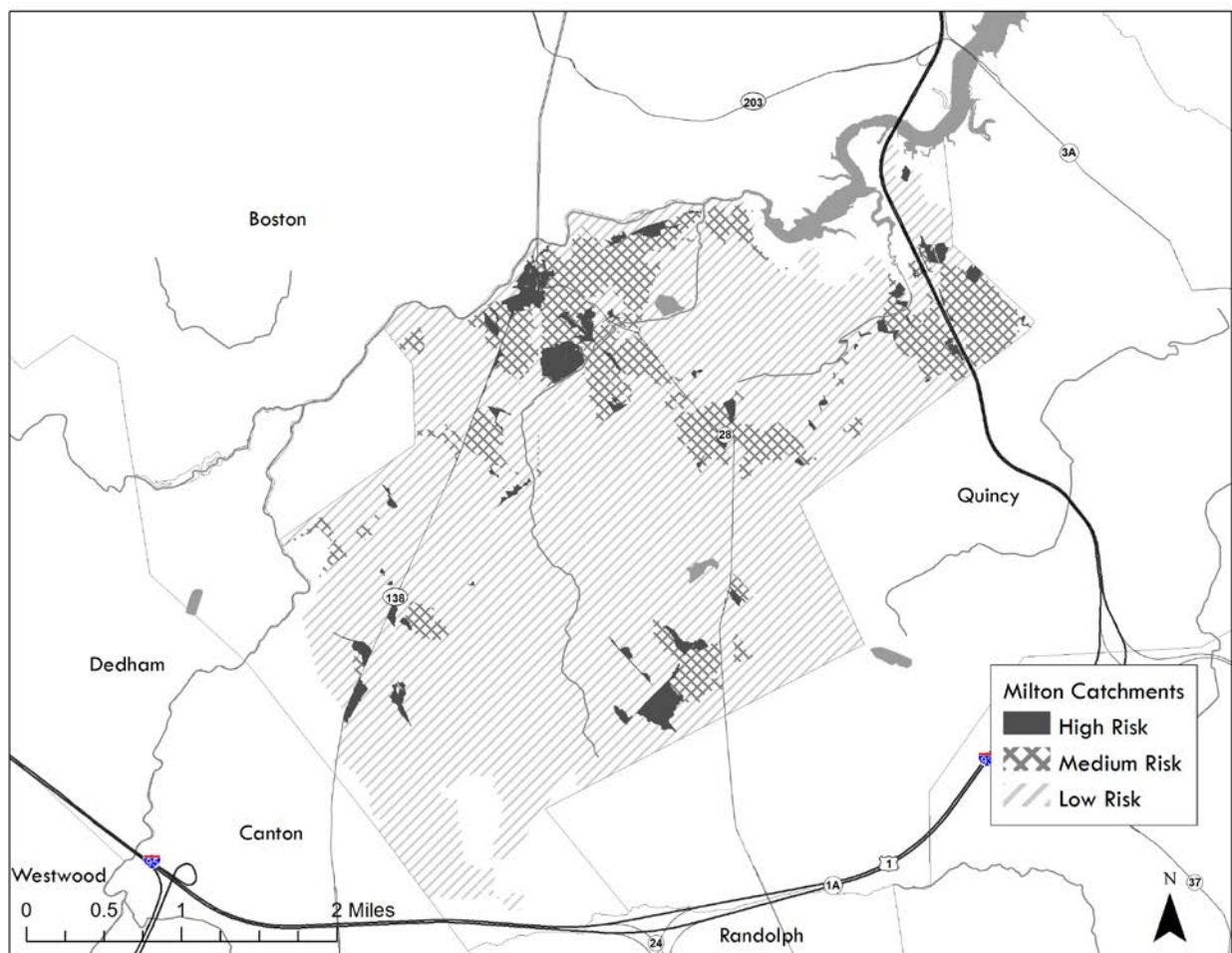


Figure 8. Catchment Ranking, low risk (hatched), medium (cross hatched), and high risk (solid).

