Chesapeake Bay Program
*Science. Restoration. Partnership.*

**DATE: January 12, 2016**

**TO: Water Quality Goal Implementation Team, and CBP Workgroups including: Forestry, Urban Stormwater, Land Use, Watershed Technical, and Modeling.**

**FROM: Peter Claggett, Coordinator**
**CBP Land Use Workgroup**

**RE: Mapping Adjustments to Forest and Tree Canopy Land Uses for Phase 6**

In October 2014, the WQGIT agreed to the list of land uses proposed for use in the Partnership's suite of Phase 6 models. These land uses included classifying all trees as either "Forest" or "Tree Canopy" with the caveat that the nutrient and sediment loads from "Tree Canopy" are different from those applied to "Forest". In 2014 and early 2015, the FWG and LUWG decided on a definition for both of these mapping units. Also in early 2015, the Forestry Workgroup and Urban Tree Canopy Expert Panel began investigating unique loading rates for the tree land uses and preliminarily determined that unique loading rates would likely be based partly on understory conditions (e.g., turf grass, impervious surfaces, or scrub-shrub). Based on these preliminary findings, in March 2015, the LUWG developed protocols for mapping the various tree land uses.

These protocols were discussed at the January 6th LUWG meeting. Some members expressed concern about the consequences of changing the classification method on the number of acres in each land classification category as well as what would happen if the WQGIT ultimately does not approve tree canopy as uniquely loading land uses. If the CBP Partners do not approve the tree canopy land uses, the loads for areas currently classed as tree canopy will default to the underlying land use (e.g., turf grass, impervious roads, and impervious non-roads). This memo provides an example in Prince George's County, Maryland of how newly proposed methods for mapping forest impact the extent of forest and tree canopy land uses compared to previous approaches.

The WQGIT will make a final decision on the mapping protocol during their January 25th conference call. The CBP Land Data Team will begin implementing the protocol in early February. The LUWG invites your comments on the proposed use of the **P6 Final v3** protocol for mapping "Forests" and "Tree Canopy over Turf Grass" and for dropping the "Tree Canopy over Scrub-shrub" class. Please email you comments to Peter Claggett (pclagget@chesapeakebay.net) by **January 20th**.

**Current Protocol for Mapping Tree Land Uses (P6 Final v1)**

1) Forests
   a) Contiguous patches of trees and shrubs >=1 acre with a minimum internal radius of 36m corresponding to a 1-acre circle and inclusive of adjacent water and wetlands.
   b) Assumed to have an unmanaged and pervious understory.
2) Tree Canopy over Turf Grass

    a) Non-forest trees within "developed" areas (e.g., residential, commercial, industrial, institutional, and recreational land uses, small parcels, and dense Census Blocks).
3) Tree Canopy over Scrub-shrub
    a) Non-forest trees outside "developed" areas
4) Tree Canopy over Impervious Roads
5) Tree Canopy over Impervious Non-roads

**Issues with Mapping Current Forest and Tree Canopy Protocols**

In the process of applying the above forest mapping protocol to recently produced high-resolution land use data for Prince George's County, Maryland, the CBP's Land Data Team found it challenging to rationalize the differences between mapped "Forest" and "Tree Canopy over Scrub-shrub" in many locations. Given that the loading rate for Scrub-shrub and Forest is the same in Phase 6.0, wrestling over which category to place them in seemed unnecessary and young forests are often conflated with Scrub-Shrub anyway. A simpler method for distinguishing Forest from Tree Canopy was tested using the new Prince George's County high-resolution land cover dataset and proved to be more transparent and defensible.

**Protocol for Mapping Tree Land Uses Proposed at 1-6-16 LUWG Meeting (P6 Final v2)**

The availability of high-resolution land cover data across the Chesapeake Bay watershed provides the opportunity to map forests based on local contextual information present in the data. "Impervious Non-Roads" is a class that includes mostly structures, parking lots, sidewalks, and driveways. Trees that are near (not over) these impervious surfaces are not functioning as forests, the underlying soils are commonly compacted and the understory is typically turf grass. Given these assumptions, by applying a small buffer around concentrations of non-road impervious surfaces, one can identify "Tree Canopy over Turf Grass". The CBP Land Data Team explored the potential for consistently mapping dense clusters of non-road impervious surfaces and using those areas to parse trees into two classes: "Forests" and "Tree Canopy over Turf Grass".[1] The proposed new protocol for mapping tree land uses is as follows:

