Chesapeake Bay Land Change Model (CBLCM v7)
Frequently Asked Questions

1. What is CBLCM?

The CBLCM is a U.S. Geological Survey computer model that spatially simulates the amount, in acres, and pattern, as patches, of future residential and commercial development within a county based on external population and employment projections. The simulation process is iterative, repeating 101 times with the results aggregated and averaged within user-specified overlay units (e.g., watersheds, catchments, Census Tracts). For each iteration, the CBLCM estimates future impervious and pervious development; conversion of natural and agricultural lands; population served by sewer and septic systems; and the number of individual septic systems.

2. What are the CBLCM base assumptions?

a. Residential and commercial development are driven by increases in housing and employment respectively.
b. Current (year 2020) housing vacancy rates remain constant in the future.
c. The relationship between housing, employment, and development is governed by infill/redevelopment, recent development patterns, and development densities.
d. Infill/redevelopment percentages remain constant in the future.
e. Future development will be as dense or denser than current development.
f. Future patterns of growth will generally resemble current patterns.
g. Lands within one kilometer of current sewer service areas are likely to be served by sewer in the future.
h. Only small secondary roads associated with residential housing development are estimated as a component of future growth. Widening of existing roads and new major roads are not considered.

3. How can jurisdictions review and critique CBLCM results?

CBP's Geospatial Science and Applications Team has developed a data viewer for CBLCM results. Initial draft results of the CBLCM for the year 2050 are currently posted and the viewer will be updated as results are revised. The viewer includes 1-km^2 hexagon representations of future development patterns, a land suitability layer, and county summary data with attributes on annualized observed and simulated rates of change. Some questions one might ask when looking at the data are:

Why is there no growth projected in a county?

- View the "County Results" layer (aka make it visible) and hit the home icon (upper left) and view the "Increase in Development based on Historic Trends" layer. Left click on any county.
- Note the difference between observed and simulated housing and residential area change and jobs and commercial area change. If simulated residential and/or commercial area

change is zero, then population and employment in the county are projected to remain stable or decline resulting in no simulated growth.
- Changing this base assumption in the model would require revisiting how we estimate demand for growth.

Why is there so little growth projected in a county?
- View the “County Results” layer (aka make it visible) and hit the home icon (upper left) and view the “Increase in Development based on Historic Trends” layer. Left click on any county.
- Note the difference between observed and simulated housing and residential area change and jobs and commercial area change. Lower than expected growth is evident if observed and simulated rates of housing and/or jobs are similar but observed residential and/or commercial area change is significantly greater than simulated residential and/or commercial area change.
- Lower than expected amounts of simulated growth are caused by high rates of infill/redevelopment, high development densities, or in rare cases- limited land suitable for growth.

Why is there so much growth projected in a county?
- View the “County Results” layer (aka make it visible) and hit the home icon (upper left) and view the “Increase in Development based on Historic Trends” layer. Left click on any county.
- Note the difference between observed and simulated housing and residential area change and jobs and commercial area change. Higher than expected growth is evident if observed and simulated rates of housing and/or jobs are similar but observed residential and/or commercial area change is significantly lower than simulated residential and/or commercial area change.
- Higher than expected amounts of simulated growth are caused by low rates of infill/redevelopment, low development densities, and abundant suitable land for development.

Why is growth projected to occur in places where it should not occur?
- Overlay the “Simulated 2050 Growth” layer over the “Suitability for Development” layer. Make the Suitability 50% transparent (double box icon) and show the aerial imagery (lower left).
- Note how the yellow areas (projected growth) are located within the suitable areas (red).
- Corrections to the suitability layer require updated or additional data on public and protected lands, current land use, new data or new decision rules relevant to land suitability for development.

Why are the patterns of projected growth so dispersed?
- View the “Simulated 2050 Growth” layer and/or the “Increase in Development based on Historic Trends” layer.
- Dispersion is caused by large amounts of land available for development with minimal differentiation (low gradients) of residential and/or commercial probabilities.
- Adjusting dispersion requires the addition of new significant explanatory variables in the logistic regression equations used to estimate development probabilities, mathematical

transformations of the probability layer, new statistical and/or machine learning approaches for estimating development probabilities, and/or the exclusion of additional land from the suitability layer.

4. Why was the CBLCM developed?

Development of the CBLCM began in the late 2000's, motivated by the need to inform land conservation decisions with information on the vulnerability of lands to future development and recognition of the limitations of existing regional-scale land change models. The CBLCM was designed to produce plausible future growth projections driven by population and employment and to be customizable, allowing alteration of infill/redevelopment rates, residential and commercial densities, and land suitability to create alternative future scenarios to inform local land-use plans.