Areas in dark gray represent high priority catchments, or catchments with the highest chance of contributing pollution to the stormwater system. Cross hatching represents catchments with a moderate chance, and hatching is the lowest chance. Much of the hatched area, for example, is in the Blue Hills conservation area.

Table 4. Milton Outfall Catchment Ranking Results. 3 = High, 2 = Medium.

PIPESYS_ID	OWNER	AU_ID	ACRES	SUITABILITY	PRIORITY LEVEL
104	Town of Milton	MA73-26	0.8	94.32	3
248	Town of Milton	MA73-29	1.9	89.51	3
253	Town of Milton	MA73-29	4.9	83.09	3
160	Town of Milton	MA73-03	0.9	76.50	3
188	Town of Milton	MA73-03	0.7	67.32	3
23	Town of Milton	MA73-02	2.2	67.32	3
217	Town of Milton	MA73-29	0.8	66.40	3
7	Town of Milton	MA73-29	4.0	64.76	3
178	Town of Milton	MA73-26	0.6	62.40	3
178	Town of Milton	MA73-26	0.5	62.22	3
103	Town of Milton	MA73-26	1.5	58.42	3
25	Town of Milton	MA73-02	4.1	57.72	3
134	Town of Milton	MA73-26	0.4	56.28	3
231	Town of Milton	MA73-29	0.6	56.27	3
76	Town of Milton	MA73-29	2.7	54.32	3
207	Town of Milton	MA73-03	1.5	52.80	3
154	Town of Milton	MA73-26	0.6	52.65	3
170	Town of Milton	MA73-26	0.4	52.23	3
82	Town of Milton	MA73-26	1.5	52.14	3
158	Town of Milton	MA73-03	4.4	51.33	3
0	Town of Milton	MA74-09	1.0	51.23	3
186	Town of Milton	MA73-04	2.1	51.10	3
193	Town of Milton	MA73-04	2.0	50.58	3
110	Town of Milton	MA73-26	0.4	50.46	3
205	Town of Milton	MA73-03	0.4	50.39	3
0	Town of Milton	MA73-26	4.8	49.96	3
146	Town of Milton	MA73-29	1.5	49.78	3
190	Town of Milton	MA73-03	0.7	49.55	3
226	Town of Milton	MA73-04	2.1	49.41	3
207	Town of Milton	MA73-03	2.8	49.25	3
129	Town of Milton	MA74-09	2.3	48.50	3
198	Town of Milton	MA73-03	2.9	48.43	3
27	Town of Milton	MA73-29	19.1	47.41	3
183	Town of Milton	MA73-03	2.9	47.06	3
83	Town of Milton	MA73-26	0.9	46.73	3
209	Town of Milton	MA73-03	4.5	46.54	3
15	Town of Milton	MA73-29	8.7	45.71	3
27	Town of Milton	MA73-29	10.4	45.13	3

