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DRB2100 Version 3.1 Alternative Scenarios

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Lead developers:

Delaware River Basin Project- Land Use Dynamics

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Product overview

DRB2100 Version 3.1 builds off DRB2070 Version 2, representing revised alternative forecasts of urban land cover in the Delaware River Basin (DRB) out to 2100. While Version 3.1 does not include a "business as usual" scenario, it does include the "Corridors" and "Centers" scenarios of urban growth from previous versions. This version also adds another two scenarios, considering "Non-Protection" scenarios for both urban growth scenarios. These "Non-Protection" scenarios consider the "what if" scenario: "what if land protections were to be entirely removed?" These scenarios allow us to envision what the future landscape would look like without protected areas, highlighting the potential value of our existing protected lands network.

This product builds on previous work to support the Delaware River Watershed Initiative. DRB2100 Versions 1-2 were funded through a grant from the William Penn Foundation. DRB2100 Version 3 was supported by a second grant through the Delaware Watershed Research Fund, and DRB2100 Version 3.1 includes components supported by the Open Space Institute.

Like DRB2070, DRB2100 modeling relies on the SLEUTH urban growth model[1]. To reflect urban growth patterns, the model is calibrated on historic urban land change from 2001-2006 and validated with 2011 data (Figure 1).[2] To generate projections of future urban land from 2011-2100, projections of population are incorporated, along with a number of other data sets, described in this document, that vary by scenario.

[1] The National Center for Geographic Information and Analysis. University of California, Santa Barbara. Project Gigalopolis. http://www.ncgia.ucsb.edu/projects/gig/
[2] From the 2011 edition of the National Land Cover Data.

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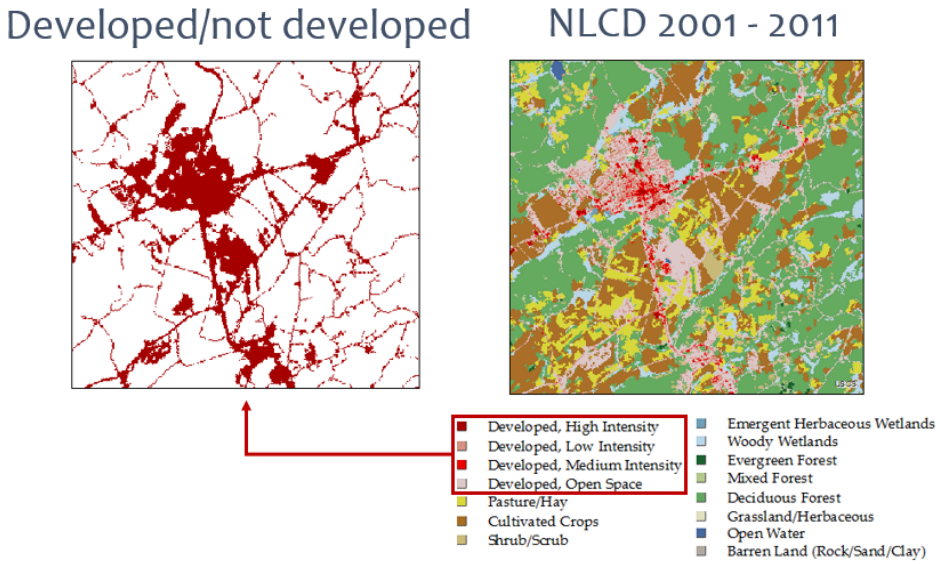

Figure 1: All four NLCD developed classes were consolidated into a single representation to designate developed/non developed as required for SLEUTH input.

DRB2100 Version 3.1 addresses another issue identified in DRB2070 Version 2.0. The total demand for new development for the modeling subregion of Harrisburg (Figure 2) was assigned incorrectly in previous versions; this produced an overestimate of urban growth for this modeling subregion. This error was corrected in DRB2100 Version 3.0 and carried over into Version 3.1.

One of the main objectives in creating the new "Non-Protection" scenarios was to maintain the overall amount of growth, so that observed differences could be attributed to the presence or absence of protected lands. While building new scenarios in Version 3.1, initial results from the "Non-Protection" scenarios brought into question the influence of the SLEUTH modeling parameter that controls the rate of development under new conditions. The growth rate parameter values that were originally derived in Version 3.0 of the model were relatively high, resulting in rapid growth at initial stages when applied to the non-protected scenarios. This rate ultimately resulted in a growth projection that was too high relative to our target. Therefore, we reviewed the values of the coefficient in all regions using these criteria:

- The growth rate parameter was set to meet the demand for growth in the "Corridors" (high growth) Scenario
- The same parameters controlling growth patterns derived in Version 3.0 were used, and they stayed constant over the forecast time period
- The model was required to generate an amount of growth matching the demand of development set in Version 3.0

The DRB2100 Version 3.1 data package includes a number of data files, along with ArcMap and ArcPro documents that help users visualize and compare results. The full data package is described and documented in ***Appendix 1***.