The CBLCM was repurposed in preparation for the Phase 6 Mid-point Assessment of the Chesapeake Bay Total Maximum Daily Load (TMDL). In 2017, the Chesapeake Bay Program (CBP) partnership's Principals' Staff Committee (PSC) approved the jurisdictions' use of the 2025 projected "Current Zoning" baseline scenario to account for growth (e.g., future change in land uses and animal and human populations) in the development and implementation of the jurisdictions' Phase III Watershed Implementation Plans (WIPs) and two-year milestones. The "Current Zoning" scenario represented a historic trend scenario with the addition of Maryland's statewide generalized zoning data, adjusted infill/redevelopment rates, and additional zoning data for several non-Maryland counties. The PSC further decided that jurisdictions may establish alternative future scenarios based on existing and planned programs, policies, and land conservation activities which may alter the magnitude and/or patterns of future growth and thereby impact nutrient and sediment loads to the Bay. Five states developed these scenarios known as "land policy BMPs" in the Chesapeake Assessment Scenario Tool (CAST).

5. How does the CBLCM work?

a. County-level population projections are converted to housing units[1].
b. County-level percentages of observed housing and employment accommodated within existing built-up areas are estimated as residential and commercial infill/redevelopment and deducted from projected increases in housing and employment. Remaining housing and jobs require the construction of new homes and office space in the form of future residential and commercial growth.
c. Future residential and commercial growth is simulated as patches of development (clusters of 30-meter cells) in urban and rural areas informed by the historic distribution of development patch sizes, suitability of land for development, and residential or commercial growth probabilities.
d. For all simulated patches, the following information is assessed:
    i. Average lot size

[1] housing units = ((total population – population in group housing) / average household size) / (1- vacancy rate in 2020).

ii. Number of housing units
iii. Number of jobs
iv. Wastewater treatment (sewer vs septic[2])

v. Current land use (forest or farmland)

e. Simulation for a single iteration stops when the demand for housing and jobs within a county equals the total housing and jobs within simulated patches of growth. Simulation for an individual timestep, e.g., 2030, 2035, stops following the completion of 101 iterations.

f. The results of 101 iterations for each timestep are aggregated and averaged within user-defined overlay summary units (e.g., Phase 7 land-river segments). These data are then further processed and interpolated to produce annual Phase 7 land use data for CAST.

6. What are the sources of population and employment projections?

County-level population and employment projections are developed by state agencies or by universities on behalf of state agencies (Table 1). While all jurisdictions produce population projections, only three project employment. For jurisdictions where employment projections are lacking, future employment is scaled to future housing by the ratio of 2020 Total Employment (Bureau of Economic Analysis) to 2020 Total Housing Units (U.S. Census Bureau).

Table 1. County-level population and employment projection data sources.

Jurisdiction	Source	Dataset	Vintage	Years
District of Columbia	Metropolitan Washington Council of Governments	Round 10.1 Cooperative Forecasts (population and employment)	11/2025	2025-2050 (5-yr intervals)
Delaware	Delaware Population Consortium	Population and Employment Projections	10/2024	2025-2050 (5-yr intervals)
Maryland	Maryland Department of Planning	Population and Employment Projections	03/2025	2030-2050 (5-yr intervals)
	Baltimore Metropolitan Council	Round 10 (population and employment)	07/2022	2030-2050 (10-yr intervals)
New York	Cornell Program on Applied Demographics	Population Projections	2025	2025-2050 (1-yr intervals)
Pennsylvania	Center for Rural Pennsylvania	Population Projections	09/2023	2025-2050 (5-yr intervals)
Virginia	Weldon Cooper Center for Public Service (UVA)	Population Projections	07/2025	2030-2055 (5-yr intervals)
West Virginia	Bureau of Business and Economic Research (WVU)	Population Projections	10/2022	2025-2040 (5-yr intervals)

[2] Septic system counts are calculated as one system per occupied housing unit, aka “households”. Vacancy rates in 2020 are applied to simulated housing units to estimate future households: ((1-vacancy rate in 2020) * simulated housing units). Population on septic is determined by multiplying the septic counts by the 2021 county-specific average household size from the Census Bureau’s American Community Survey. Remaining population is assumed to be served by sewer.