230	Town of Milton	MA73-29	3.3	44.38	3
199	Town of Milton	MA73-04	2.0	44.35	3
111	Town of Milton	MA73-29	2.9	44.16	3
242	Town of Milton	MA73-04	0.9	44.02	3
236	Town of Milton	MA73-29	4.0	43.92	3
228	Town of Milton	MA73-04	2.5	43.59	3
7	Town of Milton	MA73-29	12.9	43.47	3
39	Town of Milton	MA73003	2.0	43.38	3
84	Town of Milton	MA73-26	1.1	43.24	3
231	Town of Milton	MA73-29	3.7	43.16	3
93	Town of Milton	MA73-29	0.5	42.97	3
134	Town of Milton	MA73-26	0.8	42.59	3
100	Town of Milton	MA73-29	2.4	42.01	3
113	Town of Milton	MA73-29	8.1	41.79	3
191	Town of Milton	MA73-04	4.9	41.58	3
174	Town of Milton	MA73-03	2.8	41.29	3
239	Town of Milton	MA73-26	1.2	41.23	3
230	Town of Milton	MA73-29	10.6	41.17	3
251	Town of Milton	MA73-29	0.4	41.11	3
133	Town of Milton	MA73-29	15.0	41.09	3
121	Town of Milton	MA73-29	4.1	41.06	3
177	Town of Milton	MA73-26	0.4	40.95	3
99	Town of Milton	MA73-29	0.9	40.70	3
193	Town of Milton	MA73-04	2.9	40.64	3
147	Town of Milton	MA73-26	3.7	40.01	3
79	Town of Milton	MA73-29	0.8	39.63	3
94	Town of Milton	MA73-29	2.7	39.61	3
241	Town of Milton	MA73-26	2.2	39.60	3
173	Town of Milton	MA73-04	2.7	39.46	3
129	Town of Milton	MA74-09	1.6	39.16	2
243	Town of Milton	MA73-02	4.0	38.92	2
106	Town of Milton	MA73-29	2.4	38.78	2
215	Town of Milton	MA73-03	2.9	38.71	2
188	Town of Milton	MA73-03	20.6	38.57	2
178	Town of Milton	MA73-26	5.5	38.57	2
163	Town of Milton	MA73-03	9.6	38.54	2
148	Town of Milton	MA73-29	33.0	38.46	2
234	Town of Milton	MA73-29	40.9	37.83	2
117	Town of Milton	MA73-26	1.9	37.53	2
122	Town of Milton	MA73-29	12.8	37.23	2
92	Town of Milton	MA73-29	2.0	37.02	2
125	Town of Milton	MA73-26	13.6	36.95	2
87	Town of Milton	MA73-26	2.9	36.91	2

123	Town of Milton	MA73-26	2.5	36.91	2
81	Town of Milton	MA73-29	3.4	36.83	2
0	Town of Milton	MA74-10	2.4	36.78	2
152	Town of Milton	MA73-29	2.4	36.76	2
200	Town of Milton	MA73-03	3.6	36.64	2
86	Town of Milton	MA73-29	2.3	36.48	2
0	Town of Milton	MA73-03	2.1	36.31	2
173	Town of Milton	MA73-04	2.1	36.29	2
214	Town of Milton	MA73-29	4.2	36.22	2
41	Town of Milton	MA73003	2.2	36.04	2
159	Town of Milton	MA73-26	42.2	35.78	2
183	Town of Milton	MA73-03	13.9	35.43	2
169	Town of Milton	MA73-26	12.4	35.41	2
155	Town of Milton	MA73-03	8.9	35.22	2
85	Town of Milton	MA73-26	13.3	35.01	2
179	Town of Milton	MA73-04	3.4	34.98	2
203	Town of Milton	MA73-29	1.4	34.96	2
43	Town of Milton	MA73-02	10.0	34.81	2
218	Town of Milton	MA73-29	7.1	33.89	2
0	Town of Milton	MA74-10	0.4	33.77	2
219	Town of Milton	MA73-04	6.9	33.56	2
93	Town of Milton	MA73-29	8.5	33.53	2
181	Town of Milton	MA73-04	3.2	33.52	2
150	Town of Milton	MA73-26	1.4	33.50	2
131	Town of Milton	MA73-29	22.4	33.46	2
187	Town of Milton	MA73-04	2.8	33.45	2
104	Town of Milton	MA73-26	2.0	33.35	2
119	Town of Milton	MA73-26	6.9	33.33	2
138	Town of Milton	MA73-29	15.1	33.11	2
202	Town of Milton	MA73-03	5.4	32.99	2
87	Town of Milton	MA73-26	4.1	32.88	2
123	Town of Milton	MA73-26	2.5	32.85	2
178	Town of Milton	MA73-26	120.5	32.83	2
165	Town of Milton	MA73-26	16.9	32.30	2
45	Town of Milton	MA73-29	27.7	32.19	2
188	Town of Milton	MA73-03	2.0	32.03	2
64	Town of Milton	MA73-29	0.7	32.03	2
259	Town of Milton	MA73-04	13.3	31.69	2
104	Town of Milton	MA73-26	7.4	31.64	2
84	Town of Milton	MA73-26	19.7	31.16	2
52	Town of Milton	MA73-02	8.5	31.11	2
89	Town of Milton	MA73-26	6.4	31.02	2
159	Town of Milton	MA73-26	5.8	30.87	2

