Stormwater Banking Location and Crediting Assessment

An Example Using Vacant Properties in Baltimore City

Center for Watershed Protection, Inc.

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Center for Watershed Protection

Introduction

This banking location assessment was conducted as part of Task 2 under the Smart Growth Offset Bank (MD) project funded by a grant from the National Fish and Wildlife Foundation. The goal of this project is to develop guidelines for implementing a stormwater offset and banking system that can be used as a template for other urban areas within the Chesapeake Bay watershed using Baltimore City as a case study. Task 2, as described in this memo, includes an assessment of potential properties appropriate for being included in a banking program; and the assessment of the potential credits that would be generated on those properties.

A stormwater bank can accomplish many purposes. It can help developers meet on-site stormwater management requirements more cost effectively through the purchase of credits or the construction of off-site BMPs on marginal or underutilized properties. It can provide opportunities for the business community to build green infrastructure and sell credits. In some communities with a stormwater utility, a stormwater bank can provide relief to large property owners by allowing them to generate stormwater and sell credits. Ultimately, a stormwater banking system should allow for the construction of stormwater BMPs more competitively than a system that requires the development community to provide on-site controls regardless of costs. Furthermore, while the initial focus of this study was to develop a stormwater banking system for developers, the Department of Public Work's MS4 Program might find the Stormwater Bank an affordable option for meeting the 20 percent impervious cover treatment requirement.

One of the first steps to developing a stormwater mitigation bank is to identify the types of stormwater practices to be utilized and their potential locations. This can be done through a retrofit inventory, watershed plan, stormwater master plan, or similar effort that includes field verification to determine site feasibility, practice size, and site constraints, among other factors. The identification of available sites can also be tied to ongoing municipal transportation and other capital improvement projects. The Center for Watershed Protection (the Center), Urban Stormwater Retrofit Practices (Manual 3, Urban Subwatershed Restoration Manual Series, 2007) is a good resource for conducting a stormwater retrofit inventory. The manual can be downloaded at: http://www.cwp.org/online-watershed-library/doc_download/60urbansubwatershed-restoration-manual-series-manual-3.

The assessment of potential properties is critical because it allows the community to gauge whether there are enough sites to establish a mitigation bank and generates an initial list of potential sites that can be used in the beginning stages of a banking program. Ideally, a community would have sufficient vacant lands on public right-of-ways to generate enough BMPs to satisfy the demand. However, the Center has found the retrofit potential of public right-of-ways for BMP construction to be severely restricted. Also, BMP retrofits in public right-of-ways tend to be very expensive because of traffic issues, the location of underground utilities and other site constraints. Alternatively, public parks that aren't heavily utilized and vacant properties with limited redevelopment potential are ideal areas for potential banks. Constructing green infrastructure on these lands can often enhance their aesthetic quality. Large institutional lands such as hospitals and universities can also be ideal locations for construction of BMPs; however local governments typically exclude these areas from retrofit inventories because of the lack of incentive for property owners to participate. The development of a Stormwater Bank could likely provide the financial incentive necessary.

One of the key considerations for developing a Stormwater Bank is to not only assure that there are enough credit generating BMP's to satisfy the demand but to also assure that the geographical distribution of these BMPs is adequate to address local water quality issues. For instance, a developer in a watershed with a severely eroding stream would logically want to purchase credits within the same watershed. The purchase of credits to satisfy regulatory requirements would have to satisfy certain qualifying conditions.

This document describes the basic steps for the assessment of potential properties for the establishment of a stormwater bank and the assessment of the potential credits that would be generated on those properties. A case study from Baltimore City is also included that assessed the use of vacant lots within the City for treating stormwater. It is recommended that the City apply this same procedure to other publicly owned lands and eventually large privately-owned institutional properties once the Bank becomes established.

Assessment of Potential Properties Appropriate for Inclusion in a Banking Program

Step 1: Determine the types of practices and types of properties to be targeted through the mitigation banking program.

Discussions with the community to document their priorities will help determine the types of practices and locations. What local community interests, priorities, and resources should the program reflect? For instance, if the community is building a river corridor park or trail system to enhance water resources and spur economic activity, then at least some of the projects can be focused on river corridor projects. This information can also help establish the watershed scale for which banking can occur.

A community may have an interest in keeping the list of allowable practices as broad as possible in order to provide flexibility for project implementation. Desirable practices include those that meet multiple objectives, such as TMDL implementation, community recreational and aesthetic enhancements, revitalization of degraded areas, drinking water supply protection, and other local water resources goals. Examples of such practices may include stream restoration, reforestation, and restoration of abandoned or degraded sites in conjunction with conservation easements, streambank erosion control, and rain gardens.

Step 2: Conduct a desktop analysis of potential properties.

If Geographic Information System (GIS) data is available, it can be very useful in identifying potential properties. The data can be used to narrow down the properties within a community to those identified in Step 1. In addition, the data can be used to narrow down the properties even further to those appropriate for the preferred practices based on existing conditions at the site. For example, is the site close to an underdrain or lacking canopy cover?

Depending on the number of potential properties identified through the desktop analysis, a random representative sample may need to be selected for the field assessments in Step 3.

Step 3: Conduct field assessments.

Field assessments are conducted for the potential properties identified in Step 2. The goal is to determine their feasibility based on actual site conditions and to further refine the list of potential properties. Basic information about the site is collected, such as the existing conditions, drainage area to the site, area available for a stormwater practice, and any site constraints, such as utilities or trees. The level of detail collected during the field assessments is dictated by the goals of the community. For additional information on conducting field assessments, refer to the Center's Urban Stormwater Retrofit Practices Manual.

http://www.cwp.org/online-watershed-library/doc_download/60urbansubwatershed-restoration-manual-series-manual-3

Step 4: Analyze the findings from the field assessments and desktop analysis

Data from the field assessments should be compiled into a master spreadsheet or database for analysis. The compiled data can then be used to determine the number of sites suitable for stormwater practices from the initial list of sites identified during the desktop analysis. If the field assessment represents a random sample of the total number of potential sites within a community, the results should be extrapolated to the entire number of potential sites. For example, if 60% of sites assessed from the random sample were identified as good candidates for stormwater treatment, the entire population of potential sites within the community can then be multiplied by 60%. This assessment determines the suitability of properties for stormwater management practices. There is an entire suite of considerations that each local government will have to go through to narrow this list to viable practices especially related to the development potential of the property or potential for community concerns.