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DRB Modeling Subregions

The Delaware River Basin is a large area, with the following characteristics:

- 43 overlapping counties in 5 states
- 35,000 sq. km (13,500 sq. miles)
- 8.2 million residents [3]
- 3.6 million payroll jobs[4]
- Provides water resources and ecosystem services to more than 15 million people, or 5% of the US population. [5]

We explored trends across all counties in the DRB to identify patterns in population, employment, and commuter flows, the main drivers of development on which we focus. Because of heterogeneous land cover dynamics across this large region, we subdivided the region into smaller, homogeneous modeling subregions to improve accuracy. We found that commuter flows between counties allowed us to group counties that are linked economically into eight different subregions. In general, these subregions were named after the largest or most influential city within the region. These regions include Albany, Allentown, Harrisburg, New York Metro, and Philadelphia. The other two modeling regions are Delaware, which comprises most of Delaware State, and Upper-DRB, the northern portion of the DRB with counties not specifically related to an urban center (**Figure 2**).

Figure 2: Subregions used to model land cover dynamics in the Delaware River Basin

[3] US Census Bureau. American Community Survey Demographic and Housing Estimates, 2009-2013 American Community Survey 5-year Estimates.
[4] US Census Bureau. Longitudinal Employer-Household Dynamics, 2013.
[5] Delaware River Basin Commission. "Basin Information." http://www.state.nj.us/drbc/basin/. Accessed March 9, 2017.

Before generating forecasts, the demand for new developed land by 2100 was estimated. For the baseline land cover scenario (DRB2070 Version 2)[6], we calculated the average amount of development per person from 2001-2006 using Daily Human Intensity (DHI), or the sum of population and employment density. Finding the relationship between DHI and urban extent allows us to use population and employment projections to estimate the expected amount of development in 2100 for each subregion.

Each subregion is calibrated, validated, and modelled independently. The SLEUTH Urban Growth Model requires setting a target level of growth or development. The model was adjusted to match the demand of new development for the "Corridors" Scenario. We used the same configurations to model the "Centers" Scenario, allowing SLEUTH to adapt the results to the new conditions. The reduction of land available to develop drives SLEUTH to decrease the total area developed. We assume that increasing protection leads to higher land cost, and consequently, a higher infill rate; reduction of total land developed in the "Centers" Scenario can be attributed to accommodate more DHI in already developed areas.

The "Non-Protection" scenarios are run with the corresponding demand, dependent on the "Centers" or "Corridors" scenarios.

Modeling Scenarios

Because of the inherent difficulties in making reliable and accurate *predictions* of future land use changes, scenarios are often used to explore feasible visions, or *projections*, of what the future might look like. To develop the baseline and alternative scenarios, we held a series of focus groups throughout the DRB, deployed an on-line widely distributed survey, and held a scenario writing workshop **(Figure 3)**.[7, 8] These stakeholder engagement activities allowed us to identify and define key trends and drivers of land use change and to define a reasonable baseline scenario and two alternative scenarios, originally developed for DRB2070 Version 2.0:

- The Corridors Scenario reflects climate-induced westward expansion: the new frontier (sprawling population growth along corridors). This scenario explores a future with higher than baseline population projections and increased growth along corridors. Slope is also less restricted, allowing development on slopes up to 22%.
- The Centers Scenario reflects amenity driven development in urban centers (concentrated population growth in historic centers). It explores a future with higher

[6] Delaware River Basin Project- Land Use Dynamics. 2017. "DRB2070 Version 2 Baseline & Alternative Scenarios." Center for Land Use and Sustainability, Shippensburg University. https://2rf7dh2s2l1w1eqeab2caqmi-wpengine.netdna-ssl.com/wp-content/uploads/2017/07/DRB2070_v2.pdf

[7] Price, A., C. Jantz, S. Drzyzga, A. Yáñez Morillo, D. Minnick, J. Barth, and C. Lucas. (2017). A community-driven approach to developing future land use scenarios at the river basin scale: An example from the Delaware River Basin. US-IALE 2017 Annual Meeting- Baltimore, MD.

[8] Choosing Trajectories: An Aide for Modeling Future Land Use Scenarios in the Delaware River Basin– Created for our DRB2070 Scenario Development Workshop in Media, PA (10/18/16)

than baseline conservation efforts and increased growth in existing historic centers. Development cannot occur on slopes >15%.

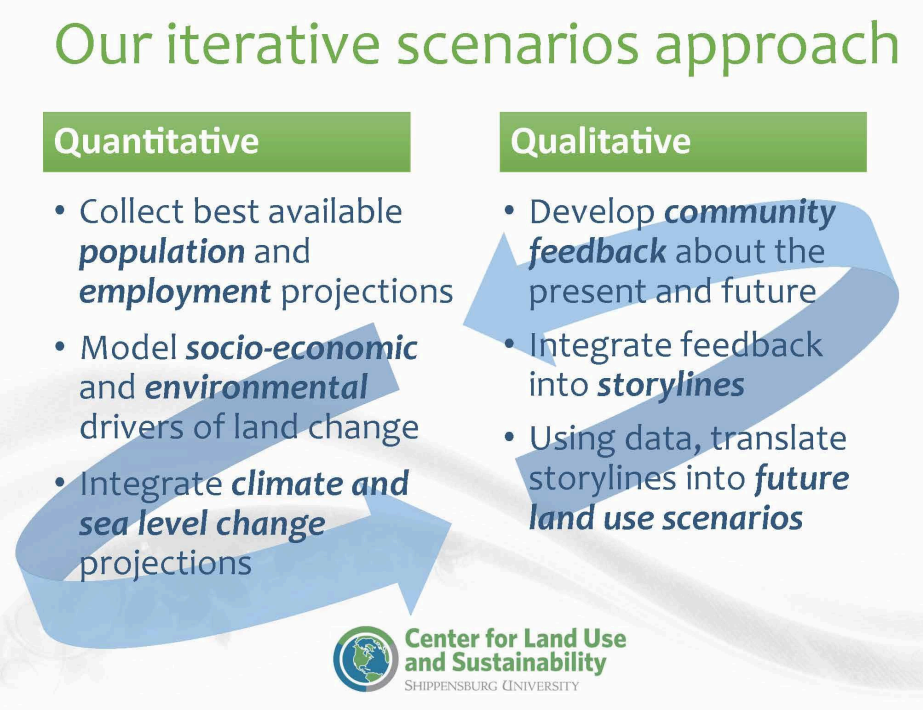

Figure 3: Iterative approach to develop scenarios in the DRB using the best available qualitative and quantitative data.