7. How are urban and rural areas defined for allocating growth within a County.

Before simulating future residential and commercial growth, demand for growth in the form of future housing units and jobs is partitioned into "urban" and "rural" zones within each county based on relative proportions of recent growth (Figure 1). This was implemented to more closely replicate historic spatial patterns of growth. A significant portion of forest and farmland conversion, however, occurs outside urban areas along their fringes and shares many characteristics growth inside urban areas even though fringe areas are classed by the Census Bureau as "rural". To ensure that future fringe growth is adequately simulated, Census Urban Areas were expanded into neighboring blocks using the National Center for Education Statistics (NCES) Locale Classifications and Criteria framework. These criteria rely on definitions and data produced by US Census Bureau and have been adapted by USGS to capture fringe areas within an urban footprint defined by a collection of qualifying Census Blocks and Places.

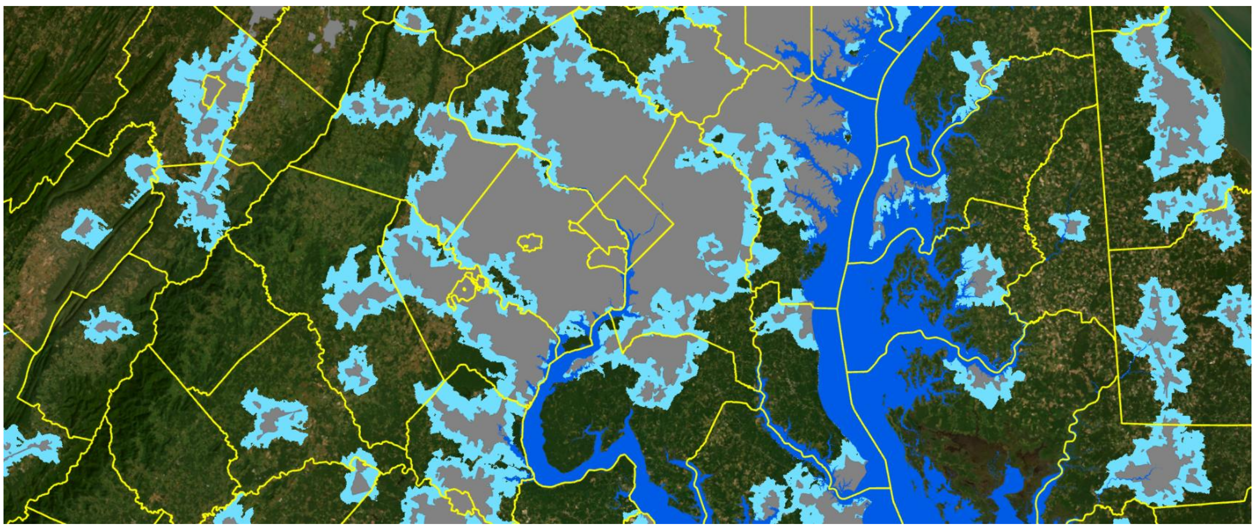

Figure 1. Census Urban Areas (grey) overlaid on the CBLCM "urban" zone (light blue).

Reference:
Geverdt, D. and Maselli, A. (2024). Education Demographic and Geographic Estimates Program (EDGE): Locale Boundaries Technical Documentation. U.S. Department of Education, National Center for Education Statistics. Washington, DC. Retrieved [date] from https://nces.ed.gov/programs/edge/Geographic/LocaleBoundaries.

8. What proportion of observed changes in impervious cover are associated with residential and commercial development?

From 2013/14 to 2021/22 (high-resolution land use mapping period), impervious surfaces in the 205 counties intersecting and adjacent to the Bay watershed increased by 136,150 acres. Regionally, most of this increase is associated with residential and commercial development. Activities decoupled from population growth, however, also contribute to increases in impervious surfaces including road widening and new alignments, natural gas extraction in northern Pennsylvania, new poultry houses in Delaware and on Maryland's eastern shore, and utility-scale solar fields in Virginia. In local areas where such activities could be extensive, they may represent most of the impervious surface change over the mapping period.