Assessment of Potential Credits Generated on Properties

In order to calculate the potential credits generated on the properties identified through the process above, it is important to recognize that the design of the practices, and the resulting volume and pollutant removal calculations align with any regulatory systems that are already in place. This will help to assure the validity of the calculated credits.

Step 1: Identify the design standards and calculation methods that apply.

In order for credits to be valid and bankable, the practices must be designed to the same standards that would be required of a new development. While the general design of stormwater practices is similar across jurisdictions, there are many specific design rules, standards, and calculations that vary by state or community. In some cases, these variations are somewhat minor, (e.g. the required depth of bioretention media varies from state to state), whereas in other cases, the variations are major, and could greatly impact how credits are calculated (e.g. Maryland regulates stormwater management on a volume basis, and Virginia regulates stormwater management on a phosphorus-loading basis). In addition to the state and local standards, there may be regional or national standards that play a part in the calculations. All of these standards should be determined in advance to ensure that the potential credits are valid and bankable.

Step 2: Calculate the potential credits available for each identified site and compile credits.

For each of the properties identified in the process above, calculations will need to be made to determine the stormwater volume or pollutant removal that the proposed practices can achieved. As noted in Step 1, these calculations should follow, as closely as possible, the stormwater practice design standards that apply to new development. Once the appropriate design equations have been selected, calculating the potential volume and pollutant removal credits is simply a matter of entering the applicable data for each site (drainage area impervious cover, practice sizing, etc.). The values achieved for each site can then be summed to determine total potential volume and load reductions.

Case Study: Baltimore City Vacant Lot Assessment

Baltimore City Assessment of Potential Properties

The case study in Baltimore City focused on vacant properties due to their high numbers, maintenance burden, and potential for stormwater retrofitting. Assisting Baltimore agencies (Housing, DPW, and Planning) in identifying vacant properties that could be utilized for stormwater management is one of the first steps in developing a stormwater mitigation bank. The mitigation bank could provide several potential benefits:

- Allow developers to provide or purchase stormwater management practices off-site, if on-site requirements cannot be met.
- Help nonresidential property owners earn credits toward their stormwater utility bills through construction of offsite stormwater BMPs.
- Allow third parties to generate credits for sale to developers and City agencies to meet stormwater permit requirements.
- Reduce the cost of meeting the City's MS4 Permit requirements.

In addition to the stormwater-related benefits, the mitigation bank could reduce the Baltimore City Department of Public Work's cost to maintain these vacant properties. Converting vacant properties to green infrastructure also improves the aesthetics, which could make the area more attractive to homebuyers and developers.

<u>Step 1:</u> *Determine the types of practices and types of properties to be targeted through the mitigation banking program.*

This assessment focused on City-owned vacant properties because of their high numbers, maintenance burden, and potential for stormwater retrofitting. It is likely that the results of this study would also apply to privately-owned properties and the potential for these properties to participate in a mitigation bank should be considered for future study. Most of the City-owned vacant properties are prime candidates for a stormwater practice, thereby having the potential for easing the maintenance burden. Other City-owned locations, such as schools and parks, were not chosen for assessment. While publicly owned schools and government buildings are easy targets for a stormwater practice, there have been several assessments of these locations and many already have proposed practices from previous watershed planning. Public parks were not considered because of concerns of stormwater practices reallocating land from recreational areas. Also, previous projects have already addressed tree planting in parks. Stormwater improvements made to streets and alleys in the City have the potential for generating stormwater credits but would most likely be used to meet the City Department of Transportation's permit requirements.

Since the focus of the field assessment was on vacant properties, the three stormwater practices most suitable for urban areas are bioretention, tree planting, and impervious cover removal. These practices are also approved practices for meeting the City's Chesapeake Bay TMDL requirements. Other vegetated practices such as swales could be substituted if more appropriate in a given location.

<u>Step 2:</u> Conduct a desktop analysis of potential properties.

Using OpenBaltimore, Baltimore City's Data Catalog, the Center downloaded the newest lists of vacant buildings and vacant lots from Baltimore Housing, which includes vacant homes and also open, empty lots where building demolition may have occurred. This list included all privately owned and City-owned properties. The Baltimore City Department of Planning office provided a list of all City-owned properties and after intersecting with the vacant property list, the City-owned vacant properties were identified.

The Baltimore City Department of Planning also provided a list of demolition clusters, which are groups of mostly vacant homes the City plans to demolish. Table 1 shows the number of vacant properties and demolition clusters in Baltimore. These demolition clusters usually have adjacent vacant lots. Figure 1 shows the location of all City-owned vacant properties and the demolition clusters.

Table 1. Number of Vacant Properties and Demolition Clusters

Property Type	**In Baltimore**	**City-Owned**	**% City-Owned**
Vacant Buildings	15,928	3,028	19%
Vacant Lots	17,169	6,865	40%
Total Vacant Properties	**33,097**	**9,893**	**30%**
Demolition Clusters	620	NA	NA

