

## **Landscape Conservation Design Data Products**

### ***Purpose***

The purpose of this appendix is to provide a brief description of the data layers included in the landscape conservation design (LCD) package developed for the Connecticut River Watershed (CTR), which served as a pilot for developing the LCD approach.

The CTR LCD is intended to focus conservation actions, including land protection, management, and restoration where it will likely do the most good towards conserving biodiversity within the landscape. The CTR LCD provides a watershed-based conservation design to complement or supplement conservation planning done at local or finer extents. Importantly, although the CTR LCD offers a way to strategically focus limited conservation resources, by itself it is not sufficient as a total solution to biodiversity conservation in the watershed. This design serves as a starting point that should be used in combination with other sources of information to direct conservation.

The CTR LCD is not a single product or map. Rather, it is a package of data products that collectively identify terrestrial core areas and connectors, aquatic core areas and their watershed-based buffers, and restoration opportunities for dam removal, culvert upgrades, and terrestrial wildlife road passage structures. This package also includes a variety of supporting data layers that separately provide information on the ecological value of all lands and waters regardless of their inclusion in the core area network.

### ***Disclaimer***

The spatial data products comprising the CTR LCD and described in this document were produced by the UMass [Designing Sustainable Landscapes \(DSL\) Project](#) in collaboration with the North Atlantic LCC and the Connecticut River Watershed Landscape Conservation Design (CTR LCD) partnership, with a few exceptions, as noted below.

- These products were developed to test procedures for landscape conservation design that could be extended to the entire Northeast Region in the next phase of the DSL project. These products are now being provided to collaborating partners for review and thus should be viewed as interim pending the outcome of the review process.
- This document provides a brief abstract on each of the data products to facilitate their immediate use and interpretation by the CTR LCD partners. Complete and detailed technical documentation is available for all products at the DSL project website.
- The products described here include only those data products deemed essential to the description of the CTR LCD. A more comprehensive set of data products derived for the entire region are available via the DSL project website.

### ***Overview of Data Products***

The CTR LCD data package consists of several tables and a large number of separate spatial data (GIS) layers. Each of these products is summarized in a separate abstract below. In these abstracts, terms in **bold** are defined in greater detail in a glossary available from the

DSL website. The entire data package can be downloaded from the DSL project website (see link above) or individual products can be downloaded from the [North Atlantic LCC website](#) or through their [Databasin site](#).

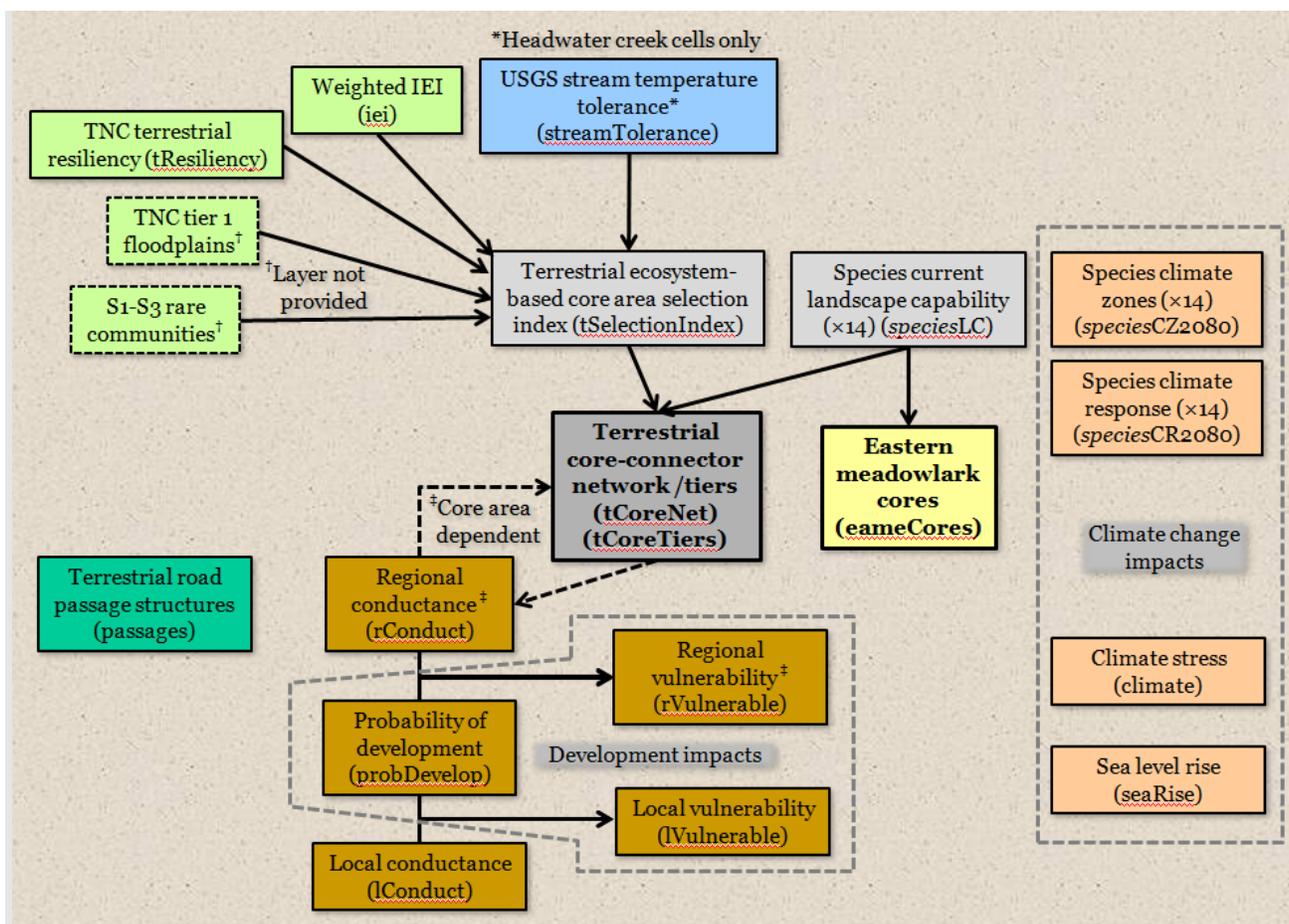
Although the data products can be used individually or any combination, to facilitate the use of this package, it is helpful to organize the products into three broad groups: 1) terrestrial design products, 2) aquatic design products, and 3) base maps and other ancillary layers, as described below. Tables are provided as comma-delimited text files (.csv) and can be viewed using any spreadsheet (e.g., Excel). GIS layers are provided as geoTIFFs (.tif), in the case of rasters, or ESRI shapefiles (.shp), in the case of vector data, both of which can be viewed using ArcGIS (or other GIS software). An ArcMap project (ctrLCD.mxd) with full symbology is included in the package for convenience in getting started.

### **Terrestrial design products**

The following data products relate directly to the terrestrial landscape design, and the relationship among the corresponding GIS layers is illustrated in **figure A1**:

- Terrestrial core-connector network ([tCoreNet.shp](#))
- Terrestrial core tiers ([tCoreTiers.shp](#))
- Eastern meadowlark cores ([eameCores.shp](#))
- Terrestrial core areas - ecosystem summary ([tCoreEcoSum.csv](#))
- Terrestrial core areas - species summary ([tCoreSpeciesSum.csv](#))
- Species landscape capability ([speciesLC.tif](#))
- Species climate zones ([speciesCZ2080.tif](#))
- Species climate response ([speciesCR2080.tif](#))
- Terrestrial ecosystem-based core area selection index ([tSelectionIndex.tif](#))
- USGS stream temperature tolerance ([streamTolerance.tif](#))
- Weighted index of ecological integrity ([iei.tif](#))
- TNC terrestrial resiliency ([tResiliency.tif](#))
- Regional conductance ([rConduct.tif](#))
- Probability of development ([probDevelop.tif](#))
- Regional vulnerability of conductance ([rVulnerable.tif](#))
- Local conductance ([lConduct.tif](#))
- Local vulnerability of conductance ([lVulnerable.tif](#))
- Climate stress ([climate.tif](#))
- Sea level rise ([seaRise.tif](#))
- Terrestrial road passage structure impacts ([passages.shp](#))

Perhaps the most important products of the terrestrial landscape design are the terrestrial core-connector network (**tCoreNet.shp**), terrestrial core tiers (**tCoreTiers.shp**), and eastern meadowlark cores (**eameCores.shp**). These products represent a synthesis of ecological information and are designed to provide strategic guidance for conserving natural areas, and the fish, wildlife, and other components of biodiversity that they support within the CTR watershed. The tCoreNet.shp layer represents the tier 1 (highest priority)



**Figure A1.** Relationship among the GIS data layers pertaining to the conservation of the terrestrial landscape.

core areas and the connectors between them. The `tCoreTiers.shp` layer provides a three-tiered, spatially-nested hierarchy in which tier 1 cores (representing 25% of the landscape) are nested within tier 2 cores (representing 50% of the landscape), which are nested within tier 3 road-bounded blocks (representing 77% of the landscape). The `eameCores.shp` layer represents a set of separate cores developed for eastern meadowlarks as a representative of grasslands. All of the remaining data layers either: 1) provide additional detailed information on why particular areas were included as core areas, 2) provide useful overlays to enhance the interpretation of the core-connector network (e.g., to help prioritize areas within the network), or 3) complement the core-connector network and tiered cores by providing seamless and continuous ecological valuation of the landscape independent of the core area network (e.g., to identify places with ecological value outside of the designated network).

The core areas are created from a combination of the 14 representative species landscape capability indices (***speciesLC.tif***), which is a measure of the relative habitat capability and climate suitability for the corresponding species, and the terrestrial ecosystem-based core area selection index (***tSelectionIndex.tif***). `tSelectionIndex.tif` is derived from a combination of: 1) USGS stream temperature tolerance (***streamTolerance.tif***), for

headwater creeks only, which is a measure of the tolerance of stream temperature to future increases in air temperature; 2) weighted index of ecological integrity (**iei.tif**), which is a composite measure of local intactness and short-term resiliency based on ecological systems; 3) TNC terrestrial resiliency (**tResiliency.tif**), which is a measure of long-term resiliency based on geophysical settings; 4) TNC tier 1 floodplains (layer not provided), representing high priorities for floodplain forest restoration; and 5) state Heritage S1-S3 rare communities (layer not provided). Note, all of the layers contributing to tCoreNet.shp and tCoreTiers.shp are stand-alone products that can be interpreted independently of the derived cores.

The terrestrial tier 1 core area network is the basis for modeling regional conductance (**rConduct.tif**), which is a measure of connectivity between cores, during which the connectors between the tier 1 cores are also created (hence the feedback loop to tCoreNet.shp in the figure. rConduct.tif is combined with the integrated probability of development (**probDevelop.tif**), which is a measure of the relative probability of development between 2010-2080, and regional irreplaceability (not provided) to create the regional vulnerability of conductance layer (**rVulnerable.tif**), which indicates places important to network connectivity that are at risk of future development. Note, both rConduct.tif and rVulnerable.tif are completely core area dependent and thus can only be interpreted in conjunction with the designated cores.

Local conductance (**lConduct.tif**) is a separate, stand-alone product that measures local connectivity at the scale of one to a few kilometers, similar to the individual ecological integrity metrics that comprise weighted *IEI*. lConduct.tif is combined with probDevelop.tif to create the local vulnerability of conductance layer (**lVulnerable.tif**), which indicates places important to local connectivity independent of the core areas that are at risk of future development. Note, although lConduct.tif and lVulnerable.tif can be interpreted in conjunction with tCoreNet.shp, they are stand-alone products derived independently of the designated cores.

Terrestrial road passage structure impacts (**passages.shp**) represent opportunities for improving or restoring terrestrial connectivity by installing road passage structures. Note, although passages.shp can be interpreted in conjunction with tCoreNet.shp and tCoreTiers it is a stand-alone product derived independently of the designated cores.

Lastly, to derive the core area network, the CTR LCD planning team opted to use data layers representing the current landscape condition. In this scenario, climate change impacts are incorporated indirectly into the selection of core areas via the *IEI* and TNC terrestrial resiliency indices, which in combination identify currently intact, ecologically connected and geophysically diverse areas that should confer resiliency to climate change over both the short and long term. However, metrics that incorporate climate change directly, such as the climate stressor and sea level rise metrics, and the individual species climate response indices were not used to derive the core areas. Consequently, these layers are provided as overlays to help inform the design. Briefly, the climate zones for each of the 14 representative species (**speciesCZ2080.tif**) depict three zones: 1) zone of persistence, representing places where the climate is suitable today and is expected to remain suitable through 2080, 2) zone of contraction, representing places where the climate is suitable today but is expected to become unsuitable by 2080, and 3) zone of expansion,

representing places where the climate is unsuitable today but is expected to become suitable by 2080. Similarly, the climate response index for each of the 14 representative species (***speciesCR2080.tif***) indicates places with both suitable habitat and climate today and where climate is expected to remain suitable at least out to 2080. Climate stress (***climate.tif***) and sea level rise (***seaRise.tif***) are two ecological integrity metrics that directly measure climate-induced stress on ecological systems. Note, although all of these climate change impact layers can be interpreted in conjunction with *tCoreNet.shp*, they are stand-alone products derived independently of the designated cores.