Exclusion/Attraction Layer

The primary input layer to SLEUTH is the exclusion/attraction layer, describing areas that are more or less suitable for urban development. The exclusion/attraction layer developed for the DRB baseline scenario in DRB2070 Version 2 is the result of statistical and spatial modeling of accessibility, environmental suitability, employment and population spatial dynamics, and land protection. In DRB2070 Version 2, we adapted the baseline exclusion/attraction layer to reflect the two alternative scenarios, "Centers" and "Corridors" (**Figure 4**). For DRB2100 Version 3.1, the exclusion/attraction layers for the Centers and Corridors scenarios were used to project growth out to 2100. These two scenarios were also modeled without current protections related to land conservation (**Figure 5**). These "Non-Protection" scenarios consider the "What if" scenario: "what if land protections were to be entirely removed?" These scenarios allow us to envision what the future landscape would look like without protected areas, highlighting the potential value of our existing protected lands network.

For the alternative scenarios, trajectories were determined for population growth, regional build-out, regional infrastructure, and conservation efforts. These factors, along with assumptions regarding sea level rise and storm surge, were used to develop individualized exclusion/attraction layers prior to projecting future land cover using SLEUTH.

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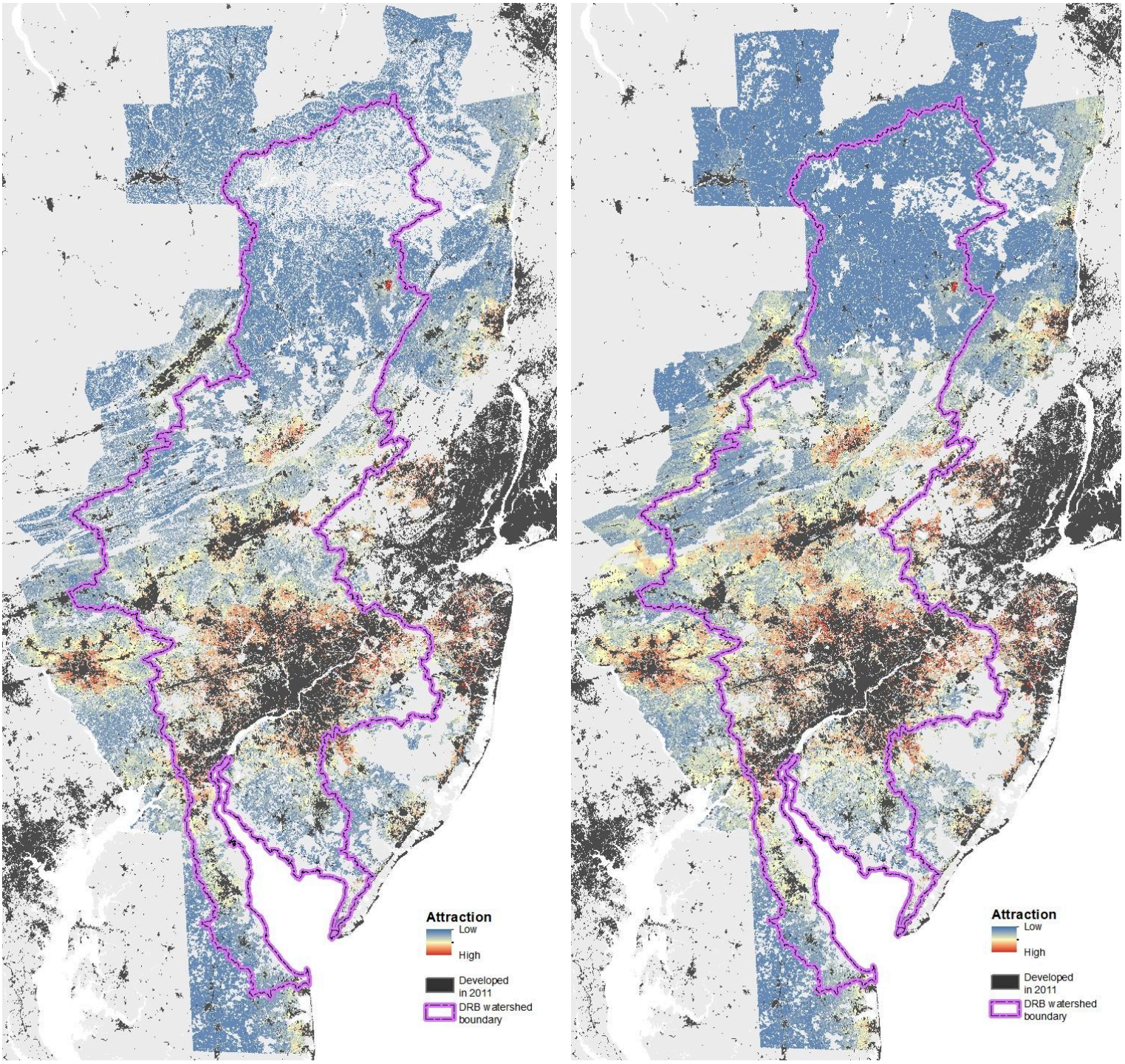

Figure 4: The exclusion/attraction layers used to drive annual projections to 2100 under alternative land use scenarios: "Centers" with conservation and growth in urban centers (left), and "Corridors" with growth along corridors (right). Areas excluded from growth are conservation areas and slope restricted zones, which appear as gaps in the attraction gradient.