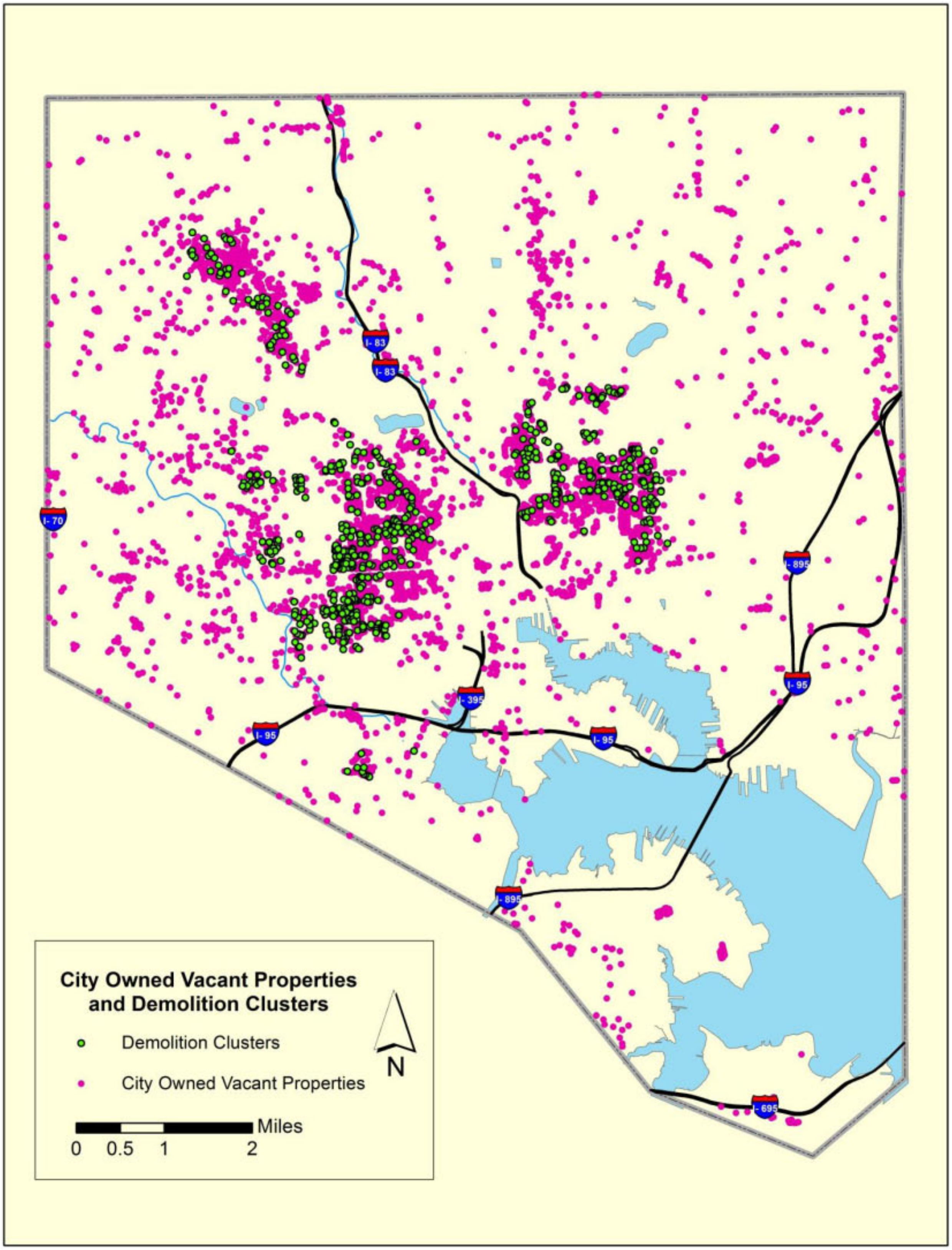

Figure 1. City-Owned Properties and Demolition Clusters

Many of the vacant properties would not be suitable for stormwater retrofitting due to current land use. Using land use data provided by Baltimore City Mayor's Office of Information Technology (OIT), the properties with the following land use were removed from the list: cemetery, natural areas, parks and recreation, transportation right-of-way, railroads, and downtown parking lot. Also, to install a bioretention in poor infiltrating soils that are characteristic of the City, an underdrain is generally required, which requires access to a catch basin. All properties that were more than 100-feet away from a catch basin were removed from the list. Table 2 lists the GIS data used during the desktop analysis.

Table 2. GIS Data Used in the Analysis

Name	Year	Description	Data Source
CityOwned	2013	City-owned parcels	Dept. of Planning
Contour_interval_2ft	2008	Topographic contour lines at 2-ft interval	City of Baltimore OIT
Demo Clusters with Adjacent Vacant	2013	Vacant lots adjacent to the City defined demolition clusters	Dept. of Planning
Demolition Clusters	2013	Clusters of adjacent buildings the City has slated for demolition	Dept. of Planning
Landuse	2009	Baltimore City land use	City of Baltimore OIT
Realprop	2010	Parcels in Baltimore City	City of Baltimore OIT
Streetcl	2010	Centerline of Baltimore City streets	City of Baltimore OIT
SW_Drain	2009	Stormwater main pipe	DPW
SW_Inlet	2009	Stormwater catch basin	DPW
SW_Open_Channel	2009	Stormwater natural stream or manmade ditch	DPW
Vacant Buildings	2013	Point location of vacant building	Baltimore Housing
Vacant Lots	2013	Point location of vacant lot	Baltimore Housing
WA_Main	2009	Water main pipe	DPW
WA_Service	2009	Water pipe between water main and customer location	DPW
Water_harbor	2009	Baltimore City harbor	City of Baltimore OIT
water	2009	Water features in Baltimore City	City of Baltimore OIT
WW_HouseConnection	2009	Wastewater pipe from customer location to primary collection pipe	DPW
WW_Sewer	2009	Wastewater main pipe	DPW

Many vacant properties were adjacent to other vacant properties and it made sense to evaluate these properties as one larger aggregated site. As bioretention sites have a minimum width and length requirement to be feasible, looking at narrow properties individually may preclude the possibility of a bioretention retrofit. However, if several adjacent vacant properties were evaluated holistically, then there is a greater possibility of installing a retrofit. After the vacant properties were aggregated, any aggregated properties that were smaller than 2,000 square feet were removed from the list. Because many of the demolition clusters included City-owned vacant properties that also met the site visit criteria, there was some overlap between the two data sets. In cases where the demolition cluster also included a vacant property selected for a visit, both sites were assessed together as one site.