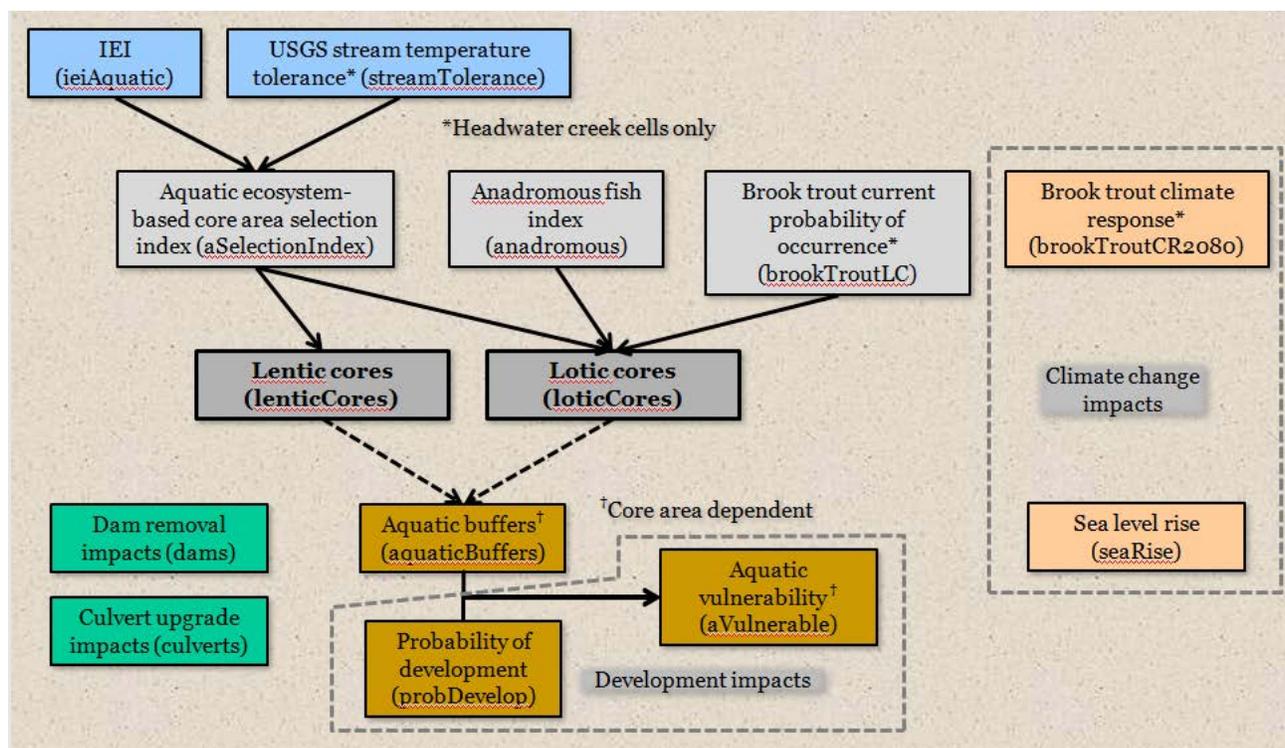
### **Aquatic design products**

The following data products relate directly to the aquatic landscape (a.k.a. "aquascape"), and the relationship among the corresponding GIS layers is illustrated in **figure A2**:

- Lotic (river and stream) cores ([loticCores.shp](#))
- Lotic core areas - ecosystem summary ([aCoreEcoSum.csv](#))
- Lentic (lake and pond) cores ([lenticCores.shp](#))
- Brook trout current probability of occurrence ([brookTroutLc.shp](#))
- Anadromous fish index ([anadromous.shp](#))
- Aquatic ecosystem-based core area selection index ([aSelectionIndex.tif](#))
- USGS stream temperature tolerance ([streamTolerance.tif](#))
- Weighted index of ecological integrity ([ieiAquatic.tif](#))
- Aquatic buffers ([aquaticBuffers.tif](#))
- Aquatic core vulnerability to development ([aVulnerable.tif](#))
- Dam removal impacts ([dams.shp](#))
- Culvert upgrade impacts ([culverts.shp](#))
- Brook trout climate response ([brookTroutCR2080.shp](#))
- Sea level rise ([seaRise.tif](#))

Perhaps the most important products of the aquatic landscape design are the lotic (i.e., river and stream) cores (***loticCores.shp***) and lentic (lake and pond) cores (***lenticCores.shp***), although the latter is an interim product and should be viewed with caution (as discussed in the abstract below). Similar to the terrestrial core-connector network, the aquatic cores represent a synthesis of ecological information and are designed to provide strategic guidance for conserving aquatic environments and the fish, wildlife, and other components of biodiversity that they support within the CTR watershed. All of the remaining data layers either: 1) provide additional detailed information on why particular areas were included as core areas, 2) provide useful overlays to enhance the interpretation of the core areas (e.g., to help prioritize areas within the cores), or 3) complement the core area network by providing seamless and continuous ecological valuation of the aquascape independent of the core area network (e.g., to identify places with ecological value outside of the designated cores).

The lotic cores are derived from a combination of: 1) anadromous fish index (***anadromous.shp***), which is a binary measure of the lower mainstem and major tributaries open to migration by five select anadromous fish species; 2) brook trout current probability of occurrence (***brookTroutLc.shp***) for headwater creeks only, and 2) aquatic



**Figure A2.** Relationship among the data layers pertaining to the conservation of the aquascape.

ecosystem-based core area selection index (**aSelectionIndex.tif**). **aSelectionIndex.tif** is derived from a combination of: 1) USGS stream temperature tolerance (**streamTolerance.tif**), for headwater creeks only, as described above, and 2) weighted index of ecological integrity (**ieiAquatic.tif**), as described above but shown for aquatic cells only (all non-aquatic cells are set to nodata). Note, we did not apply weights to aquatic systems, hence it is technically unweighted **IEI**. Note, **streamTolerance.tif** and **ieiAquatic.tif** are both stand-alone products that can be interpreted independently of the derived cores.

Lentic cores are derived solely from **aSelectionIndex.tif** and thus from **iei.tif** (since **streamTolerance.tif** applies only to headwater creeks).

The aquatic cores are the basis for deriving aquatic buffers (**aquaticBuffers.tif**), which represent graduated zones of influence (based on watershed processes) upstream and upslope of the cores. **aquaticBuffers.tif** is combined with **probDevelop.tif** (described above) to create the aquatic core vulnerability to future development layer (**aVulnerable.tif**), which indicates places in the uplands with a strong influence on the integrity of the aquatic cores that are at risk of future development. Note, **aquaticBuffers.tif** and **aVulnerable.tif** are both completely core area dependent and thus can only be interpreted in conjunction with the designated aquatic cores.

Dam removal impacts (**dams.shp**) and culvert upgrade impacts (**culverts.shp**) represent opportunities for improving or restoring aquatic connectivity by either removing a dam or upgrading a road-stream crossing structure to the equivalent of a bridge, respectively. Note,

although both dams.shp and culverts.shp can be interpreted in conjunction with loticCores.shp and lenticCores.shp, they are stand-alone products derived independently of the designated cores.

Lastly, as noted above, to derive the core area network, the CTR LCD planning team opted to use data layers representing the current landscape condition. Thus, direct climate change impacts are not incorporated into the selection of aquatic core areas. Whereas the climate stress metric (climate.tif) does not apply to aquatic ecosystems, the sea level rise metric (**seaRise.tif**) does. SeaRise.tif is an ecological integrity metric that directly measures the adaptive capacity of coastal systems to predicted sea level rise and is included here as an overlay. Note, although seaRise.tif can be interpreted in conjunction with loticCores.shp, it is a stand-alone product derived independently of the designated cores.

### **Base maps and other ancillary layers**

Several additional GIS layers are included in the package as base layers or overlays to facilitate viewing and interpreting the landscape design products:

- Land cover ([dslLand.tif](#)) -- depicts ecological systems (and their aggregation into formations) which is foundational to the ecosystem- and species-based assessment products, and thus can be useful for investigating the ecosystem composition of the core-connector network.
- TNC geophysical setting ([geoSetting.tif](#)) -- depicts TNC's geophysical settings which is the basis for scaling the corresponding resiliency index, which is used in the terrestrial ecosystem-based core area selection index and thus the selection of the terrestrial core areas.
- Stream class ([streamClass.shp](#)) -- continuous vector representation of streams classified into ecosystems, which can be useful for investigating the ecosystem composition of the lotic cores and also as a backdrop or transparent overlay on other raster products.
- Roads ([roads.shp](#)) -- attributed roads within the CTR watershed.
- Secured lands ([secure.shp](#)) -- TNC secured lands database depicting parcels with some form of permanent protection from development, which can be useful for determining which places of value, e.g. in the core-network, are already protected.
- State boundaries ([statesNer.shp](#)) -- boundaries of the 13 states plus Washington, DC, comprising the Northeast region.
- HUC 6 watershed boundaries ([huc6Ctr.shp](#)) -- boundaries of the two HUC 6-level sub-watersheds comprising the CTR watershed.
- HUC 8 watershed boundaries ([huc8Ctr.shp](#)) -- boundaries of the 13 HUC 8-level sub-watersheds comprising the CTR watershed.
- Hillshade ([hillshade.tif](#)) -- raster hillshading derived from a digital elevation model, useful as a backdrop for viewing some of the layers to highlight the topography when they are displayed using partial transparency.

### ***Individual Data Products***

#### **Terrestrial core-connector network (tCoreNet.shp)**

##### Description

This GIS product represents a set of terrestrial tier 1 **core areas** and the **connectors** between them. In combination with the aquatic core areas (see [loticCores.shp](#) and [lenticCores.shp](#)), they spatially represent the ecological network derived from the CTR LCD project. The network is designed to provide strategic guidance for conserving natural areas, and the fish, wildlife, and other components of biodiversity that they support within the Connecticut River watershed.

**Core areas** serve as the foundation of the conservation design. They reflect decisions by the CTR LCD planning team about the highest priority areas for sustaining the long-term ecological values of the watershed, based on currently available, regional-scale information. Terrestrial core areas represent the following:

- 1) areas of relatively high **ecological integrity** across all terrestrial and wetland ecosystem types, emphasizing areas that are relatively intact (i.e., free from human modifications and disturbance) and resilient to environmental changes (e.g., climate change). Integrity has the potential to remain high, both in the short-term due to connectivity to similar natural environments, and in the long-term due to proximity to diverse landforms and other geophysical settings;
- 2) areas of relatively high current habitat value (**landscape capability**) for a suite of 14 representative terrestrial wildlife species, emphasizing areas that provide the best habitat and climate conditions today;
- 3) areas of high potential for **floodplain forest restoration** along major rivers, emphasizing areas where geomorphic characteristics favor the development of floodplain forest; and
- 4) areas of **rare terrestrial natural communities** that support unique biodiversity, regardless of their landscape context; inclusive of communities listed by state heritage programs as S1 (extremely rare), S2 (rare), and S3 (uncommon), with definitions of S1-S3 varying slightly among states.

Core areas are built from focal areas with high value based on one or more of the attributes listed above. These "seed areas" are expanded to encompass surrounding areas that provide additional ecological value and resilience to both short- and long-term change. These surrounding areas within the core areas are typically of high to moderate ecological value. To maintain a coherent shape and size, in some cases core areas contain low-intensity development and minor roads, but high-intensity development and major roads are excluded. Collectively, terrestrial tier 1 core areas encompass 25% of the Connecticut River watershed area, as decided by the partnership. A total of 1,120 core areas have been identified, ranging in size from 8 to 26,515 ha, with an average size of 600 ha.

**Connectors** represent "corridors" that could facilitate the movement of plants and animals (i.e., ecological flow) between terrestrial core areas. These connectors increase the resiliency of the core area network to uncertain changing land use and climate. They are

wider where more movement between cores is expected because of larger and closer core areas and a more favorable natural environment between them. Connectors primarily link adjoining core areas where there is the greatest similarity in ecosystems; they do not necessarily represent travel corridors for any individual species. Connectors may traverse through areas of low-density development and cross roads of all classes, but they do not include high-intensity development. Connectors are not identified between core areas that are greater than 10 km apart. Collectively, connectors encompass an additional 23% of the Connecticut River watershed area.

### Considerations for Using Data Layer

The terrestrial tier 1 core-connector network can serve as a starting point for a regional conservation network that can be used in combination with other sources of information to direct action. Indeed, terrestrial core areas and connectors are not the only places of high ecological value deserving of conservation attention. Other suggestions include:

- Use in combination with other data layers to identify additional areas of high ecological value. Layers to consider include: 1) terrestrial ecosystem-based core area selection index (see [tSelectionIndex.tif](#)), 2) index of ecological integrity (see [iei.tif](#)), 3) The Nature Conservancy's (TNC) terrestrial resiliency index (see [tResiliency.tif](#)), and 4) individual species landscape capability index (see [speciesLC.tif](#)).
- Use in combination with the secured lands layer ([secure.shp](#)) to identify the places in the network that remain unsecured from development, and thus could represent priorities for land protection.
- Use in combination with the probability of development layer (see [probDevelop.tif](#)) and local and regional vulnerability layers ([lVulnerable.tif](#), [rVulnerable.tif](#)) to identify places in the core-connector network that are relatively vulnerable to future development, and thus could represent priorities for land protection.
- Identify overlap between this network and resource priorities identified at the state or local level, but that are not available across the entire watershed (e.g., from State Wildlife Action Plans, towns, and land trusts), to further rank areas for land protection.

Although the terrestrial tier 1 core areas and connectors are presented as discrete entities, it is important to recognize that their boundaries are, in fact, "fuzzy" and are best interpreted as general places to focus attention.

Lastly, the tier 1 cores and connectors can and do include some low-intensity development, minor roads and agriculture. For the core areas, this is the result of growing out the cores from the highest-valued seed areas in which we elected to allow only major roads and medium-to-high intensity development to serve as barriers to spread. For the connectors, this is the result of the necessity of moving through such developed areas when moving between cores embedded in a developed landscape context.

### GIS Formats and Definitions

ESRI shapefile (polygons); including the following attributes for each polygon.

## ***DSL Project Component: Landscape Conservation Design***

- FID = ESRI assigned unique number (which we do not use) for each polygon.
- Shape = ESRI assigned feature type = "polygon".
- coreID = connectors all have an ID of 1, each core has a unique ID > 1.
- Type = indicator designating the polygon as: "t1core", "t2core", "t3core", or "connector".
- centroidX = easting for the centroid of the core.
- centroidY = northing for the centroid of the core.
- areaCount = size of the core area in number of cells (30x30 m); this includes any developed cells.
- areaHa = size of the core area in hectares; this includes any developed area.
- ieiSum = sum of the terrestrial core area selection index (see [tSelectionIndex.tif](#)), which is a reflection of both the size of the core and the quality of the cells within in it.
- ieiRank = rank of ieiSum (1 = max ieiSum).
- import = index of the importance of each core to the entire core area network based on its size/quality (as represented by ieiSum), proximity to other cores, and strategic position in the network. Specifically, it is an index reflecting how much the connectivity of the entire network would be affected by its removal. It gives the absolute decrease in the Probability of Connectivity ( $\Delta PC$ ) of the network.
- importRank = rank of import (1 = largest  $\Delta PC$ ).
- relImport = index of the importance of each core to the entire core area network without considering node value (i.e., sum of the core area selection index) in the calculation of  $\Delta PC$ . Note,  $\Delta PC$  is heavily influenced by node value. Thus, relImport is an alternative to import10k for rating the relative importance of cores that gives more influence to node position in the network than node value.
- relImpRank = rank of relImport (1= largest relImport).
- floodplain = percentage of the core comprised of TNC's tier 1 floodplains.
- rareCom = percentage of the core comprised of S1-S3 rare communities as defined and mapped by the state Heritage Programs.
- system1, system2, system3 = The top three terrestrial or wetland ecological systems for which the core is particularly important. In other words, for these systems the cumulative ecological integrity of the system within the core is greater than expected (from a statistical perspective) given its distribution across the entire core area network. Note, the systems listed here reflect the systems for which the core is especially important, but are not necessarily the most abundant systems in the core. A complete listing of the relative importance of the core for all ecological systems, including the relative abundance of systems within the core, is available separately in the Ecosystem table described below.

- species1, species2, species3 = The top three representative species for which the core is particularly important. In other words, for these species the cumulative climate response index (lc.tif) within the core is greater than expected (from a statistical perspective) given its distribution across the entire core area network. Note, the species listed here reflect the species for which the core is especially important, but are not necessarily the species with the highest total landscape capability in the core. A complete listing of the relative importance of the core for all species, including the total landscape capability in the core attributed to each species (index2, see below), is available in the Species table described below.
- scenario = internal use (file directory) to track the specific core area scenario.