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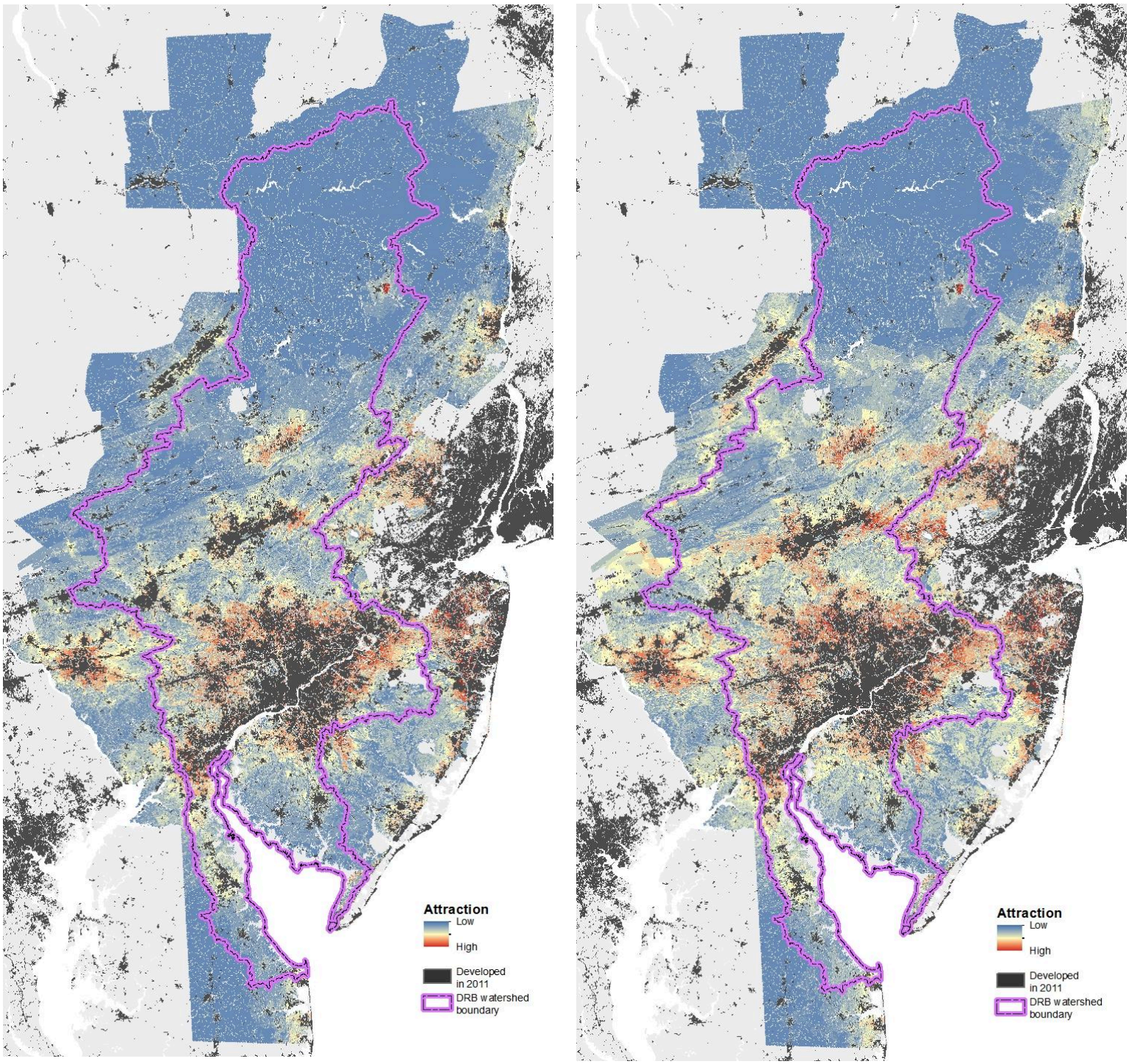

Figure 5: The exclusion/attraction layers used to drive the alternative land use scenarios without protection: "Centers" growth in urban centers (left), and "Corridors" with growth along corridors (right). In comparison to Figure 4, gaps are filled with an attraction value, as conservation and slope restrictions were lifted.

"Baseline" Land Cover Scenario (DRB2070 Version 2.0 product)

This scenario was not updated for DRB2100 Version 3.1, but we include a description of it in this documentation as it is the basis for the Version 3.1 scenarios.

The "baseline" land cover scenario represents recent trends in the Delaware River Basin for population growth, employment, regional build-out, regional infrastructure, and conservation efforts. It also assumes future sea level rise and storm surge.