Because not all 9,893 City-owned vacant properties could be field assessed, a random sample of 280 properties was chosen for a site visit. These sites went through a quality control process to confirm they met the criteria described above. Due to the data manipulation process in GIS, 76 of the random sample properties were actually privately owned or were inappropriately in a group with privately owned properties and made them smaller than the minimum 2,000 square feet, leaving 204 sites eligible for a site visit. In addition, from Baltimore City's list of 620 demolition clusters, a random sample of 40 sites was chosen for a site visit. This provided a total of 244 sites to visit in Baltimore City. Figure 2 shows the location of the 244 sites.

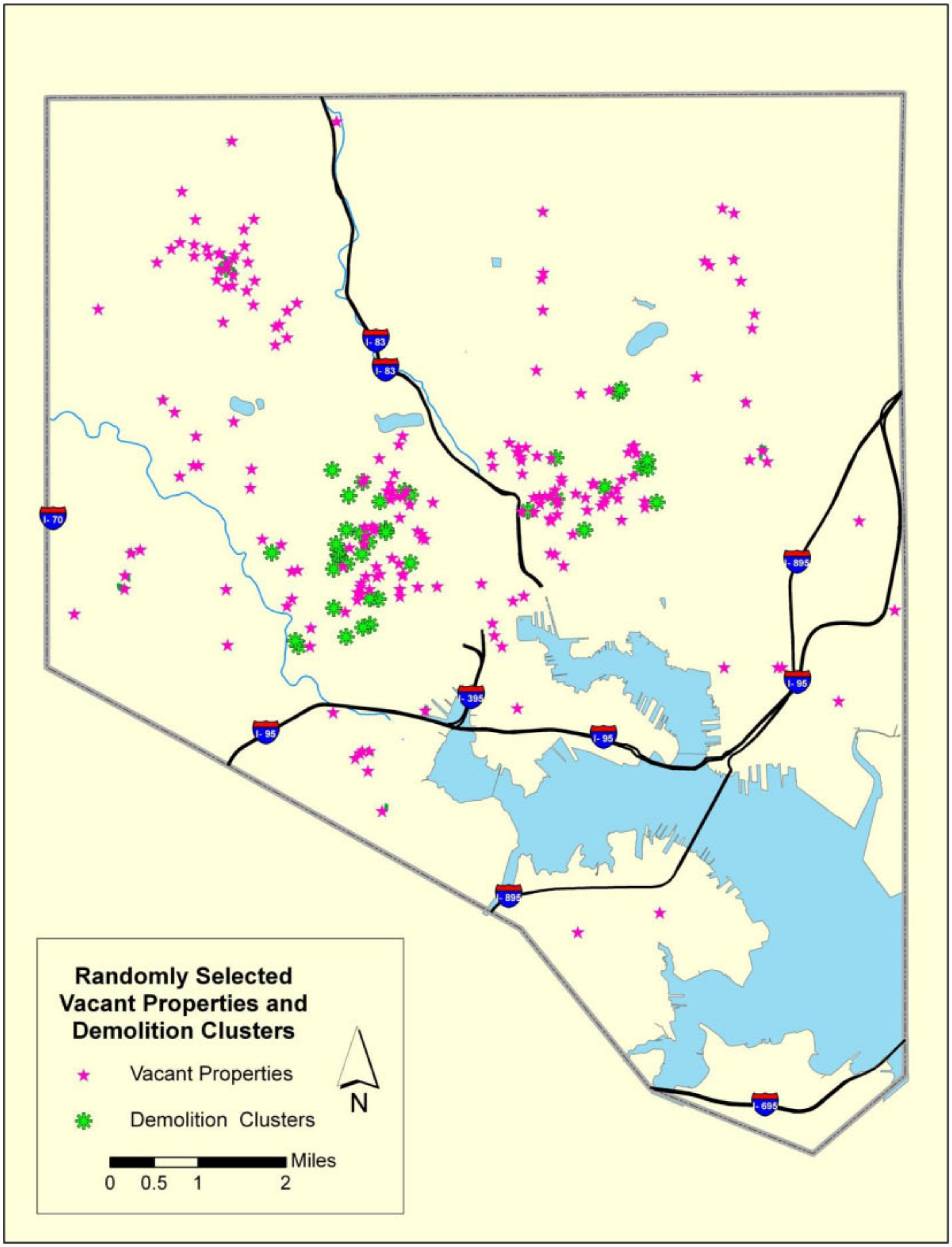

Figure 2. Sites Selected for Field Assessment

<u>Step 3:</u> Conduct field assessments.

The field assessments took place over four days in early April 2013 and were conducted by Center staff while accompanied by City employees (see Table 3).

Table 3. Field Teams

Date	Team	Center Employees	City Employee	City Division
4/2/2013	One	Greg Hoffmann, Reid Christianson	Mark Cameron	Office of Sustainability
	Two	Bryan Seipp, Laura Gardner	Norman Seldon	Dept. of Public Works
4/3/2013	One	Greg Hoffmann, Lisa Fraley-McNeal	Mark Cameron	Office of Sustainability
	Two	Bryan Seipp, Laura Gardner	Norman Seldon	Dept. of Public Works
4/4/2013	One	Greg Hoffmann, Laura Gardner	-	-
	Two	Lisa Fraley-McNeal, Reid Christianson	Norman Seldon	Dept. of Public Works
4/9/2013	One	Greg Hoffmann, Reid Christianson	Mark Cameron	Office of Sustainability
	Two	Bryan Seipp, Laura Gardner	Norman Seldon	Dept. of Public Works

The following details the field assessment procedure used for each vacant property. The procedure also includes general guidelines to help identify appropriate sites for a stormwater practice.