1) Forests
    a) All patches of trees outside dense areas of non-road impervious surfaces
    b) Assumed to have an unmanaged and pervious understory.
2) Tree Canopy over Turf Grass
    a) Trees within densely developed areas
    b) > 140$m^2$ of impervious within a 1-acre circle
3) Tree Canopy over Impervious Roads
4) Tree Canopy over Impervious Non-roads

When comparing this new mapping protocol to the existing method, one can see that in both developed and rural areas, significantly more trees are classed as forests (Figures 1 and 2). Because the new methodology focuses on mapping areas that are not forest, rather than areas that are forest, small gaps in the woods do not affect the forest vs tree canopy distinction. In addition, all scrub-shrub lands are now classed as "open space". In the original method, only small isolated patches of scrub-shrub were classed as open space and

[1] Note that "Tree Canopy over Impervious Roads" and "Tree Canopy over Impervious Non-Roads" are being mapped explicitly as part of the high-res land cover products.

large patches adjacent to large tracts of forests were classed as forests. After examining the aerial imagery underlying the high-resolution scrub-shrub class, however, it appears that most areas mapped as scrub-shrub are herbaceous and not necessarily young forests. In the proposed method, the separation of forest and tree canopy is more logical, plausible, and therefore defensible. Forests do not appear to arbitrarily stop and transition into tree canopy in the middle of the woods.

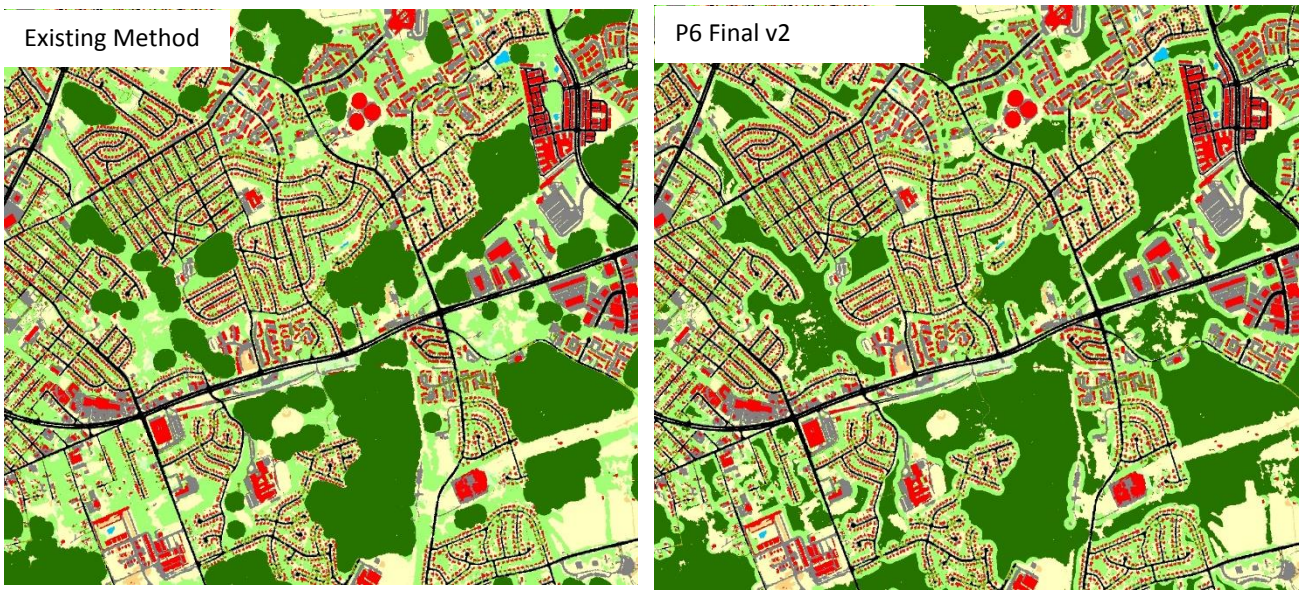


**Figure 1.** Existing (P6 Final v1) vs P6 Final v2 methodology for mapping forests (dark green) and tree canopy over turf grass (light green) in a densely developed area.