185	Town of Milton	MA73-03	35.1	30.85	2
195	Town of Milton	MA73-03	17.0	30.72	2
39	Town of Milton	MA73003	0.6	30.70	2
120	Town of Milton	MA73-29	13.8	30.64	2
88	Town of Milton	MA73-29	24.0	30.33	2
210	Town of Milton	MA73-29	11.4	30.31	2
104	Town of Milton	MA73-26	90.3	30.29	2
151	Town of Milton	MA73-03	10.8	30.14	2
136	Town of Milton	MA73-29	44.8	30.05	2
42	Town of Milton	MA73003	6.0	30.01	2
208	Town of Milton	MA73-29	14.3	29.93	2
31	Town of Milton	MA73-29	68.4	29.78	2
24	Town of Milton	MA73-29	8.2	29.71	2
256	Town of Milton	MA73059	47.4	29.07	2
180	Town of Milton	MA73-04	0.9	29.05	2
197	Town of Milton	MA73-29	36.8	29.04	2

Products

Methodology

This document consists of one of the products of the IDDE task of the CIC grant. We created the methodology with the intention of making it accessible to most MS4 municipalities in Massachusetts, so we believe it will aid municipalities across the state in meeting the requirements of the new MS4 permit.

MAPC Catchment Delineation Toolbox

In order to streamline the methodology for the municipalities, we created a set of ArcGIS script and ModelBuilder tools—the Lidar Processing Tool, the Create Burn Raster Tool, and the Complete Watershed Tool. These tools are available for download on ESRI's ArcGIS Online website as the MAPC Catchment Delineation Toolbox. Data Assessments

We also provided each Neponset Watershed municipality with a concise assessment of their stormwater infrastructure data. These assessments highlight potential challenges that the municipalities may encounter when applying the methodology outlined in this document.

The Outfalls and Impaired Waters Database

Data on the 303(d) water bodies is found within two tables, IL_SEGDEF_2012, and IL_ADB_2012. The former is a summary table that contains attributes such as Assessment Unit (AU)

size. The latter contains detailed data about uses the water body was assessed for, as well as the “attainment”, or status of the water body for that use, and the cause of the impairment. For example, Massapoag Lake, located in the center of Sharon, pictured above, has six records in the IL_ADB_2012 table (Figure 9). When assessed for Fish, other Aquatic Life and Wildlife, it was rated “Not Supporting,” because of “Non-Native Aquatic Plants,” the source of which is “Introduction of Non-native Organisms (Accidental or Intentional)”. The other five records in this table contain other information on various uses, causes, and sources of pollution for Massapoag Lake. Because this table has a many-to-one relationship with the AUs, we created a Microsoft Access database to create a report on each Neponset Watershed town.²³

Each municipality’s report contains a list of impaired waters that its outfalls drain to, along with all associated data from the summary table (IL_SEGDEF_2012). The data on each impaired water is followed by the list of assessed uses and associated data (IL_ADB_2012). A list of outfalls accompanies each impaired water as well. The outfall table included in the database includes not only the few fields added by MAPC, but also all of the original data sent to us by the municipality. This way the municipality will be able to bring the data into its own data management system using its own unique identifiers. For Milton, we have also included the rank of each outfall catchment, as defined using the above methodology. Once every municipality has defined and ranked outfall catchments, they will be able to include that information in the Outfalls and Impaired Waters database as well.