### Detailed core area composition statistics

Detailed composition statistics are available for each core and are divided into ecosystems and species tables (see files in the tCoreStats folder). In these tables, there are four different indices computed (and their corresponding ranks) that represent different ways of understanding the relative importance of the cores to specific ecosystems or species. In all cases, larger values indicate greater importance.

#### *Ecosystem table:*

- coreID = unique number assigned to each core.
- systemName = name of the ecosystem as given in the ecological systems map (developed classes are not included).
- areaCount = number of cells of the corresponding system in the core. Note, because developed classes were excluded, the sum of areaCount across systems in the core as listed in this table may be less than the core area size as given in the layer attributes.
- areaHa = hectares of the corresponding system in the core.
- index1 = index of importance of the core for the corresponding system, based on deviation of the observed sum of the selection index for the system from its expected value, which is based on the size of the core and the system's average selection index and proportional representation across all cores. The index ranges from 0 to unbounded on the upper end; <1 indicates observed value less than expected, whereas >1 indicates the opposite.
- index1Rank = rank of index1 (1 = max index1).
- index2 = index of importance of the core for the corresponding system, defined as the percentage of the core's total selection index comprised of the corresponding system. The index ranges from 0-100.
- index2Rank = rank of index2 (1 = max index2).
- index3 = index of importance of the core for the corresponding system, defined as the percentage of the system's total selection index across all cores found in the focal core. The index ranges from 0-100.
- index3Rank = rank of index3 (1 = max index3).

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- index4 = index of importance of the core for the corresponding system, defined as the difference between the system's average selection index in the focal core and its average selection index across all cores. The index ranges from -1 to 1; negative values indicate an average selection index in the focal core less than its average across all cores, whereas positive values indicate the opposite.
- index4Rank = rank of index4 (1 = max index4).
- scenario = internal use (file directory) to track the specific core area scenario.

### *Species table:*

- coreID = unique number assigned to each core.
- speciesName = name of the representative species.
- sumLC = sum of the landscape capability (LC) index for corresponding species. For scenarios considering future climate conditions, the species' climate response (CR) index is used as the LC index, except for black bear which does not have a climate model and thus current LC is used instead.
- index1 = index of importance of the core for the corresponding species, based on deviation of the observed sum of the LC/CR index for the species from its expected value, which is based on the size of the core and the species' average LC/CR index across all cores. The index ranges from 0 to unbounded on the upper end; <1 indicates observed value less than expected, whereas >1 indicates the opposite.
- index1Rank = rank of index1 (1 = max index1).
- index2 = index of importance of the core for the corresponding species, defined as the percentage of the core's total LC/CR index comprised of the corresponding species. The index ranges from 0-100.
- index2Rank = rank of index2 (1 = max index2).
- index3 = index of importance of the core for the corresponding species, defined as the percentage of the species' total LC/CR index across all cores found in the focal core. The index ranges from 0-100.
- index3Rank = rank of index3 (1 = max index3).
- index4 = index of importance of the core for the corresponding species, defined as the difference between the species' average LC/CR index in the focal core and its average LC/CR index across all cores. The index ranges from -1 to 1; negative values indicate an average LC/CR index in the focal core less than its average across all cores, whereas positive values indicate the opposite.
- index4Rank = rank of index4 (1 = max index4).
- scenario = internal use (file directory) to track the specific core area scenario.

### **Terrestrial core tiers (tCoreTiers.shp)**

#### Description

This GIS product represents a three-tiered, spatially-nested hierarchy of terrestrial **core areas**. More specifically, this layer depicts the terrestrial tier 1 cores (as in tCoreNet.shp), (encompassing 25% of the landscape), nested within tier 2 cores (encompassing 50% of the landscape), nested with tier 3 road-bounded blocks (encompassing 77% of the landscape). The tiers reflect the arbitrariness in selecting thresholds for designating priority core areas. Tier 1 represents a highly strategic scenario designed to target the very best, highest priority core areas. Tier 2 represents a more liberal scenario and a correspondingly more lofty conservation goal. Tier 3 are the road-bounded blocks containing the tier 2 cores, in which all road classes except tracks and medium-to-high intensity development function as boundaries. Tier 3 areas, as defined, are intended to represent more practical on-the-ground conservation units and provide the supporting landscape necessary to ensure maintenance of the ecological values of the tier 1 and 2 cores in the future.

#### Considerations for Using Data Layer

The tiered cores provide spatial context for the strategic tier 1 core-connector network. Importantly, tier 2 and 3 identify places of ecological importance outside of the tier 1 core area network that can be used in combination with other sources of information to direct action (see [tCoreNet](#) for suggestions).

Although the tiered core areas are presented as discrete entities, it is important to recognize that their boundaries are, in fact, "fuzzy" and are best interpreted as general places to focus attention.

Lastly, as noted previously for the tier 1 cores and connectors, all three tiers can and do include some low-intensity development, minor roads and agriculture (see previous discussion).

#### GIS Formats and Definitions

ESRI shapefile (polygons); including the attributes described previously in [tCoreNet.shp](#) for each tier 1 polygon and each tier 2 multi-part polygon. Note, the tier 2 polygons may be multi-parted, consisting of several disjunct polygons surrounding one or more embedded tier 1 polygons. For convenience, these multi-part tier 2 polygons have been dissolved so that the attribute table contains a single row for each disjunct tier 2 core. However, to view the information associated with an individual tier 2 core when using the "identify" button in ArcMap, you must click on a part of the tier 2 core outside of the embedded tier 1 polygon. In addition, the tier 2 attributes do not contain the floodplain and rareCom fields as these are entirely contained with tier 1 cores.

### **Eastern meadowlark cores (eameCores.shp)**

#### Description

This GIS product represents a set of terrestrial **core areas** for the eastern meadowlark as a representative species for grasslands. In combination with the terrestrial tier 1 and 2 core areas (see [tCoreNet.shp](#) and [tCoreTiers.shp](#)), they spatially represent the ecological core area network derived from the CTR LCD project. The CTR LCD planning team decided that eastern meadowlark and the grasslands they represent warranted separate treatment from the other terrestrial representative species due to their unique association with a culturally created and maintained habitat. Consequently, eastern meadowlark and the grasslands they represent were not explicitly included in the derivation of the tier 1 and 2 core areas. However, some grasslands did get included in the tier 1 and 2 cores areas due to other considerations, such as meeting the needs of other representative species (e.g., wood turtle) that also use grasslands to some extent, and growing out cores from their seeds through lower-valued areas that included grasslands.

Eastern meadowlark cores were derived from the eastern meadowlark landscape capability ([eameLc.tif](#)) layer, which is a measure of habitat capability and climate suitability for the species. Briefly, for each disjunct patch of habitat (defined as contiguous cells having landscape capability index >0.03), we computed the maximum landscape capability index value. Next, we rank-ordered the habitat patches from highest value to lowest maximum value and selected the top number of patches in which the cumulative landscape capability value (i.e., the sum of the landscape capability index in the patches) equalled 50% of the species' total landscape capability value for the CTR watershed. Thus, the final set of 1448 eastern meadowlark cores captured 50% of the landscape capability for this species and represented 1.15% of the CTR landscape.

#### Considerations for Using Data Layer

The terrestrial tiered cores and connectors in combination with the eastern meadowlark cores can serve as a starting point for a regional conservation network that can be used in combination with other sources of information to direct action (see [tCoreNet](#) for suggestions).

Although the eastern meadowlark core areas are presented as discrete entities, it is important to recognize that their boundaries are, in fact, "fuzzy" and are best interpreted as general places to focus attention.

Lastly, as noted previously for the tier 1 cores and connectors, all three tiers can and do include some low-intensity development, minor roads and agriculture (see previous discussion).

#### GIS Formats and Definitions

ESRI shapefile (polygons); including the following attributes for each polygon:

- FID = ESRI assigned unique number (which we do not use) for each polygon.
- Shape = ESRI assigned feature type = "polygon".
- coreID = unique number assigned to each core.

**Terrestrial core areas: ecosystem summary (tCoreEcoSum.csv)**

Description

This table provides a quantitative summary of the ecosystem composition of the terrestrial tier1 and 2 core areas relative to the entire landscape. The table contains a single row for each ecological system occurring in the landscape and the following columns (fields):

- ecosystem = ecological system (note, ecosystem here is based on the field named 'sumgroupname' in the ArcGIS raster distributed by TNC named 'syst\_ne130930' , or the field named 'habitat' in the ArcGIS raster distributed by TNC named 'syst\_ne141611').
- formation = ecological formation, consisting of closely related ecosystems.
- landscapeHa = total hectares of the system in the landscape.
- T1CoreHa = total hectares of the system in the terrestrial tier 1 core areas.
- T1PercentArea = percentage of the system's landscape extent occurring in the terrestrial tier 1 core areas =  $\text{coreHa}/\text{landscapeHa} \times 100$ .
- T1PercentSi = percentage of the system's total selection index occurring in the terrestrial tier 1 core areas; i.e., what percent of the system's cumulative selection index across the entire landscape is encompassed by the terrestrial cores.
- T2CoreHa = total hectares of the system in the terrestrial tier 2 core areas (inclusive of tier 2).
- T2PercentArea = percentage of the system's landscape extent occurring in the terrestrial tier 2 core areas =  $\text{coreHa}/\text{landscapeHa} \times 100$  (inclusive of tier 1).
- T2PercentSi = percentage of the system's total selection index occurring in the terrestrial tier 2 core areas; i.e., what percent of the system's cumulative selection index across the entire landscape is encompassed by the terrestrial tier 2 cores (inclusive of tier 1).

**Terrestrial core areas: species summary (tCoreSpeciesSum.csv)**

Description

This table provides a quantitative summary of the representative species composition of the terrestrial tier 1 and 2 core areas relative to the entire landscape. The table contains a single row for each of the 14 representative terrestrial species and the following columns (fields):

- speciesName = representative species name.
- target = conservation target established by the planning team, expressed in terms of the proportion of the species' total current landscape capability targeted for inclusion in the terrestrial core areas. However, because we put a constraint on the total area of the landscape in terrestrial core areas (25%), these targets must be viewed as relative weights.
- landscapeLc = sum of the species' current (2010) landscape capability index across the entire landscape.
- T1CoreLc = sum of the species' current (2010) landscape capability index across the terrestrial tier 1 core areas.
- T1PercentLc = percentage of the species' current (2010) landscape capability index across the entire landscape contained within the terrestrial tier 1 core areas =  $\text{coreLc}/\text{landscapeLc} \times 100$ .
- T2CoreLc = sum of the species' current (2010) landscape capability index across the terrestrial tier 2 core areas (inclusive of tier 1).
- T2PercentLc = percentage of the species' current (2010) landscape capability index across the entire landscape contained within the terrestrial tier 2 core areas =  $\text{coreLc}/\text{landscapeLc} \times 100$  (inclusive of tier 1).

### **Species landscape capability (*speciesLC.tif*)**

#### Description

This GIS product represents the **landscape capability** index for each of the 14 representative terrestrial wildlife species, provided as separate data layers for each species. See the [DSL species documentation](#) for a detailed description of the landscape capability index and associated data products, including links to abstracts of each species' landscape capability model. The layer names are prefixed by the species acronym (e.g., blbwLc.tif for the blackburnian warbler landscape capability index). Landscape capability is an integrated measure of habitat capability, climate suitability and species' prevalence, and is based on a unique model developed for each species (see the separate abstracts to learn more about each species' model). Note, there are several different landscape capability indices that reflect different decisions (or assumptions) regarding how to incorporate current versus future land use and climate changes (see [DSL species documentation](#)). The layer provided here is based on the current landscape capability index which does not explicitly consider future land use or climate. The landscape capability index for the 14 representative terrestrial wildlife species is a major input to the building of terrestrial cores (see [tCoreNet.shp](#)).

#### Considerations for Using Data Layer

These layers provide a seamless and continuous valuation of landscape capability for each of the 14 representative terrestrial wildlife species. Importantly, these layers provide an ecological valuation of areas, both inside and outside designated core areas, and thus they can be used to identify places of high ecological value for one or more representative species outside of designated core areas that are also deserving of conservation attention. It is important to recognize that the landscape capability index provided here is in its raw scale form, and both the range and distribution of values varies dramatically among species, reflecting idiosyncrasies of each species' model. Consequently, the landscape capability index is not comparable across species. It can only be used separately for each species to evaluate the relative capability of one location against another to support that species.

It is important to note that the landscape capability index is not an estimate of occupancy. It does not give the probability that a cell will be occupied by the species. Rather, it is an index of the relative capability of a site to support reproduction and survival of the focal species in a home range centered on that cell. Other suggestions include:

- Use in combination with the species climate zones (see [speciesCZ2080.tif](#)) and climate response index (see [speciesCR2080.tif](#)) to evaluate the change in each species' landscape capability due to predicted climate change.
- Use in combination with the secured lands layer (see [secure.shp](#)) to identify places with high ecological value for one or more representative terrestrial wildlife species that remain unsecured from development, and thus could represent priorities for land protection.
- Use in combination with the integrated probability of development (see [probDevelop.tif](#)) and local vulnerability (see [IVulnerable.tif](#)) layers to identify places of high value for one or more representative terrestrial wildlife species that are relatively

vulnerable to future development, and thus could represent priorities for land protection.

**GIS Formats and Definitions**

Geotiff raster (30 m cells); cell value = landscape capability index; ranges from 0 (developed) to a theoretical maximum of 1 (but the observed maximum is often much less).

### **Terrestrial ecosystem-based core area selection index (tSelectionIndex.tif)**

#### Description

This GIS product represents the selection index used to create terrestrial ecosystem-based cores. The selection index is a continuous surface in which every cell is assigned a value (0-1) based on its relative ecological integrity and/or biodiversity value within each HUC6 watershed. Specifically, for all terrestrial and wetland cells, the selection index is a composite index derived from a weighted combination of the 1) weighted index of ecological integrity (*IEI*; see [iei.tif](#)), 2) TNC's terrestrial resiliency index (see [tResiliency.tif](#)), and a binary representation of 3) TNC's tier 1 floodplains and 4) S1-S3 rare natural communities as defined and mapped by the state Natural Heritage programs. For aquatic cells (which are also included in this layer), the index is equal to *IEI*, except in headwater creeks where *IEI* is averaged with USGS's stream temperature tolerance index (see [streamTolerance.tif](#)). In addition, to enhance the establishment of a well-distributed network of core areas for connectivity and climate adaptation, both *IEI* and TNC resiliency are stratified within each of the two HUC6 subwatersheds within the Connecticut River watershed. Specifically, *IEI* is scaled by ecological system such that it ranges from 0 (low) to 1 (high) within each ecological system within each HUC6 watershed. TNC's resiliency index is scaled such that it ranges from 0 (low) to 1 (high) within each geophysical setting class within each HUC6 watershed. Consequently, high values of the selection index represent all ecological systems and geophysical settings. Terrestrial core areas are created, in part, by choosing cells above a certain index value and spreading outwards from these "seeds" to build larger, buffered cores of relatively high ecological value.

