Land Use Methods & Metrics Development Outcome

Management Strategy

2015–2025, v.3

Photo Sources: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, FSA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

I. Introduction

To minimize the extent, and mitigate the effects of land conversion, local decision-makers and the land conservation community need to be informed about: 1) land cover and use changes that affect wildlife and stream habitats, watersheds, and human communities; and 2) policy options, incentives, and tools to reduce the rate and magnitude of land conversion. To address the first part of this strategy, the Land Use Methods and Metrics Development Outcome calls for monitoring and reporting on the rates of farmland, forest and wetland conversion and the rate of impervious surface change at a local scale relevant to land use decisions. The Metrics Outcome will help inform outreach efforts and products developed as part of the Land Use Options Evaluation Outcome which will address the second part of this strategy.

The intent of the Metrics Outcome is to develop a method and metrics to monitor the conversion of valued natural and working landscapes, such as forests, wetlands and farms and to better understand the impacts of land conversion. Natural and working landscapes provide ecosystem services of value to the Chesapeake Bay and its population including water quality and quantity, habitat, recreation and food production.

II. Goal, Outcome and Baseline

This management strategy identifies approaches for achieving the following goal and outcome:

Goal

Conserve landscapes treasured by citizens in order to maintain water quality and habitat; sustain working forests, farms and maritime communities; and conserve lands of cultural, indigenous and community value.

Outcome

Continually improve the knowledge of land conversion and the associated impacts throughout the watershed. By 2016, develop a Chesapeake Bay watershed-wide methodology and local level metrics for characterizing the rate of farmland, forest and wetland conversion, measuring the extent and rate of change in impervious surface coverage and quantifying the potential impacts of land conversion to water quality, healthy watersheds and communities. Launch a public awareness campaign to share this information with citizens, local governments, elected officials and stakeholders.

Baseline and Current Condition

The temporal baselines for the outcome are the years 2013 (New York, Pennsylvania, District of Columbia, Delaware, and Maryland) and 2014 (Virginia, and West Virginia) for which 1-meter resolution land cover and land use data exist for all counties intersecting the Bay Watershed. "Hot spots" of land change will be monitored every two years while complete wall-to-wall remapping of the watershed counties will occur every four years (2017/18, 2021/22).

The economy, consumer preferences, and public investments influence the decisions of private developers and businesses which in turn influence the migration of people seeking jobs and amenities resulting in both commercial and residential growth. These factors, however, can be unpredictable and volatile as witnessed in the steep decline in new housing starts from 2006-2009 following the housing boom. Therefore, measured rates of land conversion should be interpreted in context, relative to measures of economic activity such as population and employment growth and episodic large-scale infrastructure projects.

III. Participating Partners

The following partners have pledged to help implement this strategy:

- Chesapeake Bay Commission
- Local Government Advisory Committee
- Water Quality Goal Implementation Team
- Habitat Goal Implementation Team
- Healthy Watersheds Goal Implementation Team
- Maryland Department of Planning
- Pennsylvania Department of Community and Economic Development
- U.S. Geological Survey
- USGS National Geospatial Program
- The Chesapeake Conservancy

Local Engagement

To assist in quantifying impacts on communities, the Land Use Workgroup will work with the Local Government Advisory Committee (LGAC) and the Local Leadership Workgroup to identify local governments interested in better understanding local rates of, and impacts from, land conversion, and in using new tools for better managing the rates and impacts from land conversion. Local government stakeholders are needed to advise the Chesapeake Bay Program on the development of the methodology and local level metrics, and in quantifying potential impacts.