9. How are county-level infill/redevelopment rates estimated?

The term "infill" commonly refers to new construction on vacant lots within built-up areas and "redevelopment" commonly refers to new construction on already developed lands, e.g., converting a parking lot into a multi-story office building. Using residential infill as an example, the CBLCM estimates the rate of infill/redevelopment as the percentage of reported housing unit change (2010-2020) within urban and adjacent Census Blocks that does not manifest as observed change in residential impervious surfaces from 2013/14 to 2021/22 in CBP's high-resolution land use/land cover data. For example, if the Census Bureau reports a 50-unit housing increase from 2010-2020 within a block and we observe no corresponding increase in residential impervious area in the block, then we presume that all 50 units must have been present in 2013/14 and these units are credited towards infill/redevelopment. If we observed an increase in impervious surfaces but not enough to accommodate 50 units at the maximum expected density for that block, then only a portion of the 50 units would be credited as infill/redevelopment. To estimate this portion, a curve equation was developed for each state relating the observed residential density in 2013/14 to the 75th percentile residential density for blocks with similar proportions of housing to impervious surfaces. This equation enables the estimation of the minimum expected amount of impervious associated with a change in housing. If we observe less than the minimum, the difference in acres is converted to its housing unit equivalent and credited as infill/redevelopment. For example, suppose a Census Block adds 16 new housing units over the 2010's and has a housing density of 2 units/acre and maximum expected density of 4 units/acre. We expect to observe 4 acres of impervious change (16 units / 4 units per acre) to accommodate the 16 units. If only 3 acres of impervious change were observed, then the area of new development is underestimated by 1 acre corresponding to 4 housing units of infill/redevelopment. The infill/redevelopment housing and job values were aggregated across all Census Blocks within each county and divided by the total increase in housing and jobs to generate county-level residential and commercial infill/redevelopment rates.

10. How are residential and commercial densities estimated?

Residential and commercial densities were estimated by Census block. Housing unit counts by block were provided by the 2010 and 2020 Decennial Population and Housing Census. Total job counts at place of work were provided by the Census Bureau's Longitudinal Employer-Household Dynamics Program. Residential and commercial areas within each Block were mapped using 2023 REGRID parcel data attributed with USPS Residential Delivery Indicator, impervious area, and impervious area in structures in addition to overlays of institutional properties, protected lands, and other developed lands (e.g., cemeteries, landfills, golf courses, solar fields, etc.). Compared to Maryland's Statewide Land Use Data (2018) in Montgomery County, the CBLCM commercial area captured 87% of what Maryland Department of Planning (MDP) classed as "Commercial", "Industrial", or "Institutional" and 92% of what MDP classed as "Low Density Residential", "Medium Density Residential", or "High Density Residential". Within CBLCM commercial areas, 58% was classed by MDP as "Commercial", "Industrial", or "Institutional" with an additional 34% classed as "Open Urban Land" or "Other Land". Within CBLCM residential areas, 86% was classed as "Low

Density Residential", "Medium Density Residential", or "High Density Residential" by MDP with an additional 8% classed as "Open Urban Land" or "Other Land".

Residential density = total housing units / residential area (acres).
Commercial density = total jobs / commercial area (acres).

11. How is land suitability determined?

Lands suitable for future development are undeveloped, unprotected, and on gentle to moderate slopes[3]. Floodplains (100-year), floodways, open water, emergent wetlands (mostly tidal), surface mines, federal lands, and areas forecast for no future growth by Metropolitan Planning Organizations or transportation agencies (e.g., Baltimore Metropolitan Council, Metropolitan Washington Council of Governments, Virginia Department of Transportation, and nine MPO's associated with Planning District Commissions in Virginia) are excluded and not suitable for future development.

12. How are residential and commercial growth probabilities estimated?

Residential and commercial probabilities are estimated uniquely for each state using logistic regression models that relate observed changes in residential and commercial impervious surfaces with six potential explanatory variables:

- Travel time (over the current road network) to Census urban areas and clusters
- Travel time to residential growth hotspots in the previous decade
- Travel time to commercial growth hotspots in the previous decade
- Travel time to sewer service areas
- Current land use (natural or farmland)
- Slope

Given the patterns of observed development in the Chesapeake Bay watershed, this approach essentially produces a gravity surface where probabilities are highest along the fringe of existing developed areas and decrease gradually moving further away from those areas.

13. How accurate is the CBLCM?

The original CBLCM run to support development of Phase III Watershed Implementation Plans forecast growth from 2013 to 2025 produced plausible relative results by county ($R^2 = 0.86$) relating modeled acres of development with high-resolution land use change from 2013/14 to 2021/22. However, it also systematically overestimated observed growth by ~50%. Overestimated growth in the model can be caused by too high population projections, too low infill/redevelopment rates, and too low residential and commercial densities - all of which are being addressed with more accurate data in this latest version of the CBLCM (v7).

[3] The highest 1% of the non-road impervious slope range within each county are excluded.