#### Considerations for Using Data Layer

This layer provides a seamless and continuous valuation of ecological integrity and biodiversity value based on regionally available and consistent spatial data that reflects decisions by the CTR LCD planning team. Importantly, this layer provides an ecological valuation of areas both inside and outside designated core areas, and thus it can be used to identify places of high ecological value outside of designated core areas that are also deserving of conservation attention. The primary conservation application of this data layer is likely to be in conjunction with the terrestrial core network (see [tCoreNet.shp](#) and [tCoreTiers.shp](#)); see the description for tCoreNet.shp for application suggestions.

As an intermediate product in the development of tCoreNet.shp and tCoreTiers.shp, this product also is useful in understanding how the four component products described earlier in this section are integrated and how the core areas are generated. Note, cells representing TNC's tier 1 floodplains or the state's S1-S1 rare natural communities are assigned the maximum selection index of 1.

It is important to recognize that this selection index is scaled by HUC6 watershed so as to indicate the relative ecological integrity and/or biodiversity value within each HUC6 watershed.

#### GIS Formats and Definitions

## ***DSL Project Component: Landscape Conservation Design***

Geotiff raster (30 m cells); cell value = terrestrial core area selection index; ranges from 0 (developed) to 1 (maximum ecological value).

### **USGS stream temperature tolerance (streamTolerance.tif)**

#### Description

This GIS product represents a scaled version of the headwater stream temperature tolerance index based on a model developed by Dr. Ben Letcher and associates at the USGS Conte Anadromous Fish Lab, which is a measure of the relative sensitivity of stream temperatures to rising air temperatures. Specifically, sensitivity is measured by the slope of the linear relationship between air and stream temperatures during the spring season when air temperatures are rising. A steeper slope indicates that stream temperature responds faster to air temperature change, while a shallow slope indicates that stream temperature is more independent of air temperature change. Lower values (i.e., shallower slopes) are interpreted as being more tolerant under climate change, possibly because of groundwater influence or other factors. Conversely, streams with higher slopes are likely to be more impacted by increased air temperatures.

In the layer provided here, the raw rising slope index is inverted and (quantile) scaled by HUC6 watershed so that the least tolerant headwater creek (steepest slope) gets a 0 and the most tolerant (shallowest slope) gets a 1 within each watershed. This form of scaling has an intuitive interpretation, because the value of the index expresses the proportion of cells in the same watershed with a value less than or equal to that value. Thus, a value of 0.9 in a cell means that it has a score that is greater than 90% of all the headwater creek cells in that watershed, and all the cells with >0.9 values comprise the best 10% of all headwater creek cells within the watershed. USGS stream temperature tolerance index, as scaled here, is a major component of the aquatic core area selection index (see [aSelectionIndex.tif](#)) in headwater creeks. To learn more about USGS stream temperature tolerance, see [Dr. Ben Letcher's website](#).

#### Considerations for Using Data Layer

This layer provides a seamless and continuous valuation of stream temperature tolerance in headwater creeks. Importantly, this layer provides an ecological valuation of areas both inside and outside designated lotic core areas, at least within headwater creeks, and thus it can be used to identify places of high ecological value outside of designated core areas that are also deserving of conservation attention. Note, it is important to recognize that the layer provided here is not identical to the version developed by USGS because it has been inverted and (quantile) scaled by HUC6 watershed (as described above) for consistency with other landscape design products. A suggestion for combining this dataset with another dataset in the package is:

- Use in combination with the weighted index of ecological integrity (see [iei.tif](#)) to gain a more comprehensive evaluation of ecological integrity in headwater creeks.

#### GIS Formats and Definitions

Geotiff raster (30 m cells); cell value = USGS stream temperature tolerance index, rescaled; ranges from 0 (developed) to 1 (maximum ecological value).

### **Weighted index of ecological integrity (iei.tif and ieiAquatic.tif)**

#### Description

This GIS product represents the weighted **index of ecological integrity** (*IEI*), which is a measure of relative intactness (i.e., freedom from human modifications and disturbance) and resiliency to environmental change (e.g., as caused by disturbance and climate change). Raw *IEI* is a composite index derived from 19 different landscape metrics that measure different aspects of intactness and resiliency. For the derivation of this layer, raw *IEI* is (quantile) scaled by ecological system and HUC6 watershed so that the poorest cell of each ecological system gets a 0 and the best gets a 1 within each watershed. In the layer provided here, scaled *IEI* has been modified to reflect weights assigned to each ecological system by the planning team, such that the final index gives more emphasis to certain terrestrial and wetland ecological systems deemed more vulnerable or in greater need of conservation (e.g., wetlands, alpine, boreal upland forest). Note that weights were not applied to aquatic systems. Thus, *ieiAquatic.tif*, which is provided for convenience in displaying the results of the aquatic conservation design but is otherwise equivalent to *iei.tif* except that it only has values for aquatic cells (all non-aquatic cells are set to nodata), is technically unweighted *IEI*. Weighted *IEI* is a major component of the terrestrial and aquatic core area selection indices (see [tSelectionIndex.tif](#) and [aSelectionIndex.tif](#), respectively) and thus the terrestrial and aquatic network of core areas (see [tCoreNet.shp](#), [tCoreTiers.shp](#), [loticCores.shp](#) and [lenticCores.shp](#)).

#### Considerations for Using Data Layer

This layer provides a seamless and continuous valuation of ecological integrity based on regionally available and consistent spatial data that reflects decisions by the planning team. Importantly, this layer provides an ecological valuation of areas both inside and outside designated core areas, and thus it can be used to identify places of high ecological value outside of designated core areas that are also deserving of conservation attention. It is important to recognize that the *IEI* index provided here is scaled so as to indicate the relative ecological integrity value of cells within each HUC6 watershed (as described above) for consistency with other landscape design products. Other suggestions include:

- Use in combination with the terrestrial and aquatic core area products (see links above) to identify places of high ecological value outside of designated cores.
- Use in combination with the secured lands layer (see [secure.shp](#)) to identify places with high ecological value that remain unsecured from development, and thus could represent priorities for land protection.
- Use in combination with the integrated probability of development (see [probDevelop.tif](#)) and local vulnerability (see [lVulnerable.tif](#)) layers to identify places of high value that are relatively vulnerable to future development, and thus could represent priorities for land protection.
- Use in combination with TNC's terrestrial resiliency index (see [tResiliency.tif](#)) to gain a more comprehensive evaluation of ecological integrity. Specifically, use weighted *IEI* as an assessment of intactness and short-term resiliency based on connectivity to an

ecologically similar neighborhood, and use TNC's resiliency index as an assessment of long-term resiliency based on connectivity to diverse landforms and elevations.

**GIS Formats and Definitions**

Geotiff raster (30 m cells); cell value = *IEI*; ranges from 0 (developed) to 1 (maximum ecological value).

### **TNC terrestrial resiliency (tResiliency.tif)**

#### Description

This GIS product represents a scaled version of the terrestrial resiliency index developed by Mark Anderson and associates at The Nature Conservancy (Anderson et al 2012), which is a measure of the relative long-term resiliency of a site based on connectivity to a diversity of landforms, elevations and wetlands. Specifically, in the Northeast, sites are compared with other sites of the same geophysical setting based on geology, elevation zone, and ecoregion. Within each geophysical setting class, sites are compared with respect to two metrics: 1) landscape diversity, which refers to the number of microhabitats and climatic gradients available within a given area based on the variety of landforms, elevation range, and wetland density, and 2) local connectedness, which refers to the accessibility of neighboring natural areas.

In the layer provided here, the raw resiliency index is (quantile) scaled by geophysical setting class and HUC6 watershed so that the poorest cell of each geophysical setting gets a 0 and the best gets a 1 within each watershed. This form of scaling has an intuitive interpretation, because the value of the index expresses the proportion of cells in the same geophysical setting and watershed with a value less than or equal to that value. Thus, a value of 0.9 in a cell means that it has a resiliency score that is greater than 90% of all the cells of the same geophysical setting in that watershed, and all the cells with >0.9 values comprise the best 10% of all cells across all geophysical settings within the watershed. TNC's resiliency index, as scaled here, is a major component of the terrestrial core area selection index (see [tSelectIndex.tif](#)) and thus the terrestrial core area network (see [tCoreNet.shp](#) and [tCoreTiers.shp](#)). To learn more about TNC's resiliency index, see: [Resiliency page at TNC's Conservation Gateway](#).

#### Considerations for Using Data Layer

This layer provides a seamless and continuous valuation of terrestrial resiliency based on the geophysical template as defined and implemented in TNC's terrestrial resiliency index. Importantly, this layer provides an ecological valuation of areas both inside and outside designated core areas, and thus it can be used to identify places of high ecological value outside of designated core areas that are also deserving of conservation attention. Note, it is important to recognize that the layer provided here is not identical to the version distributed by TNC because it has been (quantile) scaled by geophysical setting and HUC6 watershed (as described above) for consistency with other landscape design products.

Other suggestions include:

- Use in combination with the terrestrial core area network (see link above) to identify places of high ecological value outside of designated cores.
- Use in combination with the secured lands layer (see [secure.shp](#)) to identify places with high ecological value that remain unsecured from development, and thus could represent priorities for land protection.
- Use in combination with the integrated probability of development (see [probDevelop.tif](#)) and local vulnerability (see [IVulnerable.tif](#)) layers to identify places of

high value that are relatively vulnerable to future development, and thus could represent priorities for land protection.

- Use in combination with the weighted index of ecological integrity (see [iei.tif](#)) to gain a more comprehensive evaluation of ecological integrity. Specifically, use weighted *IEI* as an assessment of intactness and short-term resiliency based on connectivity to an ecologically similar neighborhood, and use TNC's resiliency index as an assessment of long-term resiliency based on connectivity to diverse landforms and elevations.

#### GIS Formats and Definitions

Geotiff raster (30 m cells); cell value = TNC resiliency index, rescaled; ranges from 0 (developed) to 1 (maximum ecological value).

### **Regional conductance (rConduct.tif)**

#### Description

This GIS product represents the **regional conductance** index, which is a measure of the total potential amount of movement of plants and animals (ecological flow) through a cell from nearby terrestrial core areas at the scale of a few to ten kilometers. Regional conductance increases with the size and proximity of nearby cores, because larger cores produce larger numbers of plants and animals and the probability of an individual getting to any particular location decreases with distance from the source. Regional conductance also reflects the resistance of the focal cell and intervening cells between the nearby cores based on their ecological dissimilarity to the cells in the nearby cores. For example, a forest cell between largely forested cores would have higher regional conductance than if it were lake. Regional conductance differs from local conductance (see [lConduct.tif](#)) in that it is based on a designated core area network and measures the amount of ecological flow between the designated cores.

#### Considerations for Using Data Layer

This layer provides a seamless and continuous index of conductance between designated terrestrial cores. Importantly, this metric is contingent upon the a priori designation of core areas and thus is primarily useful in the context of landscape conservation design. In particular, this product can be used to identify places that confer connectivity between cores and thereby contribute to the connectivity of the entire regional core area network. As with local conductance, the absolute value of regional conductance is not particularly meaningful, nor does it necessarily reflect connectivity between cores for any single species. Regional conductance can be used in combination with local conductance to identify places that confer greater connectivity to the terrestrial core area network. Use local conductance within cores and regional conductance between cores (note that the two products are scaled differently and thus the absolute values cannot be compared between products).

#### GIS Formats and Definitions

Geotiff raster (30 m cells); cell value = local conductance; ranges from near 0 (no conductance) to a theoretical maximum of 1 (but the maximum observed value is typically quite small).

### **Probability of development (probDevelop.tif)**

#### Description

This GIS product represents the integrated probability of development between 2010-2080 based on a custom urban growth model that accounts for the type (low intensity, medium intensity and high intensity), amount and spatial pattern of development. This index represents the probability of development occurring sometime between 2010 and 2080 at the 30 m cell level. The projected amount of development in an area is downscaled from county level forecasts based on a U.S. Forest Service 2010 Resources Planning Act (RPA) assessment. The type and pattern of development is based on models of historical development and is influenced by factors such as geophysical conditions (e.g., slope, proximity to open water), existing secured lands, and proximity to roads and urban centers.

#### Considerations for Using Data Layer

This layer provides a seamless and continuous representation of the integrated probability of development between 2010-2080. This product can be used in combination with any of the other design products that reveal places of high ecological value to indicate places of ecological value that are at risk of development and thus may warrant land protection. This product also can be used to identify places at risk of future development independent of designated core areas and any formal landscape conservation design. Although this index is a true probability, it is perhaps best used in a relative manner to compare values from one location to another.

Precautions apply in using this dataset:

- Probability of development is highest near existing roads in part because the urban growth model does not attempt to predict the building of major new roads and the development associated with them.
- At the 30m cell level there are known gross errors in the National Land Cover Dataset (NLCD) from which development is mapped and the probability of development is modeled. Therefore, this layer is best used as a general indication of where development is likely to occur; results at the cell level are not expected to be highly reliable.

#### GIS Formats and Definitions

Geotiff raster (30 m cells); cell value = probability of development; ranges from 0 (e.g., secured land, water, already developed) to a theoretical maximum of 1.

### **Regional vulnerability of conductance (rVulnerable.tif and rVulnConnectors.tif)**

#### Description

This GIS product represents the regional vulnerability of conductance index, which reflects the likelihood of development occurring in places that confer connectivity between terrestrial cores. Specifically, regional vulnerability is the product of the regional conductance index (i.e., total amount of ecological flow through a cell from nearby terrestrial cores; see [rConduct.tif](#)), regional irreplaceability index (i.e., proportion of the total ecological flow between nearby terrestrial cores that flows through each cell), and the integrated future probability of development between 2010-2080 (see [probDevelop.tif](#)). Cells with relatively low regional conductance and where flow is relatively dispersed have low vulnerability regardless of their risk of development, since regional connectivity will not be degraded too much if they get developed. Regional vulnerability is greatest where there is high regional conductance and where the flow is concentrated; i.e., in narrow "corridors" of ecologically similar areas with relatively low levels of current development between large nearby cores, and where there is also relatively high probability of development in the future.

#### Considerations for Using Data Layer

This layer provides a seamless and continuous representation of the vulnerability to development of cells important to the connectivity of the terrestrial core area network. The regional vulnerability index is computed for every cell, whether it is between terrestrial cores or within a core, but the index is primarily useful for assessing the vulnerability of cells between cores. Moreover, the index is best used in a relative manner to compare values from one location to another. Importantly, this index is contingent upon the a priori designation of core areas and thus is primarily useful in the context of landscape conservation design. In particular, this layer may be especially useful for identifying places within the designated connectors that are highly vulnerable to development. For this reason, the data package includes a separate GIS layer (rVulnConnectors.tif) in which rVulnerable.tif has been clipped to the extent of the connectors.