AU_ID	WATERSHED	WATERBODY	LOCATION1	WATERCODE	WATERTYPE	AU_SIZE	SIZE_UNIT	CLASS	QUALIFIER	CATEGORY	TMDL_COUNT
MA73030	Boston Harbor: Neponset	Massapoag Lake	Sharon	73030	FRESHWATER LAKE	389	ACRES	B	<Null>	4A	1

Assessed Uses								
ID	WATERCODE	CLASS	QUALIFIER	CATEGORY	USE	ATTAINMENT	CAUSE	
1699	73030	B	<Null>	4A	Aesthetic	Not Assessed	<Null>	
1700	73030	B	<Null>	4A	Fish Consumption	Not Supporting	Mercury in Fis	
1701	73030	B	<Null>	4A	Fish Consumption	Not Supporting	Mercury in Fis	
1702	73030	B	<Null>	4A	Fish, other Aquatic Life and Wildlife	Not Supporting	Non-Native Aquatic Plants	
1703	73030	B	<Null>	4A	Primary Contact Recreation	Not Assessed	<Null>	
1704	73030	B	<Null>	4A	Secondary Contact Recreation	Not Assessed	<Null>	

Associated Outfalls							
OF_ID	Latitude	Longitude	NUMBER	STREET_NAM	CONDITION	NOTES	AU_ID
266-2	42.110574	-71.179543	2	Beach	No flow		MA73030
266-3	42.111106	-71.180458	3	Beach	No flow		MA73030
266-13	42.107292	-71.189442	13	East Foxboro/Garden	No flow		MA73030
266-14	42.106572	-71.189407	14	East Foxboro/Lake Ave	No flow		MA73030
266-15	42.103498	-71.187563	15	East Foxboro	No flow		MA73030
266-16	42.102322	-71.185418	16	East Foxboro	No flow		MA73030
266-17	42.100475	-71.184764	17	Sturges	No flow		MA73030

Figure 9. Excerpt from Sharon’s Outfall and Impaired Waters Report.

²³ Two relationship classes are also available through MassGIS to help create the many-to-one relate between the ADB table and the line and polygon feature classes within ArcGIS.

Discussion

The increasingly stringent requirements of federal stormwater permits combined with the lack of dedicated funding streams for stormwater infrastructure maintenance present substantial challenges to local jurisdictions. Given these circumstances, municipalities will greatly benefit from tools that allow them to cost-effectively satisfy analytical permit requirements so that resources and attention can be focused on infrastructure, outreach, and enforcement. This document describes one such tool recently prepared by MAPC and now available to any city or town in Massachusetts.

The methodology and data resources described here will help many municipalities meet the “catchment delineation” requirement in the system mapping section of the new MS4 permit, provided the Outfall/ Interconnection Inventory is relatively complete, and gaps in knowledge can be filled by DPW staff.²⁴ Cities and towns do not need to collect or developed detailed stormwater infrastructure information, and MAPC has also provided highly detailed information on land uses and establishments that pose a higher risk for water pollution, eliminating the need for cities and towns to acquire or compile such data. Furthermore, the tool is structured to provide the specific types of data and designations required by the NPDES permit. For example, the permit requires municipalities to classify catchments into four groups—excluded, high priority, low priority, and problem. These products should help municipalities with the first three categories. If municipalities assign an “owner” to each catch basin, they will be able to distinguish between excluded and included catchments. The step-by-step instructions provided in this document, combined with the published data catalog and ArcGIS tool published online, will enable jurisdictions or consultants with relatively modest technical capabilities to use this method.

The delineation methodology and ranking process has some limitations that could be addressed through additional data collection. For example, it would have been useful to include the age of the sewer pipes as a criterion. Most municipalities in the Neponset Watershed do not have this data available, however. The catchment ranking described here does not distinguish between problem catchments and other catchments. For the purposes of the MS4 permit, a “problem catchment” is one that has had an outfall that tested as contaminated, or that direct observation indicates that there is some kind of illicit discharge connected to that outfall.²⁵ Such a catchment would be considered a problem catchment regardless of its ranking in this suitability analysis, and must be investigated. In the future, the ranking could include historical data on whether a catchment has ever been designated a problem catchment, so that former problem catchments will rank higher than those that have had no observed contamination. If data are available, such analysis could be easily incorporated into a future version of the tool.

²⁴ United States Environmental Protection Agency. 2014. 26-28

²⁵ United States Environmental Protection Agency. 2014. 30