1. Determine if a bioretention area is feasible for the site. Feasibility includes the following considerations:
   a. Is sufficient space for a stormwater practice on site? Approximately 500 square feet is needed. Sufficient space considers the following:
      i. Proper elevation and topography; the site generally must have less than 5% slope.
      ii. No apparent utilities (See Table 4 for Utility Constraints). However, all identifiable utility locations should be marked on concept drawings regardless of their significance to the design. For example, if the location an electric line that will run through a practice is known, it should be documented, even though it may not affect the ultimate feasibility of the practice.
      iii. Greater than 10 feet from a habitable structure.
      iv. No other obvious constraints (such as property being used for a community garden, parking lot, etc.).
      v. The width of the site – a bioretention has 3:1 side slopes for safety and to allow ponding. This means that for every foot of ponding depth, there must be at least 3 feet on each side of the surface filter area.
   b. Is there sufficient drainage area to the practice for a stormwater practice? A minimum drainage area of approximately a quarter acre is desired; measurement is confirmed using GIS. Measurements for the drainage area should also not include extreme modifications to existing conditions, such as blocking upstream catch basins, or conveying water from one side of the road to the other to reach the proposed practice site. If there is sufficient drainage, draw the drainage area on the aerial photo provided with the field form.
   c. Is there at least 3.3 feet of head from the gutter elevation to the storm sewer invert for bioretention construction? This depth is needed to account for the filter media and gravel layers of the bioretention. The underdrain must be able to drain to the catch basin and not pond water.
2. If the answer is 'yes' for Steps a, b, and c, a bioretention practice is feasible and the field form is filled out accordingly.
3. Document marginal constraints, such as fire hydrants or fencing, on the field form.

   a. Existing foundation walls for already demolished buildings should be noted, but will not be considered a major constraint for stormwater practices. The assumption will be made that portions of the walls can be removed to accommodate installation of the practice.
   b. Existing soil types should be noted if apparent, but poor soils will not be considered a major constraint for bioretention practices, since they will be designed with underdrains.
4. If a bioretention practice is not feasible, determine if trees can be planted on the property instead.
5. Determine if impervious cover removal (if any) is possible on site.
6. Photograph the vacant property and inlet (if applicable).

Concept sketches were developed for 19 sites deemed feasible for bioretention that were also identified as good demonstration sites because of their location, ease of installation, and/or ability to treat a large portion of the drainage area. These sketches were developed using CanVis image editing software that simulates what the stormwater practice would look like at the site using a scanned photograph and a library of images that includes plants and other landscaping features. See Appendix D for the concept sketches rendered using CanVis.

Table 4. Utility Field Guide

Utility	Constraint Type	Design Considerations
Fiber Optic/ Communications	Major	• Avoidance is strongly recommended. • Can be very shallow – possibly 2 feet. • Presence should be considered a major constraint, and the project should be disqualified.
Electric to Streetlights	Minor	• Generally will not disqualify a project.
Gas Main	Major	• Avoidance is strongly recommended. • Can be very shallow – possibly 2 feet. • Presence should be considered a major constraint, and the project should be disqualified.
Gas Lateral	Medium	• Usually unavoidable. • Easier to move gas laterals than gas main.
Sanitary Sewer Main	Medium	• Usually deep enough so interference is unlikely.
Sanitary Sewer Lateral	Minor	• Usually unavoidable.
Utility Poles	Minor	• Generally will not disqualify a project.
Water Main	Medium	• Assume existing depth of 42” – 48” to top of pipe. • Avoidance preferred. • Required cover may reduce the allowable ponding depth. • Presence may not be enough to disqualify a project.
Water Lateral	Minor	• Usually unavoidable. • Can typically be lowered if necessary. • In some circumstances, required cover may reduce the allowable ponding depth.

Most of the demolition clusters Baltimore City provided were surrounded by a buffer of adjacent vacant properties that the City wanted to consider when assessing the site. The adjacent vacant properties were both privately and publicly owned, and it was assumed that the vacant buildings outside the demolition cluster could not be removed for purposes of the assessment. Only the vacant buildings within the demolition cluster area were assumed to be removable.

<u>Step 4:</u> Analyze the findings from the field assessments and desktop analysis.

Once field work was complete, post-processing of the data was required in the office, including more accurate calculations of drainage area, impervious cover area, and practice size. The drainage area determined in the field, which includes the practice site, was digitized in GIS based on the aerial photos and planimetric data. The Baltimore City Mayor's Office of Information Technology provided a shapefile of impervious cover of the City. Any impervious cover within the drainage area that was not accounted for in the GIS impervious cover layer, such as sidewalks, was manually added to the impervious cover shapefile. The percent of impervious cover in the drainage area is needed to determine loading amounts. The practice size and impervious cover removal was easily measured in GIS. The size information, the drainage area, and percent impervious cover was then added to the field form.

In order to determine the banking credits and TMDL offsets that each site could provide, the data collected in the field and from GIS was entered into a spreadsheet. The data needed included the size of the site, drainage area, impervious cover in the drainage area, the tree planting area, impervious cover removal, and size of bioretention practice for each site. Some sites had only one practice type such as tree planting, and others had all three. Only the sites with a bioretention retrofit had drainage area information.

Out of the 244 sites (including demolition clusters) that were assessed, 140 were suitable for a stormwater practice. Some sites had multiple practices, e.g. the site was large enough for a bioretention and for tree planting. Table 5 shows the number of sites that had each type of stormwater practice.

Table 5. Number of Sites with Practices (including Demolition Clusters)

Type of Practice	Number of Sites
Tree Planting	103
Impervious Cover Removal	68
Bioretention	58

Looking at the randomly selected sites without the demolition clusters, 104 were suitable for a stormwater practice (see Table 6).

Table 6. Number of Sites with Practices (not including Demolition Clusters)

Type of Practice	Number of Sites
Tree Planting	77
Impervious Cover Removal	37
Bioretention	44

A total of 104 assessed sites (including demolition clusters) did not have any stormwater practice recommended. Table 7 summarizes the reasons why a practice was not identified for these sites. Most were vacant buildings (row homes) that shared a wall with an occupied or privately owned vacant building. In this case, it was assumed that the cost to stabilize the adjacent homes would be too high to justify installing a stormwater practice.