IV. Factors Influencing Success

The following are natural and human factors that influence the Bay Program's ability to attain this outcome:

- The CBP Management Board has interpreted the Outcome language as calling for the development of separate metrics for forest, farm, and wetland conversion in addition to measuring the rate of impervious surface change. For example, addressing this Outcome will require metrics that account for conversions from forests to farms and from farms to forests, in addition to conversions of both forests and farms to development.
- Sustainability of long-term monitoring. This factor is a question of political will more than technological capabilities. Over the next six years, this is only a minor factor because in 2018, the CBP Partners awarded a six-year cooperative agreement to the Chesapeake Conservancy for geospatial support that includes mapping high-resolution land cover and land use for all watershed counties every four years.
- Methodology for assessing landscape change with high-resolution data with sufficient precision to inform county-level decisions. Techniques to separate actual change in land cover from background noise and sources of confusion are rapidly advancing but are not sufficiently established to make this a non-issue. To accurately track change, updates to existing high-resolution land cover and land use datasets will be required during each 4-year remapping phase. This will ensure that the data for 2013/14 are consistent with and directly comparable to the data for 2017/18 and those for 2021/22.

- Methodology to quantify impacts to communities and the environment. The quantification of impacts from land conversion to communities and the environment needs to be explored in more detail and with input from local governments. Quantification of impacts without sufficient context for interpreting those impacts may lead to false conclusions.

V. Current Efforts and Gaps

The term “land cover” refers to a wall-to-wall classification of land surface characteristics into categories such as impervious surfaces and tree canopy. Land cover classifications are derived from aerial and satellite spectral imagery collected from passive sensors. These classifications can be enhanced by incorporating data from active sensors. Since the late 1990’s, the Bay Program has relied on 30m-resolution Landsat satellite derived land cover data to provide a spatially consistent representation of Chesapeake Bay watershed conditions to inform the suite of models used for management purposes and for tracking changes on the landscape. The U.S. Geological Survey (USGS) has recently produced annual 9-class land cover data derived from Landsat imagery for the conterminous United States for the period 1985 – 2019. In addition, the USGS has produced more detailed, 16-class, land cover classifications for the years 1984, 1992, 2001, 2004, 2006, 2008, 2011, 2013, 2016, and 2019 (to be released in late 2021). These data are invaluable for highlighting “hot spots” of change, but they can largely miss the development of 2-lane roads and low-density residential areas. While these data have an overall accuracy around 80%, this is likely insufficient for monitoring change at a scale relevant to county-level decisions every 3-5 years.

Throughout the 2000’s to the present day, counties, states, and the United States Department of Agriculture’s (USDA-FSA) Farm Service Agency have acquired high-resolution (<=2m) imagery to inform transportation, public works and natural resource decisions. Initially, these data were acquired as natural color images and used as pictures rather than analyzed as data. This practice has gradually evolved through the development of object-based feature extraction software, such as Feature Analyst, ENVI, and eCognition as well as the acquisition of imagery with a near-infrared spectral band in addition to the three visible bands. The near-infrared band enhances the ability to distinguish vegetation from non-vegetated areas.

At present, USDA-FSA collects four-band leaf-on one-meter resolution ortho-imagery for each state as part of their National Agriculture Imagery Program (NAIP) every 1-3 years. Collection dates are cyclic and vary due to the availability of state cost-share funds and other factors. In addition, the Virginia Institute of Marine Science (VIMS) collects and manually classifies black and white aerial photographs along the near-shore areas of the Chesapeake and Coastal Bays to support their annual inventory of submerged aquatic vegetation (SAV) extent and density. Some states and localities acquire sub-meter leaf-off imagery every 3-5 years to support transportation and planning needs. Leaf-on imagery is better for detecting vegetation and leaf-off imagery is better for detecting impervious surfaces and water features which may be obscured by the canopy during the growing season. Leaf-off imagery is mostly collected during the spring, but the collection years often vary by state.