- *Population Growth Trajectory*: We based the population trajectory on state county-level forecasts to 2020 and the EPA Integrated Climate and Land-Use Scenarios (ICLUS[9]) Basecase (BC) population forecast to 2070 (see **Figure 5**). The BC forecast relies on moderate fertility, domestic migration, and net international migration rates, which reflect recent historical rates. Summary statistics for the resulting urban land cover change trajectory are presented for the entire modeling domain (including the Delmarva Peninsula), the 43 counties that intersect the DRB, and the DRB in **Table 1**.

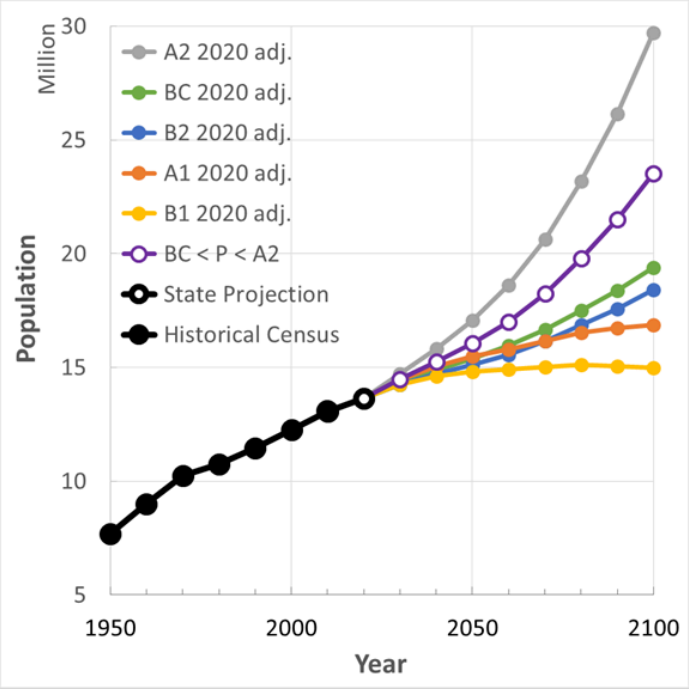

Figure 6: Population projections used to drive the Basin-wide baseline and alternative future scenarios with state projections to the year 2020, and ICLUS scenarios until 2070.

Note: for the corridors scenario, participants wished to see population growth between the BC and A2 estimates produced by the EPA. Our team combined BC and A2 to yield a 2070 population that is 8% larger than "BC 2020 adj." population for the same year.

- *Regional Build-Out Trajectory*: our model considered accessibility to different resources: transportation (e.g. roads and intersections), urban density, and recreational resources (natural areas and water) as positive drivers to attract development. Large-scale development plans were also included, such as the casino in Monticello, New York.
- *Regional Infrastructure Trajectory*: Our model includes current roads and rail. After modeling, an analysis of energy infrastructure (electric and pipeline) will be released.

[9] Integrated Climate and Land-Use Scenarios, Version 1.3.2. County Population Projections. Environmental Protection Agency. https://www.epa.gov/iclus

- *Conservation Efforts*: Non-forested wetlands are fully protected, forested or shrub wetlands have moderate to weak protection and we included protected lands as indicated in the PAD-US data. The Nature Conservancy's secured areas layer was included in our exclusion/attraction layer. The Upper Delaware Scenic & Recreational River Corridor was removed from excluded areas.
- *Sea Level Rise and Storm Surge Risk*: We accounted for a global average of 6 feet (1.8 meters) sea level rise and Category 2 storm surge risk for the basin, and added moderate repulsion of growth (with a gradient depending on depth) in affected areas.

"Corridors" Land Cover Scenario: Climate-induced westward expansion: the new frontier (population growth along corridors)

The "corridors" land cover scenario explores a future with higher than baseline population growth (i.e., more development) and increased growth along corridors (i.e., different pattern).

- *Population Growth Trajectory*: We based the population trajectory in the DRB state forecasts to 2020 and a combination of the EPA Integrated Climate and Land-Use Scenarios (ICLUS[10]) Basecase (BC) and A2 population forecasts to 2070 (see **Figure 5**). Including the A2 forecast effectively simulates a future with increased population growth and domestic migration along with decreased net international migration. Summary statistics for the resulting urban land cover change trajectory are presented in **Table 1**.
- *Regional Build-Out Trajectory*: our model considered accessibility to different resources:
    - Transportation (e.g. roads and intersections), urban density, and recreational resources (natural areas and water) as positive drivers to attract development.
    - Large-scale plans for development were also included, such as the casino in Monticello, New York.
    - Growth was focused along designated corridors (I-84, I-80, I-78, I-476, and along the Delaware Water Gap).
    - Greenfield development was emphasized with a higher land consumption ratio and more dispersed development.
- *Regional Infrastructure Trajectory*: Our model includes current roads and rail..
    - Planned stations for the Lackawanna cutoff were included
- *Conservation Efforts*: Non-forested wetlands are fully protected, forested or shrub wetlands have moderate to weak protection and we included protected lands as indicated in the PAD-US data. The Nature Conservancy's secured areas layer was included in our exclusion/attraction layer. The Upper Delaware Scenic & Recreational River Corridor was removed from excluded areas.
    - All slopes >22% were completely protected
- *Sea Level Rise and Storm Surge Risk*: We accounted for a global average of 6 feet (1.8 meters) sea level rise and Category 2 storm surge risk for the basin, and added moderate repulsion of growth (with a gradient depending on depth) in affected areas.