Table 7. Number of Sites without a Practice

Reason for No Practice	Number of Sites	Demolition Clusters	Total
Adjacent to Building(s)	23	1	24
Unsuitable for Practice	18	2	20
Park	13	0	13
Parking	9	1	10
Adopted by Neighbor	9	0	9
Forested	9	0	9
New Development	9	0	9
Community Garden	8	0	8
Sidewalk	2	0	2
Total	**100**	**4**	**104**

Other sites determined to be “unsuitable for practice” meant that the site was too small, too isolated, or located in a desirable redevelopment location such as downtown. Many sites were clearly parks, community gardens, used for parking, or had been “adopted” by a neighbor who added that lot to their yard. New development was evident at some vacant sites, a few with active construction at the time of visit. Sites that were already forested were also assumed to be inappropriate for stormwater management. Figure 3 shows the locations of the sites and identifies which ones could potentially have a stormwater practice.

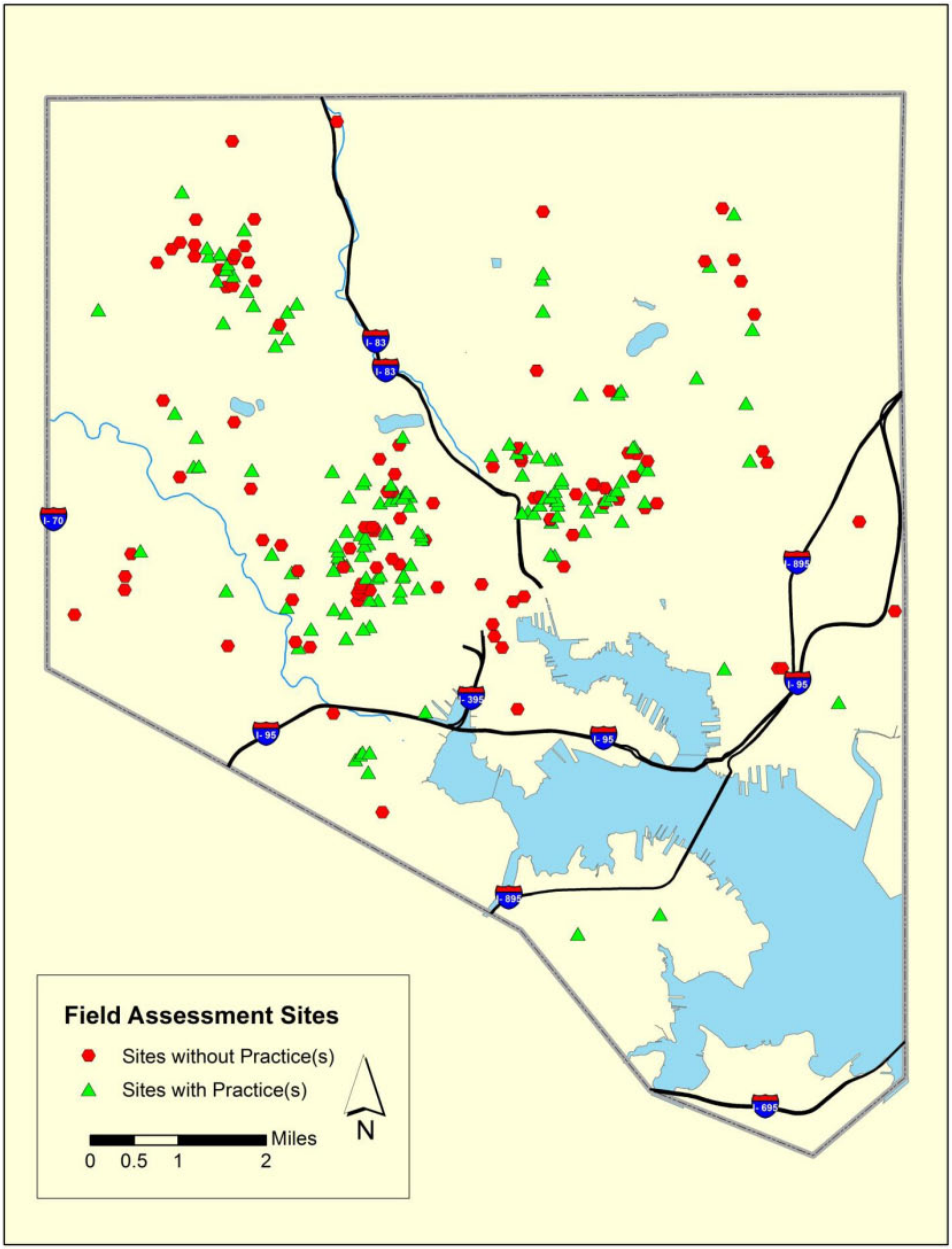

Figure 3. Site Results from Field Assessment

Using extrapolation and statistical analysis, out of the 33,097 vacant properties in Baltimore City, between 11,643 and 13,341 would be suitable for tree planting and between 5,595 and 6,411 would be suitable for impervious cover removal. Out of the 1,767 City-owned vacant properties, between 355 and 407 would be appropriate for bioretention. These values are based upon an assumed 95% confidence level. Table 8 and Table 9 summarize the findings and give a range of the number of sites that could be suitable for a stormwater practice based on the statistical analysis.

Table 8. Number of Potential Bioretention Sites

Vacant Property Type	Number of Sites	Number of Sites Appropriate for Bioretention*
Randomly chosen for site visit	204	44
City-owned vacant properties with appropriate site size, land use, and near a catch basin	1,767	381 (± 26)

*Some sites may have more than one type of practice.

Table 9. Number of Potential Tree Planting and Impervious Cover Removal Sites

Vacant Property Type	Number of Sites	Number of Sites Appropriate for:	
		Tree Planting*	Impervious Cover Removal*
Randomly chosen for site visit	204	77	37
City-owned vacant properties	9,893	3,734 (± 254)	1,794 (± 122)
City-owned and privately-owned vacant properties in Baltimore	33,097	12,492 (± 849)	6,003 (± 408)

*Some sites may have more than one type of practice.