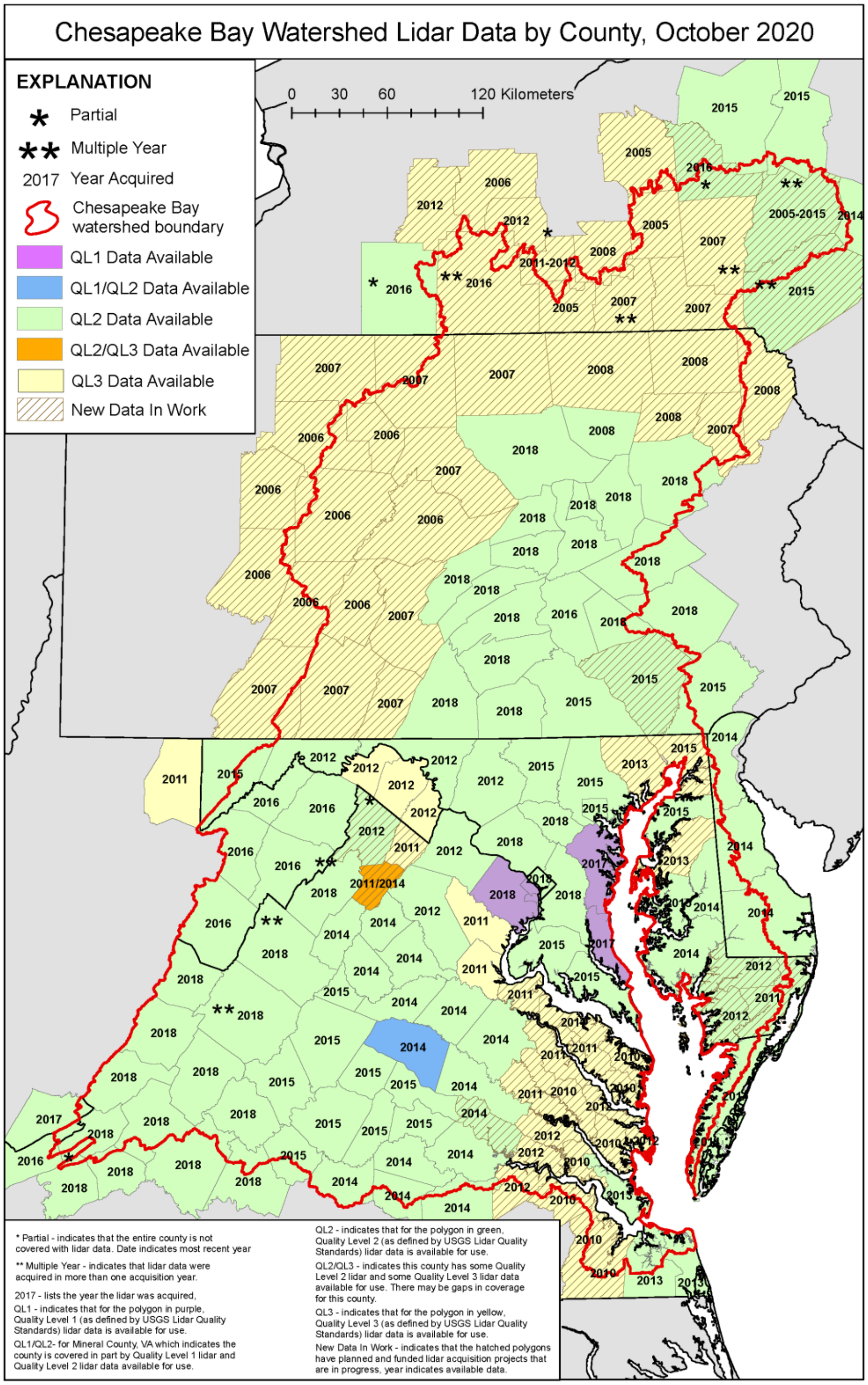

Figure 1. Status of LiDAR data acquisitions in 2020. QL1-3 refer to data Quality Levels that influence the spatial resolution and accuracy of the final product. For an updated status map, see: http://gis.chesapeakebay.net/lidarstatus/. For more information on LiDAR specifications, see: https://pubs.usgs.gov/tm/11b4/pdf/tm11-B4.pdf

LiDAR (Light Detection and Ranging) refers to a high-resolution (<=2m) active airborne sensor that emits pulses of light in near-infrared (topographic LiDAR) and/or blue-green (topo/bathymetric LiDAR) wavelengths. These pulses are directed towards the ground, reflect off surfaces (i.e., buildings, leaves, branches, pavement, dirt), and return to the sensor. The time it takes for the pulses to be detected is recorded and correlated with the travel distance or "range" of each pulse. Because the exact location of the airplane in three-dimensional space is known, travel distances can be converted to elevations revealing a wealth of information about vegetation height, structure, biomass, and ground surface characteristics. As of October 2020, LiDAR imagery has been collected on mostly a county-by-county basis at least once (occasionally twice or three times) for approximately 100% of the Bay watershed counties with dates varying from 2004 - 2018. By winter 2021, LiDAR data will exist for all watershed counties (Figure 1).