[10] Integrated Climate and Land-Use Scenarios, Version 1.3.2. County Population Projections. Environmental Protection Agency. https://www.epa.gov/iclus

"Centers" Land Cover Scenario: Amenity driven development in urban centers (population growth in historic centers)

The "centers" land cover scenario explores a future with higher than baseline conservation efforts and growth occurring in existing historic centers.

- *Population Growth Trajectory*: We based the population trajectory in the DRB state forecasts to 2020 and the EPA Integrated Climate and Land-Use Scenarios (ICLUS[11]) Basecase (BC) population forecast to 2070 (see **Figure 5**). The BC forecast relies on moderate fertility, domestic migration, and net international migration rates, which reflect recent historical rates. Summary statistics for the resulting urban land cover change trajectory are presented in **Table 1**.
- *Regional Build-Out Trajectory*: Our model considered accessibility to different resources:
    - Transportation (e.g. roads and intersections), urban density, and recreational resources (natural areas and water) as positive drivers to attract development.
    - Large-scale plans for development were also included, such as the casino in Monticello, New York.
    - Growth was deemphasized along roads and growth corridors and emphasized around existing/historic urban centers with less dispersed growth, and new growth centers are more concentrated. Higher infill rates are assumed.
- *Regional Infrastructure Trajectory*: Our model includes current roads and rail.
- *Conservation Efforts*: Non-forested wetlands are fully protected, forested or shrub wetlands have moderate to weak protection. We included protected lands as indicated in the PAD-US data. The Nature Conservancy's secured areas layer was included in our exclusion/attraction layer. The Upper Delaware Scenic & Recreational River Corridor was removed from excluded areas. In addition:
    - Strong protection of at least 100 ft. buffer was placed around all exceptional value high quality streams
    - Complete protection of contribution zones and flat zones as delineated in The Nature Conservancy (TNC)'s active river layer
    - All slopes >15% were completely protected
- *Sea Level Rise and Storm Surge Risk*: We accounted for a global average of 6 feet (1.8 meters) sea level rise and Category 2 storm surge risk for the basin, and added moderate repulsion of growth (with a gradient depending on depth) in affected areas.

[11] Integrated Climate and Land-Use Scenarios, Version 1.3.2. County Population Projections. Environmental Protection Agency. https://www.epa.gov/iclus

"Non-Protected" Land Cover Scenarios: Hypothetical situation without protection natural areas

The "Non-Protected" land cover scenario explores a hypothetical future where protected lands were removed. These "Non-Protection" scenarios consider the "what if" scenario: "what if land protections were to be entirely removed?" These scenarios allow us to envision what the future landscape would look like without protected areas, highlighting the potential value of our existing protected lands network. There are two "Non-Protected" scenarios, one with the conditions of "Corridors" and one with the conditions of "Centers." Other assumptions are outlined below.

- *Population Growth Trajectory:*
    - For the "Non-Protected" Land Cover Scenario referring to "Corridors," we based the population trajectory in the DRB state forecasts to 2020 and a combination of the EPA Integrated Climate and Land-Use Scenarios (ICLUS[12]) Basecase (BC) and A2 population forecasts to 2070 (see **Figure 5**). Including the A2 forecast effectively simulates a future with increased population growth and domestic migration along with decreased net international migration. Summary statistics for the resulting urban land cover change trajectory are presented in **Table 1**.
    - For the "Non-Protected" Land Cover Scenario referring to "Centers," we based the population trajectory in the DRB state forecasts to 2020 and the EPA Integrated Climate and Land-Use Scenarios (ICLUS[13]) Basecase (BC) population forecast to 2070 (see **Figure 5**). The BC forecast relies on moderate fertility, domestic migration, and net international migration rates, which reflect recent historical rates. Summary statistics for the resulting urban land cover change trajectory are presented in **Table 1**.
- *Regional Build-Out Trajectory*: our model considered accessibility to different resources:
    - Transportation (e.g. roads and intersections), urban density, and recreational resources (natural areas and water) as positive drivers to attract development.
    - Large-scale plans for development were also included, such as the casino in Monticello, New York.
    - For the "Non-Protected" Land Cover Scenario referring to "Corridors," growth was enhanced along designated corridors (I-84, I-80, I-78, I-476, and along the Delaware Water Gap), and near rail stations (Lackawanna cutoff).
    - For the "Non-Protected" Land Cover Scenario referring to "Centers," growth was enhanced around existing/historic urban centers.
- *Regional Infrastructure Trajectory*: Our model includes current roads and rail.
- *Conservation Efforts*: Only land protected by historical, military, or other motives than conservation and natural resources as indicated in the PAD-US data remained excluded

[12] Integrated Climate and Land-Use Scenarios, Version 1.3.2. County Population Projections. Environmental Protection Agency. https://www.epa.gov/iclus
[13] Integrated Climate and Land-Use Scenarios, Version 1.3.2. County Population Projections. Environmental Protection Agency. https://www.epa.gov/iclus

for future development. Water and non-forested wetlands were fully excluded due to low suitability for urbanization. In addition:
    - For the "Non-Protected" Land Cover Scenario referring to "Corridors," all slopes >22% were completely protected
    - For the "Non-Protected" Land Cover Scenario referring to "Centers," all slopes >15% were completely protected
- *Sea Level Rise and Storm Surge Risk:* We accounted for a global average of 6 feet (1.8 meters) sea level rise and Category 2 storm surge risk for the basin, and added moderate repulsion of growth (with a gradient depending on depth) in affected areas.