Baltimore City Assessment of Potential Credits

Step 1: *Identify the design standards and calculation methods that apply.*

In this analysis, two different approaches were undertaken – banking credits for new development, and TMDL offsets. For the banking credits, the applicable design standards are described in Chapter 5 of the Maryland Stormwater Design Manual and related documents. For the TMDL offsets, the applicable design standards (pollutant loading rates and removal values) are given by the Chesapeake Bay Program.

Banking Credits

The banking credits available for stormwater practices depend on the amount of impervious cover and the size of the drainage area. The amount of runoff volume captured for a bioretention and impervious cover removal have different rates and are explained below.

Bioretention

Bioretention banking credits are dependent on the amount of impervious cover in the drainage area and the potential size of the practice. In order to effectively treat the runoff entering the bioretention practice, the runoff must pass through the soil media. And as the soil media needs time to filter the runoff, the practice needs a sufficient ponding volume to detain the runoff. Using the Maryland Department of the Environment (MDE) Environmental Site Design (ESD) equation, the amount of runoff produced in the drainage area was found (see Equation 1).

Equation 1. Runoff Volume Produced in Drainage Area

$$ESDv_{DA} = (P_E) \times (R_v) \times (A) \times (43{,}560) \div (12)$$

$ESDv_{DA} =$ Runoff volume (ft^3)
$P_E = 2.70 =$ Rainfall target used to determine ESD goals and size of practice (in)
$R_v =$ the dimensionless volumetric runoff coefficient
$= 0.05 + 0.009(I)$
$I =$ percent impervious cover of the drainage area
$A =$ drainage area (acres)*
$43{,}560 =$ conversion factor from acres to square feet
$12 =$ conversion factor from feet to inches

*The drainage area was limited to include only up to 0.5 acres of impervious cover in order to abide by the guidelines for micro-bioretention.

Equation 2 below modifies Equation 1 for a bioretention. Depending on the size of the drainage area and the space available for a bioretention, the bioretention may not be able to capture all of the runoff. $ESDv_{achieved}$ is the runoff volume captured by the bioretention (see Equation 2). $ESDv_{achieved}$ is similar to Equation 1, but $P_E$is calculated based on a ponding volume that is a percentage of the $ESDv_{achieved}$. Since $ESDv_{achieved}$ changes based on the P_E, it is an iterative process to find the P_E. This iterative process is more fully described in the Maryland Department of the Environment draft document, "Surface Storage Volume Tables for Bioretention, Bioswales, Rain Gardens, and Landscape Infiltration" (MDE 2012). See Appendix E for an example.

Equation 2. Runoff Volume Captured by Bioretention

$$ESDv_{achieved} = (P_E) \times (R_v) \times (A) \times (43{,}560) \div (12)$$

$ESDv_{achieved} =$ Runoff volume captured by bioretention (ft^3)
$P_E =$ Rainfall target used to determine ESD goals and size of practice, based on ponding volume that is a percentage of $ESDv_{\ achieved}$ (in)
$R_v =$ the dimensionless volumetric runoff coefficient
$= 0.05 + 0.009(I)$
$I =$ percent impervious cover of the drainage area
$A =$ drainage area (acres)*
$43{,}560 =$ conversion factor from acres to square feet
$12 =$ conversion factor from feet to inches

*The drainage area was limited to include only up to 0.5 acres of impervious cover in order to abide by the guidelines for micro-bioretention.

Impervious Cover Removal
The impervious cover removal refers to any impervious cover at the site, such as a vacant building or parking area. Both the demolition clusters and randomly selected sites had impervious cover removal opportunities. It is assumed that turf cover will replace impervious cover removed and that the City has D soils; therefore, the runoff curve number (RCN) is changed from 98 to 80 (USDA, 1986). According to Table 5.3 in Chapter 5 of the Maryland Stormwater Design Manual, reducing the RCN from 98 to 80 in D

soils is equivalent to capturing a 1.6-inch rainfall event (MDE, 2000). Equation 3 shows the runoff volume credited for impervious cover removal.

Equation 3. Impervious Cover Removal Volume

$$IC\ Removal\ Volume = (1.6) \times (A_{Removed}) \times (0.95) \times (43{,}560) \div (12)$$

$IC\ Removal\ Volume =$ Runoff volume for impervious cover removal (ft^3)
$1.6 =$ rainfall depth (in)
$A_{Removed} =$ Amount of impervious cover removed from the site (acres)
$R_v =$ the dimensionless volumetric runoff coefficient $= 0.95$
$= 0.05 + 0.009(I)$
$I =$ percent impervious cover of the drainage area
$43{,}560 =$ conversion factor from acres to square feet
$12 =$ conversion factor from feet to inches

The total amount of runoff volume available for banking is shown in Equation 4 below. The spreadsheet uses these equations and found the banking volume possible if the practices were implemented.

Equation 4. Total Banking Volume

$$Banking\ Volume = ESDv_{achieved} + IC\ Removal\ Volume$$

TMDL Offsets

Pollutant loading rates from the Chesapeake Bay Program (CBP) Model were used to calculate TMDL credits for total nitrogen (TN), total phosphorus (TP), and total suspended sediment (TSS), shown in Table 10 (MDE, 2011). It was assumed that tree planting would use the forest land cover and impervious cover removal would use the urban pervious land cover for post-retrofit analysis. These values were used to determine the pollutant loads for each site prior to any stormwater retrofits.

Table 10. CBP Annual Urban Runoff Loads per Acre

Parameter	High Density Urban Impervious	High Density Urban Pervious	Forest Land Cover
TN (lbs)	10.48	9.10	3.16
TP (lbs)	2.01	0.55	0.13
TSS (tons)	0.44	0.07	0.03

For proposed bioretention areas, the Chesapeake Bay Program Stormwater Retrofit Expert Panel (Bahr et al., 2009) runoff reduction graphs were used to determine the percentage of pollutant load removed by the bioretention practice. For ease of calculation, the equations used to develop these graphs were utilized (see Equation 5, Equation 6, and Equation 7 below).