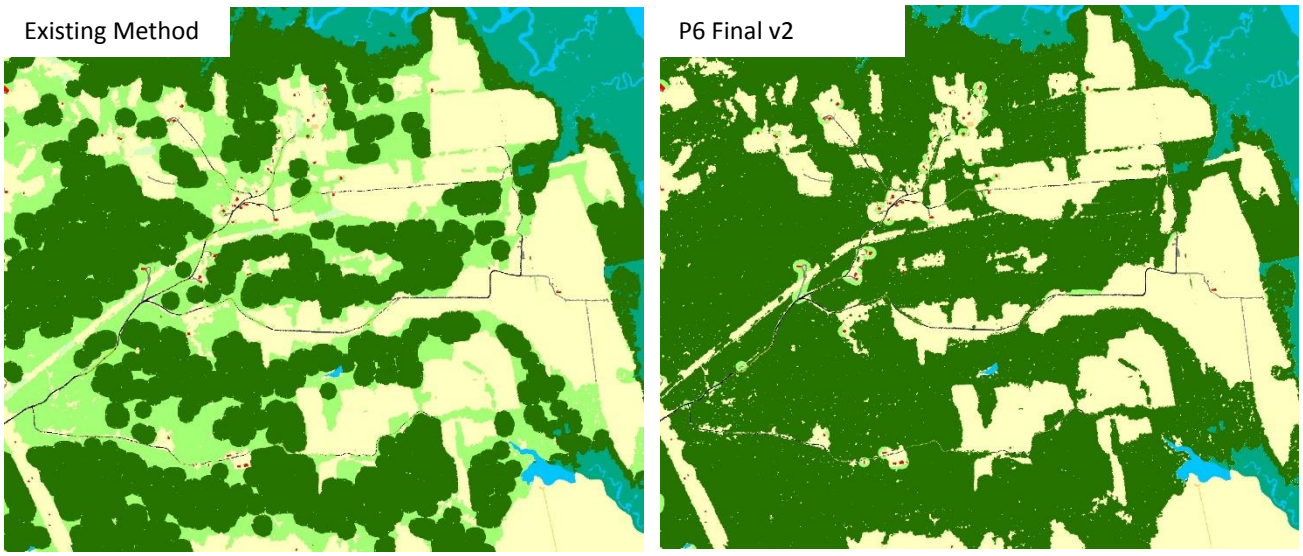


**Figure 2.** Existing vs P6 Final v2 methodology for mapping forests (dark green) and tree canopy over turf grass (light green) in a rural area.

Analysis of the threshold (140m$^2$ impervious area within a 1-acre circle) reveals that the P6 Final v2 method is not very sensitive to the threshold setting and that 140m2 is reasonable (Figures 3a & b). Note how the low values in blue quickly transition to very high values in red (Figure 3b). The yellow transition zone ranges from 100m$^2$ to 160m$^2$ over a span of only 3-10m (less than the width of the canopy for many trees). This analysis is more sensitive to the size of the moving window (1-acre circle). Reducing the moving window size to a half-acre circle reveals a similar narrow transition zone with values ranging from 100m$^2$ to 160m$^2$ (Figure 4a). By reducing the size of the moving window from 1-acre (37m radius) to a half-acre (18m radius), the transition zone shifted ~18m inward towards the structures resulting in a corresponding increase in forest area (Figure 4b). However, this also results in classifying small patches of trees within subdivisions and trees immediately adjacent to structures as forest (blue "islands" in Figure 4b).



**Figure 3a.** Subdivision in Prince George's County.
**Figure 3b.** Overlay of a 1-acre focal window with values representing the total area of impervious surfaces not associated with roads.



**Figure 4a.** Overlay of a half-acre focal window with values representing the total area of impervious surfaces not associated with roads.
**Figure 4b.** Overlay of half-acre focal window on the 1-acre focal window.

To further examine the impact of the focal window size on the extent of forests, three different window sizes were tested (1-acre, ¾-acre, and ½-acre with each thresholded at 140m$^2$) and the extent of tree canopy within each was assessed (Table 1). Figure 5 illustrates the differences in spatial extent between the three different window sizes and illustrates why the difference between the ½-acre (dark red) and ¾-acre (bright red) windows is twice the difference as that between the ¾-acre and 1-acre (white) windows.