The initial draft run of CBLCM v7 produced similar annual growth rates out through 2050 compared to the observed data from 2013/14 to 2021/22 in the three highest growth jurisdictions: Delaware, Maryland, Virginia. Growth rates through 2050 in New York, Pennsylvania, and West Virginia are lower than recently observed growth rates and are being further investigated.

Claggett et al., 2023 demonstrated that a “Historic Trend” scenario for Maryland was more accurate than the “Current Zoning” scenario and therefore the CBP Land Data Team recommends that an unadjusted historic trend scenario serve as the baseline for the Phase 7 model.

Regarding the patterns of simulated growth, the accuracy of those patterns can be partly evaluated by the R-squared values produced by the logistic regressions for residential and commercial growth (Table 2).

Table 2. Logistic regression results from the initial draft simulation of the CBLCM (May 2026)

Jurisdiction	Residential Probability	Commercial Probability
District of Columbia	**n/a**	**n/a**
Delaware	**0.28**	**0.55**
Maryland	**0.46**	**0.53**
New York	**0.76**	**0.77**
Pennsylvania	**0.66**	**0.72**
Virginia	**0.57**	**0.82**
West Virginia	**0.70**	**0.74**

Additional planned analyses include comparing infill/redevelopment estimates derived from MD and DE parcel data with CBLCM estimates, comparing observed and simulated growth relative to distance to roads and urban areas, and comparing observed and simulated patterns of growth at different spatial scales: 0.1 km2, 1 km2, 10 km2.

14. Can the CBLCM simulate other activities in addition to residential and commercial development?

Yes. Data required to simulate a new type of activity, e.g., land conservation, include:

- land demand by county for each modeled outyear
  - 2030, 2040, and 2050 land conservation acres in Anne Arundel County, Maryland.
  - If land demand is expressed in a unit other than area, such as AC megawatt, generation for solar fields, translation to area is required, e.g., 1 MW of utility-scale solar requires 7 acres of land;
- probability surface (30-m raster) representing the relative likelihood an activity will occur on any suitable location;
- suitability surface (30-m raster) representing where the activity is allowed to occur (e.g., undeveloped and unprotected lands);
- frequency distribution of observed activity patches (e.g., residential subdivisions, solar fields, conserved parcels).

15. Why and how are solar fields being simulated as part of the “Business-As-Usual” scenario?

Over the next 15 years, the construction of utility-scale solar (USS) fields may result in as much conversion of forests and farm fields as residential development. They are also decoupled from long-term job growth because they employ few people following construction. USS fields Utility-scale solar fields produce at least one megawatt of AC electricity and utilize about 7 acres of land per megawatt. It is not uncommon for USS fields to cover hundreds of acres, and some cover several thousand acres. While the largest USS fields in the Chesapeake Bay watershed are in Virginia, USS fields are being developed in all states in the Bay watershed. Industry associations and energy providers anticipate significant expansion of solar energy production in the mid-Atlantic states over the next decade. Part of what is fueling this expansion is the rapid construction of data centers and associated corporate sustainability goals. USGS does not have the information needed to simulate data centers using the CBLCM, however, we do have data on approved and proposed data centers and plan to incorporate them into the 2030, 2035, and 2040 forecasts.

To simulate USS in the Bay watershed, data are needed to estimate the land area necessary to accommodate future solar fields (demand), suitable locations for future solar (suitability), the relative spatial probability of solar development, and the size distribution of USS fields. The following data were used and studies were referenced to produce the necessary CBLCM inputs:

- National photovoltaic database of large-scale solar facilities developed by USGS and Lawrence Berkeley National Laboratory (DOE): https://eerscmap.usgs.gov/uspvdb/
- Renewable Energy Permits, Virginia DEQ
- Data Centers (operating, approved, and proposed), FracTracker Alliance: https://fractracker.org/data-centers/#top
- State Solar Fact Sheets, Solar Energy Industries Association, seia.org/states
- PJM Long-Term Load Forecast Report, January 24, 2025, Prepared by PJM Resource Adequacy Planning Department
- Pitt, D., J. Ciminelli, and J. LaPrad (2025). Utility-Scale Solar in Virginia – Current Trends and Future Impacts
- Stewart, R., et al., 2025. Preliminary Report on Runoff Characteristics from Utility-Scale Solar Sites, College of Agriculture and Life Sciences, Virginia Tech
- STAC, 2023. Best Management Practices to Minimize Impacts of Solar Farms on Landscape Hydrology and Water Quality, STAC Workshop Report, Publication 24-001.