There are different types of airborne LiDAR (e.g., waveform, discrete return, pulse width, and photon counting) which are not discussed here. The LiDAR data characteristics most relevant to the CBP needs are spatial accuracy, vertical accuracy, and penetration through water. Accuracies are influenced partly by the height and speed of the plane and frequency of pulses. The National Digital Elevation Program has developed a convention for characterizing the quality of elevation datasets. Most of the LiDAR elevation data currently available in the Chesapeake Bay watershed are classed as either Quality Level 2, "QL-2" (nominal pulse density of ≥ 2.0 pls/m^2; 10 cm vertical RMSEz) or "QL-3" (nominal pulse density of ≥ 0.5 pls/m^2; 20 cm vertical RMSEz). The QL-2 products have sufficient accuracy to produce a 1m resolution Digital Elevation Model (DEM) or Digital Surface Model (DSM) whereas the QL-3 products only support the production of a 2-3m resolution derivative products. Quality Level 1, "QL-1", data are now available for three jurisdictions and have nominal pulse density of ≥ 8.0 pls/m^2; 10 cm vertical RMSEz. These LiDAR products have mostly been collected using laser pulses with near-infrared wavelengths that cannot penetrate through water. Surface waters are depicted as flat, constant elevation surfaces similar to some building and pavement surfaces. Bathymetric and topo-bathy LiDAR instruments emit pulses in the blue-green wavelength that can penetrate water surfaces up to depths of 1- 10 meters depending on water clarity. Submerged surface elevations are also more accurate if the substrate is hardened (e.g., oyster bed) vs. soft (e.g., mud).

Coupling LiDAR data with high-resolution spectral imagery has proven very useful for improving the accuracy of semi-automated land cover classifications (e.g., differentiating buildings from parking lots and forests from scrub-shrub and herbaceous vegetation). The more data informing a classification (e.g., # of spectral bands, elevation and biomass data, parcels, and land use), the more automated the process can become to produce an accurate product. The costs of production are generally positively correlated with the degree of automation, yet all products require some level of manual editing to increase overall and individual class accuracies above 90%.

In 2015, 1-meter land cover data were produced for the entire Bay watershed (including all adjacent counties) using a combination of 2013/14 leaf-on NAIP imagery, available state or county leaf-off imagery, and a Digital Surface Model (1st return indicating the tops of surfaces) derived from LiDAR.[1] In 2016, the land cover data was translated into 1m land use by the CBP GIS Team.[2]

The Metrics Outcome calls for "continually improving the knowledge of land conversion" which requires attention towards monitoring land change rather than just mapping land cover once or periodically. Assessing and mapping land use and cover change from high-resolution imagery is challenging but holds

[1] https://chesapeakeconservancy.org/conservation-innovation-center/high-resolution-data/land-cover-data-project-2/
[2] https://chesapeakeconservancy.org/conservation-innovation-center/high-resolution-data/land-use-data-project/

great promise for meeting the objectives of this outcome. Changes in spectral surface properties over multi-date images, however, introduce a lot of noise into interpretations of change. Sources of noise might include variations in sun-angle, atmospheric conditions, vegetation phenology, and infrastructure materials and aggregates. Image properties can also vary from one image tile to another and from one year to another. These problems limit the ability to track subtle changes in land cover at high-resolution such as changes in the types of agriculture (pasture vs cropland) and evidence of secondary succession (e.g., low vegetation to scrub-shrub). Changes which are readily apparent in high-resolution imagery include new structures, roads, and other forms of impervious cover and the presence/absence of tree canopy.