Precautions outlined for the integrated probability of development layer (see [probDevelop.tif](#)) also apply to this layer. Consequently, this layer is best used as a general indication of where regional connectivity is most vulnerable to development.

#### GIS Formats and Definitions

Geotiff raster (30 m cells); cell value = regional vulnerability index; ranges from 0 (e.g., secured land, water, already developed) to <100.

### **Local conductance (lConduct.tif)**

#### Description

This GIS product represents the **local conductance** index, which is a measure of the total potential amount of movement of plants and animals (ecological flow) through a cell from neighboring cells as a function of the ecological similarity between the focal cell and neighboring cells at the scale of one to a few kilometers. The conductance of a focal cell is affected by the amount of development and ecological similarity of its neighborhood (within one to a few kilometers) as well as the resistance of the focal cell itself (i.e., its ecological dissimilarity to neighboring cells). Conductance increases as the proportion of the neighborhood that is undeveloped increases, as the ecological similarity among neighboring cells increases, and as the ecological similarity between the focal cell and its neighbors increases. For example, a forested cell surrounded by forested cells would have high conductance, whereas a forest cell surrounded by aquatic and wetland cells would have lower conductance, and a forested cell surrounded by development would have the least conductance.

#### Considerations for Using Data Layer

This layer provides a seamless and continuous index of local conductance that is independent of any designated core area network. Thus, this product can be used to identify places that confer connectivity at the local scale (one to a few kilometers) independent of designated core areas and any formal landscape conservation design. Note, it is best to consider the relative values from one location to another rather than trying to interpret the absolute value of conductance. In addition, local conductance is based on ecological similarity between locations and thus may not reflect connectivity for any single species.

Local conductance can be used in combination with regional conductance (see [rConduct.tif](#)) to identify places that confer greater connectivity to the terrestrial core area network. Use local conductance within cores and regional conductance between cores (note that the two conductance products are scaled differently and thus the absolute values cannot be compared).

#### GIS Formats and Definitions

Geotiff raster (30 m cells); cell value = local conductance; ranges from near 0 (no conductance) to a theoretical maximum of 1.

### **Local vulnerability of conductance (IVulnerable.tif and IVulnCores.tif)**

#### Description

This GIS product represents the local vulnerability of conductance index, which reflects the likelihood of development occurring in places with high local conductance. Specifically, this index is computed as the product of the integrated probability of development between 2010-2080 (see [probDevelop.tif](#)) and the local conductance index (see [lConduct.tif](#)). Thus, cells that confer high local conductivity at the scale of one to a few kilometers that also have a high probability of development are most vulnerable. Conversely, cells that confer high local conductivity but have a low probability of development are relatively less vulnerable.

#### Considerations for Using Data Layer

This layer provides a seamless and continuous representation of the vulnerability of cells important to local connectivity being developed between 2010-2080. The local vulnerability index is computed for every cell independent of designated core areas and any formal landscape conservation design, and it is best used in a relative manner to compare values from one location to another. This layer can be used to identify important places -- those that confer local connectivity -- at risk of future development independent of designated core areas. However, this layer can also be used in a complementary manner with the regional vulnerability layer, whereby regional vulnerability is used to assess vulnerability between core areas (or just in the designated connectors: rVulnConnectors.tif) and local vulnerability is used to assess vulnerability within core areas. For this reason, the data package includes a separate GIS layer (IVulnCores.tif) in which IVulnerable.tif has been clipped to the extent of the terrestrial cores.

Precautions outlined for the integrated probability of development layer (see [probDevelop.tif](#)) also apply to this layer. Consequently, this layer is best used as a general indication of where local connectivity is most vulnerable to development.

#### GIS Formats and Definitions

Geotiff raster (30 m cells); cell value = local vulnerability index; ranges from 0 (e.g., secured land, water, already developed) to a theoretical maximum of 1.

### **Species climate zones (*speciesCZ2080.tif*)**

#### Description

This GIS product represents the climate zones for each of the 14 representative terrestrial wildlife species, provided as a separate data layer for each species. See the [DSL species documentation](#) for a detailed description of the climate zones and other species data products. Climate zones are derived by intersecting the species' current and future climate niche envelopes (CNE) averaged across RPC 4.5 and 8.5 climate change scenarios. The CNE is a binary representation of where the species is expected to occur due solely to climate suitability (i.e., ignoring habitat). Climate zones depict three distinct zones of uncertainty in the predicted future distribution of a species based solely on climate suitability: 1) *zone of persistence* - overlap of the current and future CNE; thus, where the climate is suitable today and is expected to remain suitable through 2080, and consequently where we have high confidence in the species' predicted future occurrence; 2) *zone of contraction* - current CNE outside of the future CNE; thus, where the future climate is no longer predicted to be suitable, and consequently where we have lower confidence in the species' predicted future occurrence due to unknown population time lags and other factors; and 3) *zone of expansion* - future CNE outside of the current CNE; thus, where the future climate becomes suitable but is not currently suitable, and consequently where we have lower confidence in the species' predicted future occurrence due to unknown population time lags and other factors. These climate zones are an attempt to depict the extent to which a species distribution is expected remain stable, contract or expand due solely to predicted climate changes through 2080 (i.e., ignoring habitat changes). Climate zones for the 14 representative terrestrial wildlife species were not used as an input to the building of terrestrial cores (see [tCoreNet.shp](#) and [tCoreTiers.shp](#)), but are provided as an overlay to help inform the design with respect to potential climate change impacts.

#### Considerations for Using Data Layer

These layers provide a seamless and continuous valuation of expected changes in climate suitability for each of the 14 representative terrestrial wildlife species. Importantly, these layers provide an ecological valuation of areas, both inside and outside designated core areas, and thus they can be used to identify places of high ecological value for one or more representative species outside of designated core areas that are also deserving of conservation attention. It is important to recognize that the climate zones depicted here reflect the expected changes in a species 'potential' distribution due solely to changes in climate suitability; they do not reflect changes in a species distribution driven by habitat alterations. Consequently, the climate zones should not be interpreted as a species distribution map, but rather as a quick and easy way to visually assess the degree to which future climate conditions are expected to improve or worsen for a species. In addition, note that because black bear is a wide-ranging species, it does not have a climate suitability model, and thus it does not have climate zones.

Other suggestions include:

- Use in combination with the species current landscape capability index (see [speciesLC.tif](#)) and climate response index (see [speciesCR2080.tif](#)) to evaluate the change in each species' landscape capability due to predicted climate change.

## ***DSL Project Component: Landscape Conservation Design***

- Use in combination with the secured lands layer (see [secure.shp](#)) to identify places with high ecological value for one or more representative terrestrial wildlife species (e.g., zone of persistence or expansion) that remain unsecured from development, and thus could represent priorities for land protection.
- Use in combination with the integrated probability of development (see [probDevelop.tif](#)) and local vulnerability (see [IVulnerable.tif](#)) layers to identify places of high value for one or more representative terrestrial wildlife species that are relatively vulnerable to future development, and thus could represent priorities for land protection.

### **GIS Formats and Definitions**

Geotiff raster (30 m cells); cell value = climate zone; ranges from 0-3, as follows:

- 0 = outside of any climate zone
- 1 = zone of contraction
- 2 = zone of expansion
- 3 = zone of persistence

### **Species climate response (*speciesCR2080.tif*)**

#### Description

This GIS product represents the climate response index for each of the 14 representative terrestrial wildlife species, provided as a separate data layer for each species. See the [DSL species documentation](#) for a detailed description of the climate response index and other species data products. Climate response is one of several different measures of landscape capability that reflect different decisions (or assumptions) regarding how to incorporate current versus future land use and climate changes. The climate response index is based on the current landscape capability (see [speciesLC.tif](#)) and predicted climate conditions in 2080 (averaged between RCP 4.5 and 8.5 scenarios). Specifically, this index is based on (1) current habitat conditions (reflecting current land use patterns) and (2) the average of current and future climate conditions. The climate response index is an attempt to emphasize areas that provide the best habitat and climate conditions today and where future climate conditions through 2080 are likely to remain suitable. The climate response index for the 14 representative terrestrial wildlife species was not used as an input to the building of terrestrial cores (see [tCoreNet.shp](#) and [tCoreTiers.shp](#)), but is provided as an overlay to help inform the design with respect to potential climate change impacts.

#### Considerations for Using Data Layer

These layers provide a seamless and continuous valuation of landscape capability based on the climate response index for each of the 14 representative terrestrial wildlife species. Importantly, these layers provide an ecological valuation of areas, both inside and outside designated core areas, and thus they can be used to identify places of high ecological value for one or more representative species outside of designated core areas that are also deserving of conservation attention. It is important to recognize that the climate response index provided here is in its raw scale form, and both the range and distribution of values varies dramatically among species, reflecting idiosyncrasies of each species' model. Consequently, the climate response index is not comparable across species. It can only be used separately for each species to evaluate the relative capability of one location against another to support that species. In addition, note that because black bear is a wide-ranging species, it does not have a climate suitability model, and thus it does not have a climate response index.

It is important to note that the climate response index is not an estimate of occupancy. It does not give the probability that a cell will be occupied by the species. Rather, it is an index of the relative capability of a site to support reproduction and survival of the focal species in a home range centered on that cell taking into consideration future climate suitability. Other suggestions include:

- Use in combination with the species current landscape capability index (see [speciesLC.tif](#)) to evaluate the change in each species' landscape capability due to predicted climate change.
- Use in combination with the secured lands layer (see [secure.shp](#)) to identify places with high ecological value for one or more representative terrestrial wildlife species that remain unsecured from development, and thus could represent priorities for land protection.

## ***DSL Project Component: Landscape Conservation Design***

- Use in combination with the integrated probability of development (see [probDevelop.tif](#)) and local vulnerability (see [LVulnerable.tif](#)) layers to identify places of high value for one or more representative terrestrial wildlife species that are relatively vulnerable to future development, and thus could represent priorities for land protection.

### GIS Formats and Definitions

Geotiff raster (30 m cells); cell value = climate response index; ranges from 0 (developed) to a theoretical maximum of 1 (but the observed maximum is often much less).

### **Climate stress (climate.tif)**

#### Description

This GIS product represents the climate stress metric, which is a measure of the estimated climate stress that may be exerted on a focal cell in 2080. Specifically, the climate stress metric reflects the 2080 departure from the current climate conditions that a cell may be exposed to in relation to its current climate niche breadth. Essentially, this metric measures the magnitude of climate change stress at the focal cell based on the climate niche of the corresponding ecological system (based on 2010) and the predicted change in climate (i.e., how much is the climate of the focal cell moving away from the climate niche of the corresponding ecological system) between 2010-2080 based on the average of two climate change scenarios: RCP 4.5 and 8.5. Cells where the predicted climate suitability in the future decreases (i.e., climate is becoming less suitable for that ecological system) are considered stressed, and the stress increases as the predicted climate becomes less suitable based on the ecological system's current climate niche model. Conversely, cells where the predicted climate suitability in the future increases (i.e., climate is improving for that ecological systems) are considered unstressed and assigned a value of zero.

#### Considerations for Using Data Layer

This layer provides a seamless and continuous index of climate stress independent of any designated core area network. Thus, this product can be used to identify places that are likely to experience climate stress in the future independent of designated core areas and any formal landscape conservation design. Other suggestions include:

- Use in combination with the sea level rise metric (see [seaRise.tif](#)) to identify places within coastal systems that are predicted to become doubly stressed by both climate change (via air temperature and precipitation) and sea level rise.
- Use in combination with the terrestrial core area network (see [tCoreNet.shp](#) and [tCoreTiers.shp](#)) to identify places within designated cores that are likely to face stress from climate stress in the future.

Precautions apply in using this dataset:

- Because climate niche models are developed and applied separately for each ecological system, it is best to consider climate stress separately for each ecological system. Abrupt changes in the absolute value of the climate stress metric between adjacent cells is likely to be due to changes in the underlying mapped ecological system; it does not reflect an abrupt change in the absolute climate stress. Consequently, it is best to use an ecological system mask when viewing the results.
- This layer reveals the magnitude of climate change stress; it does not reveal places where climate suitability is improving for a particular system.
- Although it does not affect the CTR LCD, it is worth noting that we excluded the climate stressor metric for ecological systems that range beyond the southern edge of the Northeast region to avoid building climate niche models on a small portion of the system's range.

GIS Formats and Definitions

Geotiff raster (30 m cells); cell value = climate stress index; ranges from 0 (no change or improving climate suitability between 2010-2080) to 1 (100% decrease in climate suitability between 2010-2080). Note, this is equivalent to  $(\text{climateNiche2010.tif} - \text{climateNiche2080}) \times \text{climateNiche2010}$ , and set to zero if negative.

### **Sea level rise (seaRise.tif)**

#### Description

This GIS product represents the sea level rise metric based on a model developed by Rob Theiler and associates at USGS Woods Hole, which is a measure of the probability of a focal cell being unable to adapt to predicted inundation by sea level rise. Specifically, whether a site gets inundated by salt water permanently due to sea level rise or intermittently via storm surges associated with sea level rise clearly determines whether an ecosystem can persist at a site and thus its ability to support a characteristic plant and animal community. USGS examined future sea-level rise impacts on the coastal landscape from Maine to Virginia by producing spatially-explicit, probabilistic predictions using sea-level projections (based on an average of two climate change scenarios: RCP 4.5 and 8.5), vertical land movement (due to glacial isostasy) rates, elevation, and land cover data. The data span the coastal zone from an elevation of 5 m inland to -10 m offshore, and are provided for the forecast year 2080.

In the layer provided here, the raw coastal response metric produced by USGS is scaled and inverted so that a cell with high probability of exhibiting a dynamic (or adaptive) response to sea level rise gets a zero (low stress) and a cell with low probability of exhibiting a dynamic response gets a value approaching 1 (high stress). In addition, we set all cells classified as sub-tidal to nodata for consistency with other products. To learn more about USGS's coastal response model, see [Lentz et al. \(2015\)](#).

#### Considerations for Using Data Layer

This layer provides a seamless and continuous index of the capacity of a site to adapt to sea level rise independent of any designated core area network. Thus, this product can be used to identify places that are likely to experience stress from sea level rise in the future independent of designated core areas and any formal landscape conservation design. Note, it is important to recognize that the layer provided here is not identical to the data product distributed by USGS because it has been scaled to range 0-1 and inverted so that larger values indicate greater stress -- for consistency with other stressor metrics. Other suggestions include:

- Use in combination with the climate stress metric (see [climate.tif](#)) to identify places within coastal systems that are predicted to become doubly stressed by both climate change (via air temperature and precipitation) and sea level rise.
- Use in combination with the terrestrial core area network (see [tCoreNet.shp](#) and [tCoreTiers.shp](#)) to identify places within designated cores that are likely to face stress from sea level rise in the future.