Urban land cover trajectories

To observe and summarize change over time, we present total developed land cover for the observational time period (2001, 2006, and 2011) and for each forecast scenario for 2025, 2050, 2075 and 2100 for the DRB boundary (**Table 1)**. Observational data for 2001-2011 were derived from the NLCD 2011 edition, while projections, along with standard error, were calculated as the average of 100 Monte Carlo trials per year. We initially calculated developed land cover area for NHDPlus catchments for the entire modeling domain, and then summarized the catchment data for each region of interest.

Table 1: Developed land (in acres) for the observational time period (2001-2011) and for forecasts of development in the baseline and alternative scenarios (2030-2070). Standard error is given in acres for the 95% confidence interval over 100 Monte Carlo trials.

Scenario	Year	Developed Land within DRB Boundary (acres)
(Observed)	2001 2006 2011	1,600,820 1,650,695.8 1,683,996
Corridors *Corridors NP* *Centers* *Centers NP*	2025	1,754,429.6 ± 1,233.9 1,775,079. ± 1,426.3 1,727,730.9 ± 872.7 1,746,389.4 ± 1,059.6
Corridors *Corridors NP* *Centers* *Centers NP*	2050	1,991,424.2 ± 3,831.2 2,033,524.6 ± 4,118 1,859,829.6 ± 2,691.9 1,898,098.1 ± 2,903
Corridors *Corridors NP* *Centers* *Centers NP*	2075	2,216,071.3 ± 5,129 2,228,863.3 ± 5,393.9 1,996,568.8 ± 3,846.5 2,013,538.6 ± 3,866.7
Corridors *Corridors NP* *Centers* *Centers NP*	2100	2,377,418.6 ± 5,701.5 2,355,901. ± 6,029.3 2,111,389.2 ± 4,539.9 2,089,474.8 ± 4,372.7

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Urban land cover change trajectories within the DRB boundary for each of the alternative scenarios are summarized in **Figure 7**. Note that the corridors scenario predicts the highest levels of development, while the centers scenario has the lowest. Also note that the overall levels of growth in the Non-Protection scenarios are more or less the same for the corresponding Centers and Corridor scenarios, so that differences can largely be attributed to changes in development patterns that occur in the absence of protected lands, rather than changes in the overall amount of growth.

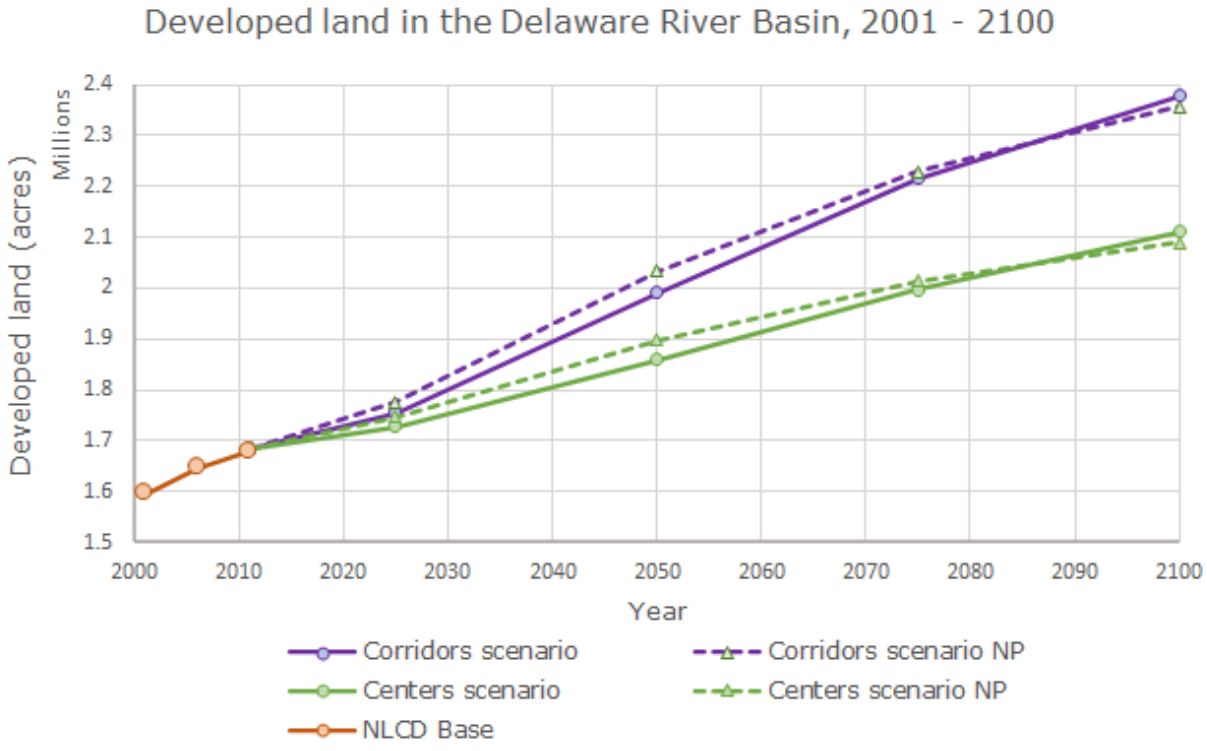

Figure 7: Urban land cover change trajectory within the DRB boundary from 2001 - 2011 (observed from NLCD 2011 edition) and from 2011 - 2100 (DRB2100 Version 3 forecast) for the alternative scenarios.