VI. Management Approaches

There are three elements to the Metrics Outcome:

1. Monitor the rates of impervious surface change and conversion of forests, wetlands and farmland.
    - High-res land use change: 2013/14 – 2017/18 – 2021/22
    - Note: change detection for tidal and non-tidal wetlands is not yet financially feasible at the watershed scale given the lack of tide-corrected LiDAR and aerial imagery and the inability to remotely-sense facultative and obligate wetland vegetation using freely available imagery.
2. Quantify the impacts of land conversion on:
    a. Water quality
        - Total Nitrogen Edge-Of-Stream Load (kg/yr)
        - Total Phosphorus Edge-Of-Stream Load (kg/yr)
        - Total Suspended Sediment Edge-Of-Stream Load (kg/yr)
        - Total Nitrogen Edge-Of-Tide Load (kg/yr)
        - Total Phosphorus Edge-Of-Tide Load (kg/yr)
        - Total Suspended Sediment Edge-Of-Tide Load (kg/yr)

    b. Healthy watersheds (local and accumulated downstream aerial estimates)
        - Natural Cover, e.g., trees, wetlands, water (% area)
        - Tree Canopy (% area)
        - Tree Canopy in the 30-meter Riparian Zone (% area)
        - Impervious Cover (% area)
        - Agriculture (% area)

    c. Communities (emphasis on under-represented and economically vulnerable populations)
        - Natural Cover, e.g., trees, wetlands, water (% area)
        - Tree canopy (% area)
        - Tree Canopy in the 10-meter Riparian Zone (% area)
        - Impervious Cover (% area)
3. Communicate results to the public, elected officials and to the Bay Program.

In February 2018, the U.S. Environmental Protection Agency's Chesapeake Bay Program Office issued a Request for Proposals to provide "geospatial analysis support for the CBP partnership in support of the targeted implementation of actions in support of reaching the goals and outcomes of the 2014 Chesapeake Bay Watershed Agreement. In the summer of 2018, a six-year, $7.5 million Cooperative Agreement was awarded to the Chesapeake Conservancy (CC). Funding for this RFP was provided at the sole discretion of USEPA and subject to the availability of funds on an annual basis. It's important to note that this is a Cooperative Agreement and not a contract or grant. This is critical because it allows the CBP Partners to actively participate in the development of products and enables adjustments to the scope to address evolving technology and partnership needs.

The successful proposal consists of four objectives, the first of which involves the production of comparable land cover and land use data for the years 2017 and 2021, an accuracy assessment, and corrections to the existing 2013 land use data so that is directly comparable with the data produced for 2017 and 2021. The estimated total cost of this first objective is $4 million, distributed over six years. The CC subcontracted with the University of Vermont's Spatial Analysis Laboratory to produce the 12-class land cover data while the CC leads the development of the 60-class land use data. Land cover and land use data are being developed for all 206 counties intersecting the Bay watershed which equates to a 100,000 square mile area (note that the watershed is 64,000 square miles). The decision to include full-county coverage was made to ensure that the data would be useful for county-level decisions as called for by this Outcome.

In addition to these three dates of high-resolution land cover and land use data, the USGS is developing a historical estimate of land use change from the mid-1980's to present using tax parcel information coupled with the USGS' newly released Land Change Monitoring, Assessment, and Projection data (https://www.usgs.gov/core-science-systems/eros/lcmap). This analysis will be conducted in 2022 to provide a more accurate historical perspective on land conversion rates.

The production of "land cover" involves the direct classification of aerial imagery based on the spectral properties of the imagery and height information derived from LiDAR. Land cover represents the surface characteristics of the land such as impervious cover, tree canopy, herbaceous, and barren classes. In contrast, "land use" represents how the land is used (e.g., turf grass, cropland, timber harvest, etc.). Producing land use from land cover data requires a variety of ancillary datasets (e.g., tax parcels, abandoned mine lands, solar panel arrays, landfills, and quarries) combined with spatial rules that leverage the contextual information inherent in the high-res land cover data. For example, "forest" land use is defined as patches of trees larger than 1 acre with a minimum width of 72m and further than 10-20 meters from structures.