A precaution applies in using this dataset. Because sea level rise predictions at the 30 m cell level are highly dependent on the mapped elevation above sea level, the model predictions are highly pixelated due to noise in the digital elevation model. In addition, some sections of the coast do not have LIDAR-enhanced digital elevation models (DEM) in the National Elevation Dataset used here, and thus there is often a notable seam or abrupt change in the predicted coastal response that is an artifact of the DEM and not reflective of reality. Lastly, because the predicted coastal response is highly dependent on the mapped ecological system, errors in the ecological systems map translate into errors in the sea level rise metric at the 30 m cell level. For these and other reasons, this layer is best used as a general indication of where sea level rise is likely to cause problems; results at the cell level are not expected to be highly reliable.

### **GIS Formats and Definitions**

Geotiff raster (30 m cells); cell value = sea level rise index; ranges from 0 (no sea level impacts expected between 2010-2080) to a theoretical maximum of 1 (100% probability of an inundation response between 2010-2080), although in practice the maximum is never realized.

### **Terrestrial road passage structure impacts (passages.shp)**

#### Description

This GIS product represents opportunities to restore connectivity for terrestrial wildlife by building road passage structures. Specifically, this product tabulates the results of a model in which each 300 meter segment of road outside of urban centers, and excluding minor roads receiving relatively little traffic, has a passage structure installed (virtually). Next, we (virtually) reduce the value of the terrestrial barrier and traffic setting variables by 90% for the road cells associated with the passage structure, one at a time. The predicted improvement in connectedness from the passage structure is then recorded. The delta, or difference, in the connectedness score, before and after the installation of the passage structure for each cell within the affected neighborhood, is computed and multiplied by the average index of ecological integrity (*IEI*) of the affected neighborhood. The weighting by *IEI* emphasizes the potential ecological benefits of a road passage structure in an area that is otherwise in good condition but depressed by the road barrier.

#### Considerations for Using Data Layer

The restoration score (impact) is an index of the potential improvement in local connectedness to be achieved in places where it matters most -- where the current ecological integrity is not already severely degraded. Based on these restoration scores and the corresponding ranks, road segments can be prioritized for restoration. Note, these road passage restoration scores do not take into account other socio-economic considerations, such as the cost of a particular passage structure given local engineering considerations, which ultimately will determine the cost-benefit tradeoffs of any particular passage structure. Given the large number of potential road crossings, it may be useful to bin the road crossings into categories representing high, medium and low impact, or simply threshold the restoration (impact) score or its rank (see below) at some level to highlight the highest priority road crossing locations.

This layer may best be used to direct field surveys of road crossings of interest, during which complete and accurate assessments can be made. It can also be used in combination with the terrestrial core-connector network (see [tCoreNet.shp](#) and [tCoreTiers.shp](#)) to identify places where road crossing improvements and restoration may have the added benefit of improving the integrity of the designated terrestrial cores or improving the conductance of the connector.

Use of this layer should be done considering the scope and limitations of this dataset:

- Because of known data gaps and errors inherent in the source data, the data layer should be used cautiously. The roads data are known to include both errors of omission (i.e., missing roads) and commission (i.e., false roads). Terrestrial barrier scores are intended to reflect the physical and psychological impediments to wildlife movement across roads; the scores are assigned by road class (e.g., primary road, secondary road, or local road) based on the average physical characteristics of each road class, but they do not take into account local information (due to the lack of data) about the actual physical character of the road, nor do they account for other sources of physical barriers to wildlife movement such as Jersey barriers and fencing. The

interpolated road traffic rates that are used to estimate wildlife mortality rates have substantial uncertainty (noisiness); thus, the modeled traffic rate may not accurately reflect the actual traffic rate on a road segment.

- The road passage restoration score represents the potential gain in local connectivity from installing a single wildlife passage structure without considering other potential nearby restoration actions to improve connectivity. Due to the computational challenges, we did not consider the benefit of installing multiple road passage structures in nearby locations. However, it is quite possible that there would be synergy in installing multiple structures, and this should be considered in prioritizing any location for restoration.
- The road passage restoration scores do not take into account the combined benefits of installing a terrestrial wildlife passage structure at a road-stream crossing, and thereby increase both terrestrial connectedness and aquatic connectedness with the same structure. Clearly, all other things being equal, placing a road passage structure at a close-by road-stream crossing makes sense since the potential gains in connectivity are much greater.

### GIS Formats and Definitions

ESRI shapefile (points); including the following attributes for each point:

- FID = ESRI assigned unique number (which we do not use) for each point.
- Shape = ESRI assigned feature type = "point".
- passageid = unique number assigned to each road segment.
- x\_coord = easting.
- y\_coord = northing.
- base = sum of connectedness in the vicinity of the road segment under the current conditions without a passage structure.
- alt = sum of connectedness in the vicinity of the road segment after installing (virtually) the road passage structure.
- delta =  $(alt - base) * 1000$ , the potential improvement in connectedness from installing the road passage structure.
- impact = delta weighted by the average Index of Ecological Integrity of the affected neighborhood.
- impactLn = natural log of impact.
- rank = rank of impact (out of 25,989 passages).

### **Lotic (river and stream) cores (loticCores.shp)**

#### Description

This GIS product represents the set of lotic (river and stream) **core areas**. In combination with the lentic (lake and pond) cores (see [lenticCores.shp](#)) and terrestrial cores and connectors (see [tCoreNet.shp](#) and [tCoreTiers.shp](#)), they spatially represent the ecological network derived from the CTR LCD project. The network is designed to provide strategic guidance for conserving natural areas, and the fish, wildlife, and other components of biodiversity that they support, within the Connecticut River watershed.

**Core areas** serve as the foundation of the conservation design. They reflect decisions by the CTR LCD planning team about the highest priority areas for sustaining the long-term ecological values of the watershed, based on currently available, regional-scale information. **Lotic cores** represent the following:

- 1) streams of relatively high **ecological integrity** across all lotic (i.e., riverine) ecosystem types, emphasizing rivers and streams that are relatively intact (i.e., free from human modifications and disturbance locally and within the upstream catchments) and resilient to environmental changes (e.g., climate change). Integrity has the potential to remain high, both in the short-term due to the connectivity to similar natural environments within the riverine network, and in the long-term for headwater streams due to the relative insensitivity of stream temperature to air temperature changes;
- 2) headwater streams of relatively high current habitat value (i.e., **landscape capability**) for **brook trout**, emphasizing streams that provide the best habitat conditions under current climate conditions; and
- 3) Large and medium rivers that provide habitat for **anadromous fish**, including the portions of the mainstem and major tributaries of the Connecticut River from the mouth of the river upstream to the limit of passability for American shad, blueback herring, shortnose sturgeon, alewife, and sea lamprey.

Core areas are built from focal areas with high value based on one or more of the attributes listed above. These "seed areas" are expanded upstream and downstream to include areas that provide additional ecological value and resilience to long-term change and to encompass a minimum of 1 km in stream length. Consequently, the cores may include sections of lower-valued streams and extend beyond road-stream crossings; however, they do not extend past dams.shp. Collectively, lotic core areas encompass 28% of the total stream length in the CTR watershed, as decided by the partnership. A total of 523 lotic core areas have been identified, ranging in stream length from 1 to 442 km, with an average stream length of 16 km.

#### Considerations for Using Data Layer

This set of lotic core areas can serve as a starting point that can be used in combination with other sources of information to direct specific management and conservation actions or decisions. Although the lotic cores are presented as discrete entities, it is important to recognize that their boundaries are, in fact, "fuzzy" and are best interpreted as general places to focus attention. Lotic cores are not the only places of high ecological value within the riverine network deserving of conservation attention. Suggestions for combining the lotic core network with other sources of information include:

- Use in combination with the foundational data layers to identify additional areas of high ecological value. Layers to consider include: 1) aquatic ecosystem-based core area selection index (see [aSelectIndex.tif](#)), 2) index of ecological integrity (see [iei.tif](#)), 3) USGS headwaters stream temperature tolerance index (see [streamTolerance.tif](#)), and 4) brook trout current probability of occupancy (see [brookTroutLc.shp](#)).
- Use in combination with landscape capability layers for other stream-dependent representative species, such as Louisiana waterthrush and wood turtle (see [speciesLC.tif](#)), to identify core areas with additional ecological value.
- Use the aquatic buffers layer (see [aquaticBuffers.tif](#)) to identify places predicted to have a strong influence on the ecological integrity of the lotic cores; i.e., places where anthropogenic disturbances may adversely affect the lotic cores through watershed processes such as nitrification and sedimentation.
- Use in combination with the dam removal impacts layer (see [dams.shp](#)) and culvert upgrade impacts layer (see [culverts.shp](#)) to identify places where the integrity of the aquatic cores is limited by dams and/or culverts, and thus may represent priorities for restoration.

Use of the aquatic core network should be done considering the scope and limitations of this dataset:

- For convenience, the size of each core area is expressed in terms of stream length, but note that the core includes the entire shore-to-shore aquatic environment, and often encompasses or extends through adjacent wetlands and water bodies, as depicted in the ecological systems map (see [dslLand.tif](#)).
- It is critical to remember that lotic cores are in large part derived from the index of ecological integrity (see [iei.tif](#)), which is scaled from relatively low to high separately for each ecological system within each HUC6 watershed. Consequently, the best areas available for each ecological system is captured by the lotic cores. However, this does not mean that the areas selected are always unimpaired. For example, the best available area for a cool, medium-sized river may be quite degraded since these are areas that tend to be developed if not otherwise in conservation ownership.

### GIS Formats and Definitions

ESRI shapefile (polylines); including the following attributes for each polyline. Note, for convenience, this attribute table is also included as a separate table (aCoreStats.csv):

- FID = ESRI assigned unique number (which we do not use) for each polygon.

- Shape = ESRI assigned feature type = "polyline".
- coreID = unique number (ID) assigned to the core. Lotic cores contiguous with or connected by lentic cores are considered to be a single lotic core and assigned a single coreID.
- type = indicator designating the polyline as "core".
- lengthKm = stream length (km) of the core. The length of the lotic core is approximated by the number of 30 m centerline cells. In addition, lotic cores can include centerlines through contiguous wetlands as well as contiguous lentic cores; thus, length of the lotic core represents the approximate length of contiguous lotic (including through wetlands) and lentic cores.
- system1, system2, system3 = list of the top three lotic ecosystems for which the core is particularly important; specifically, systems for which the cumulative ecological integrity of the system within the core is greater than expected (from a statistical perspective) given its distribution across the entire core area network. Note, the lotic systems listed here are not necessarily the most abundant systems in the core, but rather reflect the systems for which the core is especially important. A complete listing of all aquatic systems present in the core (including wetland and lentic systems), along with their relative abundance, is available separately in the Ecosystem table described below.
- scenario = internal use (file directory) to track the specific core area scenario.

### Detailed core area composition statistics

Detailed aquatic ecosystem composition statistics are available for each lotic core and are provided as a separate table for each lotic core (see files in the aCoreStats folder). In these tables, there are four different indices computed (and their corresponding ranks) that represent different ways of understanding the relative importance of the cores to specific ecosystems. In all cases, larger values indicate greater importance.

#### *Ecosystem table:*

- coreID = unique number assigned to each core.
- systemName = name of the ecosystem as given in the ecological systems map. Note, although wetland and lentic systems are included in the composition of the core (lengthKm), the four importance indices described below apply only to the riverine systems for which the lotic cores have been developed.
- lengthKm = stream length (km) of the corresponding system in the core. Note, the length of the system in the core is approximated by the number of 30 m centerline cells of the system.
- index1 = index of importance of the core for the corresponding lotic system, based on deviation of the observed sum of the selection index for the system from its expected value, which is based on the size of the core and the system's average selection index and proportional representation across all cores. The index ranges from 0 to

unbounded on the upper end; <1 indicates observed value less than expected, whereas >1 indicates the opposite.

- **index1Rank** = rank of index1 (1 = max index1).
- **index2** = index of importance of the core for the corresponding lotic system, defined as the percentage of the core's total selection index comprised of the corresponding system. The index ranges from 0-100.
- **index2Rank** = rank of index2 (1 = max index2).
- **index3** = index of importance of the core for the corresponding lotic system, defined as the percentage of the system's total selection index across all cores found in the focal core. The index ranges from 0-100.
- **index3Rank** = rank of index3 (1 = max index3).
- **index4** = index of importance of the core for the corresponding lotic system, defined as the difference between the system's average selection index in the focal core and its average selection index across all cores. The index ranges from -1 to 1; negative values indicate an average selection index in the focal core less than its average across all cores, whereas positive values indicate the opposite.
- **index4Rank** = rank of index4 (1 = max index4).
- **scenario** = internal use (file directory) to track the specific core area scenario.

**Lotic (river and stream) core areas: ecosystem summary  
(aCoreEcoSum.csv)**

Description

This table provides a quantitative summary of the ecosystem composition of the lotic (river and stream) cores relative to the riverine aquascape. The table contains a single row for each ecological system occurring in the aquascape and the following columns (fields):

- ecosystem = ecological system. Note, wetland and lentic (lake and pond) systems are often included, as often lotic cores extend along stream centerlines through these systems.
- formation = ecological formation, consisting of closely related ecosystems.
- landscapeKm = total approximate stream length (km) of the system in the aquascape.
- coreKm = total approximate stream length (km) of the system in the lotic cores.
- percentLength = percentage of the system's total approximate stream length in the aquascape occurring in the lotic cores =  $\text{coreKm}/\text{landscapeKm} \times 100$ .
- percentSi = percentage of the system's total selection index across the aquascape occurring in the lotic cores; i.e., what percent of the system's cumulative selection index across the entire aquascape is encompassed by the lotic cores.

### **Lentic (lake and pond) cores (lenticCores.shp)**

#### Description

This GIS product represents the set of lentic **core areas**. In combination with the lotic cores (see [loticCores.shp](#)) and terrestrial cores and connectors (see [tCoreNet.shp](#) and [tCoreTiers.shp](#)), they spatially represent the ecological network derived from the CTR LCD project. The network is designed to provide strategic guidance for conservation of natural areas, and the fish, wildlife, and other components of biodiversity that they support, within the Connecticut River watershed.

**Core areas** serve as the foundation of the conservation design. They reflect decisions by the CT River LCD planning team about the highest priority areas for sustaining the long-term ecological values of the watershed, based on currently available, regional-scale information. Lentic cores represent the following:

- 1) lakes and ponds of relatively high **ecological integrity**, emphasizing lakes and ponds that are relatively intact (i.e., free from human modifications and disturbance locally and within the water body catchment) and resilient to environmental changes (e.g., climate change) due to their size and connectivity to similar natural environments.