Appendix 1. DRB2100 Version 3.1 Data Release

To visualize the future land use forecasts, we provide a variety of packages:

I. ArcGIS OnLine Interactive Web Maps

Associated Files:

- DRB 2100 Version 3.1 Urban Land Cover Projections https://arcg.is/0HrrSy
- DRB 2100 Version 3.1 Forest Loss Projections https://arcg.is/1f0jTm0

Description:

These web maps allow for quick and easy visualization of urban land projections and forest loss projections at the HUC12 watershed scale. This Urban Land Cover Projection web map shows the percent of urban land cover in HUC 12 watersheds for the Delaware River Basin for 2011 (as represented in the National Land Cover Dataset 2011 edition) and for 2100 under the four different scenarios. The Forest loss Projections web map shows projected forest loss for HUC 12 watersheds for the Delaware River Basin under the four different scenarios of projected urban growth in 2100. Forest loss is calculated as a decrease in percent forest cover from 2011 (as represented in the National Land Cover Dataset 2011 edition).

II. Access Databases

Associated Files:

- accessdb_Catchments.zip
- accessdb_HUC12.zip

Description:

Access databases of projected urban growth, one for HUC12s and one for NHD catchments. Tables for the Centers, Centers - No Protection, Corridors, and Corridors - No Protection are included. In addition, when the “Urban Forecasts” form is opened, users can select HUC12 watersheds or NHD catchments and a chart showing the percent of watershed or catchment area developed from 2011-2100 is automatically generated.

III. Summaries for NHD Catchments and HUC12 Watersheds

Associated Files:

- DRB2100_Catchments.zip
- DRB2100_HUC12s.zip

Description

Each zip file contains a geodatabase that includes DRWI cluster boundaries (for reference), DRB and county boundaries (for reference), and NHD catchments or HUC12 boundaries National Hydrography Dataset Plus (NHDPlus, Version 2.0). The geodatabase also includes a number of summary tables that report projected land use change for urban, forest, and all NLCD categories.

Also included in the zip file are a series of ArcGIS 10.7 map documents that visualize forest loss or urban change for the Centers and Corridors scenarios, and includes comparison maps in each case to the "Non-Protection" version of these scenarios. The ArcGIS map documents incorporate visualizations using the Time Slider function, so that change between 2011-2100 can be visualized as an animation.

Finally, an ArcPro 2.6 project file is also included that features two maps, one showing urban change and one showing forest loss.

We note that forest loss (in all cases) is visualized as a percent of the 2011 forest cover that is lost to development. For urban visualizations, catchments or watersheds are symbolized based on the proportion occupied by developed land cover (e.g. catchments or watersheds in the <1% category have less than 1% of developed land cover in any given time period) for the observational time periods of 2001 and 2011, 2030, 2060, and 2090 under each forecast scenario. We note that while these are the only time periods symbolized in the ArcMap documents; decadal summaries from 2020 to 2100 are available in the attribute tables. All data sets include an item description that can be referred to for additional information.

IV. *Raster Data*

Associated Files:

- DRB2100_Projection_Centers_Scenario.zip
- DRB2100_Projection_Centers_Non_Protection.zip
- DRB2100_Projection_Corridors_Scenario.zip
- DRB2100_Projection_Corridors_Non_Protection.zip

Description:
Each zip file contains 30m resolution rasters for each of the four scenarios. The "ProbabilityUrban" raster is a single band raster that shows the probability that a pixel is projected to urbanize by 2100. This raster is scaled from 0-1, where 1 represents pixels that have a 100% chance of being selected for development and pixels with a value of 0 were never selected for development.

The *NLCDSummaryBands* raster is a multiband raster file summarizing the number of times a National Land Use Dataset (NLCD) class occurs in each cell in 100 simulations of projected urban growth in 2100. This raster file contains 15 bands, one for each NLCD class. The cell value indicates the number of times a cell was assigned to that NLCD class across 100 simulation runs (Monte Carlo trials) projecting urban growth to 2100. The raw outputs from the modeling software, SLEUTH, are binary maps of urban/non-urban. To create these probability maps of each NLCD land cover class in 2100, first we modeled the NLCD 2011 urban classes using a logistic model to discriminate commercial and residential land uses and then we applied a linear model specific for the Delaware River Basin to estimate impervious surface values. Pixels classified as "commercial" were assigned the NLCD class 24 (Developed, High Intensity); non-commercial pixels were assigned NLCD categories 21-23 based on their estimated impervious surface values. Finally, non-urban areas were updated by overlaying the 2100 urban map with the NLCD 2011 map.

Bands in the *NLCDSummaryBands* rasters

1: CLASS 11 Open water
2: CLASS 21 Developed, Open space
3: CLASS 22 Developed, Low Intensity
4: CLASS 23 Developed, Medium Intensity
5: CLASS 24 Developed, High Intensity
6: CLASS 31 Barren land
7: CLASS 41 Deciduous forest
8: CLASS 42 Evergreen forest
9: CLASS 43 Mixed forest
10: CLASS 52 Shrub/Scrub
11: CLASS 71 Grassland/Herbaceous
12: CLASS 81 Pasture/Hay
13: CLASS 82 Cultivated crops
14: CLASS 90 Woody wetlands
15: CLASS 95 Emergent herbaceous wetlands