These data are foundational, authoritative, and transformative to the Bay restoration effort. They are foundational because they inform most outcomes in the 2014 Agreement and will serve as the basis for developing the next generation of watershed models. They are authoritative due to their accuracy and transparency; any person viewing the data can recognize features and areas of interest and compare them to their local knowledge. They are transformative because they will ultimately change the way restoration and conservation actions are implemented, enabling both to be targeted at a fine scale to locations where they will be most effective. Moreover, establishing accurate trends in impervious cover, forests, and tree canopy will enable the CBP Partners to improve the efficiency and effectiveness of stormwater and forest management activities.

Quantifying the impacts of land conversion on water quality will be accomplished through processing the high-resolution land use data in the Chesapeake Assessment Scenario Tool (CAST) in coordination with the CBPO's Modeling Team. Quantifying the impacts of land conversion on healthy watersheds will be accomplished by incorporating the land use change data into the Chesapeake Healthy Watersheds Assessment in close coordination with the Habitat and Healthy Watersheds Goal Implementation Team. Assessing the impacts of land conversion on communities will be coordinated with the Healthy Watersheds Goal Implementation Team, Forestry Workgroup, and Diversity Workgroup. Initial attention will be given on focusing on under-represented and economically vulnerable populations. Note that while residential and commercial development is often viewed as a negative environmental indicator, it can be a positive economic one, particularly for under-represented and economically vulnerable populations.

Approaches Targeted to Local Participation

The Land Use Workgroup will work with the CBP Local Engagement Team and Healthy Watershed Goal Implementation Team to develop a common strategy for communicating information on land use change and it's impacts on water quality, watersheds, and communities. The strategy will involve identifying and facilitating communication among target audiences, trusted sources, translators, and subject matter experts. Several targeted audiences have already been identified for these data including land trusts, watershed organizations, stormwater managers, County planners, and local elected officials.

Cross-Outcome Collaboration and Multiple Benefits

Restoration and conservation efforts in the watershed will benefit from the availability of high-resolution land cover and elevation data produced every 2-4 years. The data will inform goals outlined by the Bay Program's GITs and inform almost all of the outcomes specified in the Chesapeake Bay Watershed Agreement—particularly the Vital Habitats, Healthy Watersheds, and Land Conservation Outcomes. Specific benefits include:

- Characterizing, mapping, and tracking of wetlands, riparian forest buffers, forests and impervious surfaces;
- Characterizing, mapping, and tracking habitat conditions;
- Developing habitat suitability maps;
- Prioritizing and targeting restoration, conservation, education and public access efforts;
- Understanding the effects of management actions on water quality;
- Verifying riparian buffer and urban tree canopy Best Management Practices;
- Verifying the effects of Land Policy BMPs;
- Assessing the vulnerability of watersheds and stream restoration BMPs to altered flow regimes;
- Improving the accuracy of nutrient and sediment load estimates; and
- Educating people on the value and location of high-functioning landscapes

VII. Monitoring Progress

N/A

VIII. Assessing Progress

Progress in developing the methods and metrics will be assessed annually by the Land Use Workgroup and will be based on the feasibility and accuracy of the derived metrics and impact measures. Following development and approval of the metrics, they will be reassessed every 2-4 years corresponding to the receipt of updated land cover information.

IX. Adaptively Manage

The 2013-2017-2021 datasets only cover an eight-year period which constrains our ability to interpret trends and patterns and relate them to drivers of change and impacts which is the purpose of the Land Use Methods and Metrics Outcome. This data series needs to be continued through 2029 to fully leverage their transformative potential. The addition of land cover and land use data for the years 2025 and 2029 will enable the CBP Partners to examine longer-term trends and compare them with changes in management actions, stream flow, stream temperature, water quality, and species diversity. The total cost of extending the land data series through 2029 is expected to be $4 million.

While measuring current rates of land conversion will require use of existing imagery and data which varies in spatial resolution, accuracy and temporal currency, significant improvements in derived metrics and cost savings to local, state and federal government agencies could be achieved through a coordinated effort to synchronize the acquisition of imagery and agree on a classification schema and change detection approach.

X. Biennial Workplan

Biennial workplans for each management strategy will be developed by April 2016. The Land Use Methods and Metrics Development Workplan is expected to include the following information:

- Key actions
- Timeline for the action
- Expected outcome
- Partners responsible for each action
- Estimated resources