Lentic core areas are built from focal areas in ponds and lakes with high ecological integrity. These "seed areas" are expanded to include the entire water body in order to create logical conservation units. Consequently, the larger lentic cores may include partially-developed shorelines. Collectively, lentic core areas encompass 27% of the total area of ponds and lakes in the CTR watershed, as decided by the partnership. Note, Quabbin Reservoir, which itself comprises 20% of the total area of ponds and lakes in the CTR watershed, was not included as a lentic core in this scenario. A total of 1,206 lentic core areas have been identified, ranging in size from 0.06 to 1,323 ha, with an average size of 11.7 ha.

#### Considerations for Using Data Layer

The lentic cores are based on a simple classification of lentic systems into ponds (<8 ha) and lakes (≥8 ha) due to the lack of a more detailed classification at the time of this analysis. Thus, they do not account for other environmental factors, such as depth, trophic status, and water chemistry that can influence the composition, structure and function of lentic systems. In addition, there are no representative species included for lentic systems to complement the ecological integrity assessment. As such, the selection of lentic cores should be viewed as very preliminary and as an interim solution until a more detailed classification and assessment of lentic systems can be completed. Other suggestions include:

- Use in combination with the index of ecological integrity (see [iei.tif](#)) to identify other ponds and lakes with high ecological value.
- Use in combination with landscape capability layers for other lentic-associated representative species, such as moose and wood duck (see [speciesLC.tif](#)), to further understand the potential ecological value of the lakes and ponds.

## ***DSL Project Component: Landscape Conservation Design***

- Use in combination with the lotic cores (see [loticCores.shp](#)) to identify contiguous networks of high-valued lentic and lotic systems; i.e., places where lentic cores are connected to lotic cores.

### GIS Formats and Definitions

ESRI shapefile (polygons); including the following attributes for each polygon:

- FID = ESRI assigned unique number (which we do not use) for each polygon.
- Shape = ESRI assigned feature type = "polygon".
- coreID = unique number assigned to each core. Note, each lentic core is assigned a unique coreID regardless of whether it is contiguous with a lotic core.
- area = area (hectares) of the corresponding core.

### **Brook trout current probability of occurrence (brookTroutLc.shp)**

#### Description

This GIS product represents the probability of occurrence of brook trout in headwater creeks based on current habitat and climate conditions. Brook trout are a representative species for cool/cold headwater creeks. This layer was derived from a model developed by Ben Letcher and associates at the USGS Conte Anadromous Fish Lab. Specifically, this index represents the species' current probability of occurrence, presented as an integerized range from 0 (low=0% probability of occurrence) to 100 (high=100 % probability of occurrence). The brook trout probability of occurrence model is applied only to headwater creeks. Note, the brook trout current probability of occurrence is analogous to the landscape capability index developed for representative terrestrial wildlife species (see [speciesLC.tif](#)); it represents the suitability of habitat and climate conditions today. This index is an input into the selection of core areas (see [loticCores.shp](#)) in headwater creeks along with the Index of Ecological Integrity (see [iei.tif](#)).

#### Considerations for Using Data Layer

This layer provides a seamless and continuous valuation of current habitat and climate suitability for brook trout in headwater creeks. Importantly, this layer provides an ecological valuation of areas both inside and outside designated lotic cores, and thus it can be used to identify places of high value for brook trout outside of designated lotic cores that are also deserving of conservation attention. It is important to recognize that the brook trout selection index as distributed here is not scaled by HUC6 watershed like some of the other products used to create cores; nevertheless, the highest-valued headwater creeks within each HUC6 watershed are selected to complement what has already selected from the ecosystem-based approach to create the final set of lotic cores. Furthermore, the brook trout occupancy model is applied at the scale of small catchments (rather than 30m x 30m cells), and thus this layer has a coarser resolution than the analogous landscape capability indices developed for the representative terrestrial wildlife species.

#### GIS Formats and Definitions

ESRI shapefile (polylines); including the following attributes for each polyline:

- FID = ESRI assigned unique number for each polyline.
- Shape = ESRI assigned feature type = "polyline".
- index = value of the brook trout current probability of occurrence; range 0-100.

### **Anadromous fish index (anadromous.shp)**

#### Description

This GIS product identifies large and medium rivers within the Connecticut River watershed that provide habitat for five anadromous fish species: American shad, blueback herring, shortnose sturgeon, alewife, and sea lamprey. Habitat includes the mainstem and major tributaries of the Connecticut River from the mouth of the river upstream to the limit of passability for these species. This layer is derived from a product entitled "diadromous fish habitat in the Connecticut River watershed" developed in 2010 by The Nature Conservancy, Connecticut River Basin Program. Digital data updates were performed by Renee Farnsworth working with USFWS personnel through the NALCC. Specifically, river segments identified and known to be accessible to the five species listed above were extracted from the diadromous data layer, and each river segment was assigned a score from 1-5 indicating the number of species having known access to the segment. In addition, each segment was scored as "free-flowing," "impounded" or "unknown." All river sections with a score >0 for the five focal species are included in the final set of lotic cores (see [loticCores.shp](#)).

#### Considerations for Using Data Layer

This layer provides a seamless and continuous indication of river accessibility for the five anadromous fish species and an indication of whether each section is free-flowing or not. Importantly, it is not an indication of habitat suitability for any life stage for any of the focal species, as it does not account for habitat characteristics such as flow, water temperature, and substrate. Moreover, it is not a comprehensive indicator of riverine accessibility for all diadromous species, as there are other diadromous species that access other portions of the riverine network.

#### GIS Formats and Definitions

ESRI shapefile (polylines); including the following attributes for each polyline:

- FID = ESRI assigned unique number for each polyline.
- Shape = ESRI assigned feature type = "polyline".
- riverFlow = "free flowing", "impoundment", or NA.
- numSpp = number of focal anadromous.shp fish species having access to the segment; range 1-5.

### **Aquatic ecosystem-based core area selection index (aSelectionIndex.tif)**

#### Description

This GIS product represents the selection index used to create aquatic ecosystem-based cores. The selection index is a continuous surface in which every cell is assigned a value (0-1) based on its relative ecological integrity within each HUC6 watershed. Specifically, the selection index is equal to the index of ecological integrity (see [iei.tif](#)), except in headwater creeks where it is the average of *IEI* and USGS's stream temperature tolerance index (see [streamTolerance.tif](#)). Aquatic core areas are created, in part, by choosing cells above a certain index value and spreading from these "seed areas" through adjacent aquatic cells to build larger, buffered cores of relatively high ecological value.

#### Considerations for Using Data Layer

This layer provides a seamless and continuous valuation of ecological integrity based on regionally available and consistent spatial data that reflects decisions by the planning team. Importantly, this layer provides an ecological valuation of areas both inside and outside designated core areas, and thus it can be used to identify places of high ecological value outside of designated core areas that are also deserving of conservation attention. The primary conservation application of this data layer is likely to be in conjunction with the aquatic core network; see the descriptions for the lotic ([loticCores.shp](#)) and lentic cores ([lenticCores.shp](#)) for application suggestions as well as additional usage considerations.

As an intermediate product in the development of [tCoreNet.shp](#) and [tCoreTiers.shp](#), this product also is useful in understanding how *IEI* and stream temperature tolerance were integrated and how the core areas were generated.

It is important to recognize that the selection index is scaled by HUC6 watershed so as to indicate the relative ecological integrity value within each HUC6 watershed.

#### GIS Formats and Definitions

Geotiff raster (30 m cells); cell value = aquatic core area selection index; ranges from near 0 (low ecological value) to 1 (maximum ecological value) for aquatic cells (including centerlines through wetlands) and is 'nodata' elsewhere.

### **Aquatic buffers (aquaticBuffers.tif)**

#### Description

This GIS product represents **buffers** around the aquatic (lotic and lentic) cores. Aquatic buffers spatially represent the areas estimated to have a strong influence on the integrity of the aquatic cores based on watershed processes. Specifically, the buffers represent areas hydrologically connected to the aquatic cores through surface runoff and instream flow processes, such that anthropogenic stressors within the buffers are likely to adversely impact the integrity of the aquatic cores. Importantly, the buffers represent places upstream and upslope of the cores where human activities such as development, and point and non-point pollution, etc., may have a strong impact on the ecological condition of the cores. Unlike the cores, therefore, the buffers do not necessarily represent areas of high ecological integrity.

Buffers are established for all aquatic cores (both lotic and lentic) based on a time-of-flow model that extends as a gradient upstream and upslope from the cores, varying in distance depending on slope and land cover. Areas immediately upstream and upslope of the cores have the greatest influence (i.e., shortest time-of-flow). The influence decreases much faster across land than water so that the buffer typically extends much farther upstream than upslope from the core. Thus, the buffer does not represent a discrete zone distinguishing "inside" from "outside" of the buffer. Rather, it represents a graduated zone of influence in which cells upstream and closer to the core have greater influence. Cells in the upland and farther from the stream, especially on flat slopes with forest cover, have less influence. In addition, the graduated zone of influence increases in size with decreasing stream size. The zone of influence on larger rivers tends to be relatively narrow, whereas the zone of influence on headwater creeks tends to be wider and often encompasses the entire upstream catchment.

#### Considerations for Using Data Layer

Overall, aquatic buffers are best interpreted as a way to focus attention on generally where in the watershed human disturbance will likely have the greatest influence on the integrity of the aquatic cores. Although the buffers are presented as an absolute gradient of decreasing influence with increasing distance upstream and upslope of the cores, it is important to recognize that the gradient depicted is relative. Moreover, the gradient is thresholded to extend progressively greater distances upslope on increasingly smaller streams. Because this graduated zone of influence can be difficult to visualize and interpret, it may be more useful to threshold the gradient at one or more levels to depict tiered zones of influence that are more akin to conventional fixed-width buffers. A suggestion for combining this dataset with another dataset in the package is:

- Use in combination with the probability of development layer (see [probDevelop.tif](#)) to identify places where development is both likely and predicted to have a strong influence on the ecological integrity of the aquatic cores, and thus may represent priorities for land protection and/or management.

#### GIS Formats and Definitions

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Geotiff raster (30 m cells); cell value = the magnitude of influence based on the time-of-flow model; values range from 1 (maximum influence) at the core to zero 0 (no influence) at the cell with the least influence (i.e., furthest upstream and upslope of the core).

### **Aquatic vulnerability to development (aVulnerable.tif)**

#### Description

This GIS product represents the aquatic vulnerability to development index, which reflects the likelihood of development occurring in places in the uplands that are likely to impact the aquatic cores. Specifically, aquatic vulnerability is the product of the aquatic buffers, which represent the areas estimated to have a strong influence on the integrity of the aquatic cores based on watershed processes (see [aquaticBuffers.tif](#)), and the integrated future probability of development between 2010-2080 (see [probDevelop.tif](#)). Cells with relatively low watershed influence on the aquatic cores have low vulnerability regardless of their risk of development, since the integrity of the cores will not be degraded too much if they get developed. Aquatic vulnerability is greatest where there is high watershed influence; i.e., uplands in close proximity to the cores as the water flows, and where there is also relatively high probability of development in the future.

#### Considerations for Using Data Layer

This layer provides a seamless and continuous representation of the vulnerability to development of cells that are especially important to the integrity of the designated aquatic cores based on watershed processes. The index is best used in a relative manner to compare values from one location to another. Importantly, this index is contingent upon the a priori designation of core areas and thus is primarily useful in the context of landscape conservation design. In particular, this layer may be especially useful for identifying places within the landscape in close proximity (as the water flows) to the designated aquatic cores that are highly vulnerable to development.

It is important to recognize that due to the intrinsically highly connected nature of aquatic systems, and riverine systems in particular, that adverse human land uses anywhere in the entire watershed will impact the integrity of the aquatic environment and the designated aquatic cores within. This layer is intended to highlight where those adverse land uses will likely have the greatest affect on the designated aquatic cores.

Precautions outlined for the integrated probability of development layer (see [probDevelop.tif](#)) also apply to this layer. Consequently, this layer is best used as a general indication of where the uplands are most vulnerable to development impacts on the designated aquatic cores.

#### GIS Formats and Definitions

Geotiff raster (30 m cells); cell value = aquatic vulnerability index; ranges from 0 (e.g., secured land, water, already developed, outside the watershed buffer zone of the designated aquatic cores) to <1.

### **Dam removal impacts (dams.shp)**

#### Description

This GIS product represents potential opportunities to restore aquatic connectivity by removing dams. Specifically, this product tabulates the results of a model in which each dam is systematically removed (virtually), one at a time, and the predicted improvement in aquatic connectedness from the removal is recorded. The delta, or difference, in the aquatic connectedness score, before and after the bridge removal for each cell within the affected neighborhood, is computed and multiplied by the average index of ecological integrity (see [iei.tif](#)) of the affected neighborhood. Therefore, improvements are scored higher where conditions are not highly degraded and dam removal may have greater ecological benefits.

#### Considerations for Using Data Layer

The dam removal impact score (impact) is an index of the potential improvement in local aquatic connectedness to be achieved in places where it matters most -- where the current ecological integrity is not already severely degraded. Based on these scores and the corresponding ranks, dams can be prioritized for restoration. Note, these scores do not take into account other socio-economic considerations, such as whether the impoundment is a public drinking water supply, which ultimately will determine the cost-benefit tradeoffs of any particular dam removal. Given the large number of dams, it may be useful to bin the dams into categories representing high, medium and low impact, or simply threshold the score or its rank (see below) at some level to highlight the highest priority dams.

This layer may best be used to direct field surveys of dams of interest, during which complete and accurate assessments can be made. It can also be used in combination with the lotic ([loticCores.shp](#)) and lentic cores ([lenticCores.shp](#)) to identify places where dam removal may have the added benefit of improving the integrity of the designated aquatic cores.

Use of this layer should be done considering the scope and limitations of this dataset:

- The actual restoration potential of a dam may be quite different than the modeled estimate. For example, unmapped dams certainly exist and affect the real-world aquatic connectivity not reflected in our scores. Incomplete and/or inaccurate data on dam height and other attributes (such as the partial breach of the dam) result in incorrect estimates of aquatic passability. Also, for many dams with incomplete data, especially the smaller dams, we are forced to make an assumption about dam height and also to assume that the dam has not been breached. In addition, unreliability of data on fish passage structures forced us to omit this factor from consideration in the model. Because of these known data gaps and errors inherent in the source data, the data layer should be used cautiously.
- The dam removal impact score represents the potential gain in local aquatic connectivity from removing each dam without considering other natural or anthropogenic barriers (e.g., waterfalls, culverts) or potential nearby restoration actions to improve connectivity. Of course, dams often do not exist as isolated barriers. The score of a dam is dependent to some extent on the degree to which natural barriers and road-stream crossings nearby on the same waterway are also

acting as barriers to movement. For example, removal of a dam will result in less improvement in connectivity if there is an undersized culvert a short distance from the dam than if no movement barriers are nearby. The undersized culvert will continue to depress aquatic connectedness even after the dam is removed. Unfortunately, evaluating the combined (and possibly synergistic) effect of multiple restoration activities, such as removing the dam and upgrading the nearby undersized culverts, is computationally beyond the scope of this project, but should be taken into account when prioritizing dam restoration opportunities in practice.