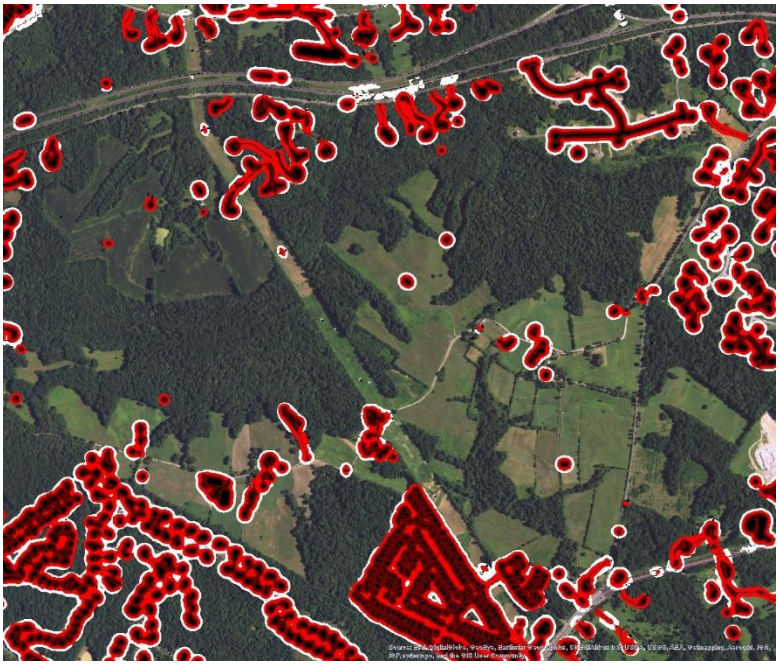

**Figure 5.** Overlay of the ½-acre focal window (dark red), ¾-acre window (bright red), and 1-acre window (white).

**Table 1.** Comparison of "Tree Canopy over Pervious" acreages using different focal windows and ignoring wetlands.

| Window size | 1-acre | ¾-acre | ½-acre |
|---|---|---|---|
| **Tree Canopy over Pervious** | 40,143 | 32,867 | 18,109 |

The 1-acre window captures small patches of trees within dense subdivisions but overestimates tree canopy coverage in rural areas. The ½-acre and ¾-acre windows leave large gaps in dense subdivisions that would be mistakenly classed as forest and the ½-acre window provides only an 8m buffer around structures. To minimize omission errors in the forest class (i.e., classifying forest edges as tree canopy) while minimizing commission errors (e.g., classifying small islands of trees in the middle of a subdivision as forest), one could apply a 1-acre window in densely developed areas and the ½-acre window in rural areas. For the purpose of this exercise, mapping densely developed areas consistently across the watershed using locally provided land use and parcel data is a challenge due to inconsistencies in the way urban land uses and parcel sizes relate to development densities. This challenge can be addressed using the contextual information inherent in the high-resolution land cover data. Larger focal filters (i.e., 10-acre and 100-acre circular moving windows) were applied to the "Impervious Non-Road" class to divide Prince George's County into densely developed and non-densely developed areas. Based on visual inspection, the 10-acre window proved most successful for mapping densely developed areas (Figure 6). Using this dataset, a 1-acre window was applied within densely developed areas and a ½-acre window applied to non-densely developed areas. The ¾-acre window was also used to further refine the transition from tree canopy to forests along the outer edges of densely developed areas. For sake of discussion, this proposed method is called "P6 Final v3" (Figure 7).