Equation 5. TN Removal Percentage by Bioretention for Runoff Reduction

$$TN\ Removal\ \% = 0.0308x^5 - 0.2562x^4 + 0.8634x^3 - 1.5285x^2 + 1.501x - 0.013$$

Equation 6. TP Removal Percentage by Bioretention for Runoff Reduction

$$TP\ Removal\ \% = 0.0304x^5 + 0.2619x^4 + 0.9161x^3 - 1.6837x^2 + 1.7072x - 0.0091$$

Equation 7. TSS Removal Percentage by Bioretention for Runoff Reduction

$$TSS\ Removal\ \% = 0.0326x^5 - 0.2806x^4 + 0.9816x^3 - 1.8039x^2 + 1.8292x - 0.0093$$

$$x = runoff\ depth\ captured\ per\ impervious\ acre$$

By subtracting the post-retrofit pollutant load from the pre-retrofit load, the total reduction in pollutant load can be found.

<u>Step 2:</u> *Calculate the potential credits available for each identified site and compile credits.*

Table 11 and Table 12 show the potential range of banking volume and TMDL credits available if stormwater practices were installed on all the vacant properties identified in Table 8 and Table 9.

Table 11. Potential Banking and TMDL Credits for Bioretention Sites

Vacant Property Type	# of Sites	# appropriate for bioretention	Impervious Cover Treated in DA Banking* (acres)	Impervious Cover Treated in DA (acres)	Banking Volume (ft^3/yr)	TN Load Reduction (lbs/yr)	TP Load Reduction (lbs/yr)	TSS Load Reduction (tons/yr)
Randomly chosen for site visit	204	44	15	24	111,965	258	51	11
City-owned and appropriate site size, land use, and near a catch basin	1,767	381 (± 26)	130 (± 9)	208 (± 14)	969,814 (± 65,947)	2,235 (± 442)	442 (± 30)	95 (± 6)
	* The drainage area was limited to include only up to 0.5 acres of impervious cover in order to abide by the guidelines for micro-bioretention. This limitation would not apply for calculation of TMDL offsets.							

Table 12. Potential Banking and TMDL Credits for Tree Planting and Impervious Cover Removal

Vacant Property Type	Number	Banking Volume (ft^3/yr)	TN Load Reduction (lbs/yr)	TP Load Reduction (lbs/yr)	TSS Load Reduction (tons/yr)
Randomly chosen for site visit	204	16,494	103	12	2
City-owned	9,893	799,878 (± 54,392)	4,995 (± 340)	582 (± 40)	97 (± 7)
All Vacant Properties in Baltimore	33,097	2,675,990 (± 181,967)	16,711 (± 1,136)	1,947 (± 132)	324 (± 22)

Applicability and Next Steps

Table 11 and Table 12 clearly show that the City of Baltimore's vacant properties represent significant opportunities for the implementation of stormwater practices that could serve as the basis for a stormwater banking system or aid the City in its progress toward meeting its Chesapeake Bay TMDL goals.

Appendix B includes all of the properties that were assessed as part of this project and found to be suitable for a stormwater practice, along with the potential banking volumes and pollutant load reduction. While this list can be used as an initial identification of potential banking sites, it represents just a random sample of the vacant properties in the City. Many more opportunities likely exist that have not yet been assessed. The assessment of other retrofit sites is recommended especially in the sections of the City (south of I-95) where BMP opportunities are limited.

The results of this vacant lot assessment can be useful to developers, Baltimore City, and nonresidential property owners within the City. Below are example scenarios of how the results can be utilized as part of a stormwater banking system:

- Developer A cannot provide stormwater management onsite using LID practices and is in need of 300 cubic feet of stormwater credit. The cost for structural sand filtration practices is prohibitively expensive, so he is looking to build an offsite bioretention practice. After reviewing the spreadsheet in Appendix B, Developer A finds several suitable sites for possible offsite mitigation. Developer A consults with his design engineer to advise him on the most cost-effective site to construct a BMP. Because of economies of scale, Developer A opts to build a project that creates 600 cubic feet of volume and to sell the extra 300 cubic feet as a stormwater credit.

- Similar to Developer A, Developer B is in need of 300 cubic feet of stormwater credit. Rather than building an offsite BMP, Developer B decides that it would be easier to purchase credits and therefore buys the 300 cubic feet of stormwater credit created by Developer A.

- Baltimore City DPW can only meet 4,000 acres of their impervious cover requirement only one year into their MS4 permit. The City opts to purchase a credit that would equate to this requirement (runoff volume can be converted to impervious cover treated or nutrient reduction).

- A nonresidential property owner would like to reduce the cost of her stormwater utility fee. She reviews the spreadsheet in Appendix B and finds several suitable sites nearby in the community to potentially construct stormwater BMPs. She builds several BMPs and takes the allowed reduction to her utility fee. Her BMPs have additional storage volume which she can sell for credit which can also offset the expense of her stormwater utility fee.

References

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Maryland Department of the Environment (MDE), Accounting for Stormwater Wasteload Allocations and Impervious Acres Treated, June (Draft) 2011.

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United States Department of Agriculture (USDA), Urban Hydrology for Small Watersheds, Technical Release 55, June 1986.

Appendices

Appendix A – Task 2 Work Plan

Appendix B – Master Excel Post Processing Spreadsheet

- Lists the vacant properties visited during site assessments that are suitable for stormwater practices.

Appendix C – Field Forms

- Copy of the field forms completed during site assessments over the four days of field work.

Appendix D – Concept Sketches

- Example drawings of stormwater practices of a select number of sites.

Appendix E – Site Visit Example with Calculations

- An example site showing the field assessment process and all calculations found in the spreadsheet.