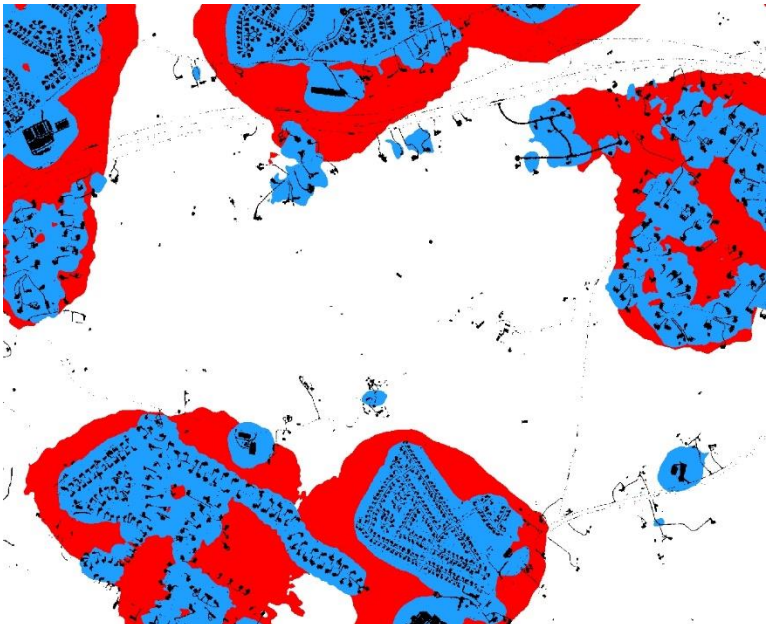

**Figure 6.** Overlay of a 10-acre focal window with > 3000m$^2$ impervious surfaces (blue) on a 100-acre focal window with > 18,000m$^2$ of impervious surfaces (red). Both were thresholded to maximize separation between densely developed and non-densely developed areas.

**Figure 7.** Example result from the final proposed method, P6 Final v3, for mapping forests (dark green) and tree canopy over turf grass (light green).

Tree Land Use Mapping Protocol (**P6 Final v3**)

1) Forests
   a) All patches of trees outside dense areas of non-road impervious surfaces.
   b) Assumed to have an unmanaged and pervious understory.
2) Tree Canopy over Turf Grass
   a) Trees within densely developed areas.
   b) > 140m$^2$ of impervious within a 1-acre circle within densely developed[2] areas and >140m$^2$ of impervious within a ¾-acre circle along the edges[3] of densely developed areas.
   c) > 140m$^2$ of impervious within a ½-acre circle outside densely developed areas.
3) Tree Canopy over Impervious Roads
4) Tree Canopy over Impervious Non-roads

Comparing the extent of pre-BMP tree land uses in Prince George's County across different watershed model land use versions provides an example of how the availability of high-resolution land cover data combined with different mapping protocols impacts the estimates of the extent of trees on the landscape (Table 2). Woody wetlands were included in the forest area estimates to enable an apples-to-apples comparison across land use versions. The approximate year represented for each of these estimates is provided for information purposes but has little impact on the magnitude of the estimates. All Phase 6 datasets and methods yield more tree cover than was estimated for Phase 5.3.2 but this difference is mainly due to areas classed as turf grass or impervious in P5.3.2 that will be classed as "Tree Canopy over Turf Grass" or "Tree Canopy over Impervious" in Phase 6. The differences between P5.3.2 and P6a are fairly minor and can be explained by the use of the National Land Cover Dataset (NLCD) fractional tree canopy dataset to represent tree cover in place of the NLCD categorical land cover data used in P5.3.2. MDE and MDP used 2011 1m-resolution tree cover data, planimetric impervious surface data, and our current forest mapping protocol to produce their estimates.

**Table 2. Comparison of Forest and Tree Canopy Acreage Estimates for Prince George's County.**
The current method P6 Final v1 is highlighted in blue and the proposed method, P6 Final v3, is highlighted in red.

| | P5.3.2[4] | P6a (national)[5] | P6b (MDE)[6] | P6 Final v1[7] | P6 Final v2[8] | P6 Final v3 |
|---|---|---|---|---|---|---|
| **Year** | **2010** | **2011** | **2011** | **2013** | **2013** | **2013** |
| **Forest + Woody Wet.** | 130,619 | 113,370 | 125,119 | 104,040 | 126,518 | 134,822 |
| **TC over Pervious** | n/a | 27,548 | 31,658 | 62,541 | 40,063 | 31,759 |
| **TC over Impervious** | n/a | 1,698 | 4,177 | 6,020 | 6,020 | 6,020 |
| **Total Tree Cover** | 130,619 | 142,616 | 160,955 | 172,601 | 172,601 | 172,601 |

[2] Local context afforded by the high-resolution imagery was used to consistently map and define "densely developed" areas as areas with >3000m$^2$ of non-road impervious surfaces within a 10-acre circle.
[3] Edges of densely developed areas were identifying by expanding non-densely developed tree covered areas inward to the boundary of ¾-acre window with >140m$^2$ non-road impervious surfaces.
[4] Phase 5.3.2 forest land use includes harvested forest which was estimated to be approximately 1% of the total forest area.
[5] This dataset was developed for use in the summer 2015 practice calibration and was based on nationally available datasets (e.g, 2011 National Land Cover Database)
[6] MDE and MDP land use as delivered to CBPO on 9/14/15. Forests exclude 15,900 acres of forested wetlands.
[7] The existing forest protocol includes 1,189 acres of scrub-shrub.
[8] Interim method proposed during the January 6th LUWG call