### GIS Formats and Definitions

ESRI shapefile (points); including the following attributes for each point:

- FID = ESRI assigned unique number (which we do not use) for each point.
- Shape = ESRI assigned feature type = "point".
- damid = unique number assigned to each dam.
- x\_coord = easting.
- y\_coord = northing.
- dam = name of dam.
- damheight = structural height of dam (m).
- base = sum of aquatic connectedness in vicinity in current condition.
- alt = sum of aquatic connectedness after removing (virtually) the dam.
- delta =  $(alt - base) * 1000$ , the potential improvement in aquatic connectedness from removing (virtually) the dam.
- impact = delta weighted by the average Index of Ecological Integrity of the affected neighborhood.
- impact\_ln = natural log of impact.
- rank = rank of impact (out of 1,365 dams).

### **Culvert upgrade impacts (culverts.shp)**

#### Description

This GIS product represents opportunities to restore aquatic connectivity by upgrading culverts. Specifically, this product tabulates the results of a model in which each road-stream crossing is systematically upgraded (virtually) to a bridge having the minimum aquatic barrier score, one at a time, and the predicted improvement in aquatic connectedness from the upgrade is recorded. The delta, or difference, in the aquatic connectedness score, before and after the crossing upgrade for each cell within the affected neighborhood, is computed and multiplied by the average index of ecological integrity (see [iei.tif](#)) of the affected neighborhood. The weighting by *IEI* emphasizes the potential ecological benefits of a crossing upgrade in an area that is otherwise in good condition but depressed by the crossing structure. Conversely, the score is lower where conditions are already so degraded that an upgrade would not improve local ecosystem conditions.

#### Considerations for Using Data Layer

The culvert upgrade impact score (impact) is an index of the potential improvement in local aquatic connectedness to be achieved in places where it matters most -- where the current ecological integrity is not already severely degraded. Based on these scores and the corresponding ranks, road-stream crossings can be prioritized for restoration. Note, these scores do not take into account other socio-economic considerations, such as the cost of a particular upgrade given local engineering considerations, that ultimately will determine the cost-benefit tradeoffs of any particular crossing upgrade. Given the large number of road-stream crossings, it may be useful to bin the crossings into categories representing high, medium and low impact, or simply threshold the score or its rank (see below) at some level to highlight the highest priority crossings.

This layer may best be used to direct field surveys of road-stream crossing of interest, during which complete and accurate assessments can be made. It can also be used in combination with the lotic ([loticCores.shp](#)) and lentic cores ([lenticCores.shp](#)) to identify places where crossing improvement may have the added benefit of improving the integrity of the designated aquatic cores.

Use of this layer should be done considering the scope and limitations of this dataset:

- The actual restoration potential of a road-stream crossing may be quite different than the modeled estimate, especially in cases where the model predicts the crossing to be a bridge when in fact it is a culvert. Perhaps the biggest concern is the lack of information about aquatic passability for most road-stream crossings. Less than 1% of the road-stream crossings within the Northeast region have been assessed in the field. We use this field-based assessment where it exists ([www.streamcontinuity.org](http://www.streamcontinuity.org)), but for the vast majority of road-stream crossings that have not been assessed in the field, we are obliged to predict whether the crossing is a culvert or bridge and then assign the mean passability score for surveyed culverts or bridges, accordingly. Another example of potential errors is the existence of “phantom” road-stream crossings erroneously generated by the intersection of roads and streams data in GIS. Because

of these known data gaps and errors inherent in the source data, the data layer should be used cautiously.

- The culvert upgrade impact score represents the potential gain in local aquatic connectivity from upgrading each road-stream crossing to a bridge with the minimum aquatic barrier score. This does not consider other natural or anthropogenic barriers (e.g., waterfalls, culverts) or potential nearby restoration actions to improve connectivity. Of course, road-stream crossings often do not exist as isolated barriers. The score of a road-stream crossing is dependent to some extent on the degree to which natural barriers and other road-stream crossings and dams nearby on the same waterway are acting as barriers to movement. For example, a culvert upgrade will result in less improvement in connectivity if there is a dam or an undersized culvert a short distance from the crossing, compared to that same crossing without other movement barriers nearby. Unfortunately, evaluating the combined (and possibly synergistic) effect of multiple restoration activities, such as removing the nearby dam and upgrading the nearby undersized culverts, is computationally beyond the scope of this project. However, this should be taken into account when prioritizing culvert restoration opportunities in practice.
- For the road-stream crossings assessed in the field, we use an algorithm developed by the River and Stream Continuity Partnership (2010, [www.streamcontinuity.org](http://www.streamcontinuity.org)) for scoring crossing structures according to the degree of obstruction they pose to aquatic organisms. Of course, as with any such algorithm, it cannot deal effectively with the myriad species-specific constraints on passability that affect the entire aquatic community. Thus, the score must be viewed as a generalized index on aquatic passability and cannot be used to infer passability for any single species.

### GIS Formats and Definitions

ESRI shapefile (points); including the following attributes for each point:

- FID = ESRI assigned unique number (which we do not use) for each point.
- Shape = ESRI assigned feature type = "point".
- crossingid = unique number assigned to each crossing.
- x\_coord = easting.
- y\_coord = northing.
- group = unique number for paired/grouped crossings, for example with divided highways.
- groupsize = number of crossings in the group (usually 1, sometimes 2, rarely more).
- anysurvey = 1 if any of the crossings in the group were field surveyed.
- surveyed = 1 if the focal crossing was field surveyed.
- base = sum of aquatic connectedness in the vicinity of the crossing with the crossing structure in its current condition.

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- alt = sum of aquatic connectedness in the vicinity of the crossing after upgrading (virtually) the culvert.
- delta = (alt – base)\*1000, the potential improvement in aquatic connectedness from upgrading (virtually) the culvert.
- impact = delta weighted by the average Index of Ecological Integrity of the affected neighborhood.
- impact\_LN = natural log of impact.
- aquatic = aquatic passability score derived either from field measurements (if surveyed) or set equal to the mean score for surveyed culverts.shp or bridges (depending on whether it is predicted to be a culvert or bridge).
- bridge = indicator of whether crossing is observed/predicted to be a culvert = 0 or bridge =1.
- rank = rank of impact (out of 27,141 crossings).

### **Brook trout climate response (brookTroutCR2080.shp)**

#### Description

This GIS product represents the climate response index for brook trout in headwater creeks based on current habitat and current and future climate conditions. Brook trout are a representative species for cool/cold headwater creeks. This layer was derived from a model developed by Ben Letcher and associates at the USGS Conte Anadromous.shp Fish Lab. Specifically, this index is the average of the current probability of occurrence (see [brookTroutLc.shp](#)) and the future probability of occurrence in 2080 (averaged over two future climate scenarios: RCP 4.5 and 8.5), presented as an integerized range from 0 (low) to 100 (high) probability of persistent occurrence. The brook trout climate response is applied only to headwater creeks, as used in the probability of occurrence model. Note, the brook trout climate response index, as computed, is analogous to the climate response index (see [speciesCR2080](#)) developed for representative terrestrial wildlife species; it represents the suitability of habitat and climate conditions today and where future climate conditions are likely to remain suitable for brook trout. This index is an input into the selection of core areas (see [loticCores.shp](#)) in headwater creeks along with the Index of Ecological Integrity (see [iei.tif](#)).

#### Considerations for Using Data Layer

This layer provides a seamless and continuous valuation of current habitat and persistent climate suitability for brook trout in headwater creeks. Importantly, this layer provides an ecological valuation of areas both inside and outside designated lotic cores, and thus it can be used to identify places of high value for brook trout outside of designated lotic cores that are also deserving of conservation attention. It is important to recognize that the brook trout climate response index as distributed here is not scaled by HUC6 watershed like some of the other products used to create cores; nevertheless, the highest-valued headwater creeks within each HUC6 watershed are selected to complement what has already selected from the ecosystem-based approach to create the final set of lotic cores. Furthermore, the brook trout occupancy model is applied at the scale of small catchments (rather than 30m x 30m cells), and thus this layer has a coarser resolution than the analogous climate response indices developed for the representative terrestrial wildlife species.

#### GIS Formats and Definitions

ESRI shapefile (polylines); including the following attributes for each polyline:

- FID = ESRI assigned unique number for each polyline.
- Shape = ESRI assigned feature type = "polyline".
- index = value of the brook trout selection index; range 0-100.

### **Ecological systems map (dslLand.tif)**

#### Description

This GIS product represents a version of the ecological systems map (ESM+), originally derived by TNC and modified for the Designing Sustainable Landscapes (DSL) project. Major modifications include improvements to the classification and mapping of roads, development, streams, and coastal wetlands. In this map, ecological systems are hierarchically organized such that at the finest level cells are classified into ecological systems (or ecosystems), which are aggregated into formations. Thus, the map can be symbolized to depict the distribution of ecological units at either the ecosystem or formation level.

#### Considerations for Using Data Layer

This layer is the foundation for much of the ecological assessment in the DSL project. Indeed, the derived DSL products, such as the terrestrial and aquatic core area networks (see [tCoreNet.shp](#), [tCoreTiers.shp](#), [loticCores.shp](#) and [lenticCores.shp](#)), cannot be understood without reference to this layer. In particular, the weighted index of ecological integrity (see [iei.tif](#)), which forms an important basis for the selection of terrestrial core areas, is scaled by ecological system as depicted in this layer. Similarly, the representative species landscape capability indices (see [speciesLC.tif](#)), which also form an important basis for the selection of terrestrial core areas, universally use ecological systems in the habitat capability component of the individual species' models. Ultimately, an important objective of the terrestrial and aquatic core area networks is to identify an integral network of places that include redundant representation of all ecological systems, which are as delineated by this layer.

#### GIS Formats and Definitions

Geotiff raster (30 m cells); attributed as follows:

- **OID** = ESRI assigned unique number (meaningless).
- **Value** = unique number assigned to each ecological system.
- **Count** = number of cells of the corresponding ecological system.
- **ecosystem** = ecological system (note, ecosystem here is based on the field named 'sumgroupname' in the ArcGIS raster distributed by TNC named 'syst\_ne130930', or the field named 'habitat' in the ArcGIS raster distributed by TNC named 'syst\_ne141611').
- **formation** = ecological formation, consisting of closely related ecosystems.
- **index** = arbitrary number assigned for internal use to facilitate sorting of ecological systems.

### **TNC geophysical setting (geoSetting.tif)**

#### Description

This GIS product represents TNC geophysical settings as used in the TNC terrestrial resiliency index (see [tResiliency.tif](#)), which is used in the terrestrial ecosystem-based core area selection index and thus the selection of the terrestrial core areas. To learn more about this product and TNC's resiliency index, see: [Resiliency page at TNC's Conservation Gateway](#).

#### Considerations for Using Data Layer

This layer is the basis for scaling the TNC terrestrial resiliency index. Specifically, the resiliency index is (quantile) scaled within each geophysical setting class within each HUC6 watershed. To better understand the scaled resiliency index as used in the terrestrial ecosystem-based core area selection index, this layer can be used as a mask to view one geophysical setting class at a time.

#### GIS Formats and Definitions

Geotiff raster (30 m cells); attributed as follows:

- OID = ESRI assigned unique number (meaningless).
- Value = unique number assigned to each geophysical setting class.
- Count = number of cells of the corresponding geophysical setting class.
- setting = geophysical setting class (see TNC documentation, link above, for descriptions of each setting class).

### **StreamClass.shp (streamClass.shp)**

#### Description

This GIS product represents a classified version of the stream network in which streams are classified and mapped along centerlines, even through wetlands and lentic systems, to provide a contiguous, classified stream network. This product differs from the ecological systems map (see [dslLand.tif](#)) in that this layer 1) is a vector versus raster representation of streams (i.e., lines versus cells) and 2) has streams classified as lotic systems throughout, whereas wetlands and lentic systems take precedence in the ecological systems map. This layer is provided for the sole purpose of facilitating the display (in GIS) and mapping of landscape design products, as it is much easier to visualize vector features than raster features for narrow linear features such as streams.

#### Considerations for Using Data Layer

This layer is for the purpose of displaying the contiguous, linear stream network. Note, however, that centerlines through wetlands and lentic systems are evaluated as wetland and lentic systems, respectively, in the ecological assessment that forms the basis for the landscape conservation design. It may be useful in combination with the aquatic core area selection index, brook trout selection index, and USGS stream temperature tolerance index to better understand the ecological setting (i.e., lotic system) of any particular place that is evaluated with these additional products.

#### GIS Formats and Definitions

ESRI shapefile (polylines); attributed as follows:

- FID = ESRI assigned unique number to each line segment.
- Shape = ESRI assigned feature type = "polyline".
- class = unique number assigned to each ecological system.
- descrip = ecological system name.

### **Roads (roads.shp)**

#### Description

This GIS product represents an attributed road network. Each road segment is attributed with a variety of attributes from the Open Street Map data source. Here, the attribute ROADCLASS is our main interest (see below), which can be symbolized meaningfully and then displayed as an overlay on the other landscape design products to enhance the interpretation.

#### Considerations for Using Data Layer

This layer is included for the purpose of displaying the road network as an overlay to the other landscape design products.

#### GIS Formats and Definitions

ESRI shapefile (polylines); with many attributes, but here we are considering the single attribute ROADCLASS with the following values:

- 1 = Motorway
- 2 = Primary road
- 3 = Secondary road
- 4 = Tertiary road
- 5 = Local road
- 6 = Track

### **Secured lands (secure.shp)**

#### Description

This GIS product represents TNC's secured lands data (inclusive of all GAP status levels: 1-4, 9, and 39), which strives to include all legally or for all practical purposes permanently protected lands in the eastern 18 U.S. states. It is compiled annually from over sixty sources. For the most part, it is a combination of public land information maintained by each state and private conservation land information compiled by TNC's state field offices. TNC staff in each state office compile the dataset for their state, assign the securement status to each tract, and fill out the other standard fields (e.g., designation, acres, ownership type). The completed state datasets are then compiled by the regional science office and quality checked for consistency and discrepancies. Each year, the data set is posted for public use and submitted to the Protected Areas Database U.S. (PAD US) and National Conservation Easement database to become part of the national datasets of protected lands. The layer provided here is a snapshot of the dataset as of 2011.

#### Considerations for Using Data Layer

This layer is provided here in its original form for convenience to be used as an overlay for the other landscape conservation design products. In particular, the secured lands layer can be overlaid on the terrestrial core-connector network to determine what has already been protected and what still needs protection. Note that this layer is current through 2011, and therefore, may omit parcels protected more recently. Updates to this data layer can be found on the [Secured Lands page at TNC's Conservation Gateway](#). In addition, as a rule, open water is not represented in this layer as secured, which may reflect the real-world difficulty of determining how to consider open water with respect to securement from development.

#### GIS Formats and Definitions

ESRI shapefile (polygons); including a variety of attributes for each polygon as defined in the reference listed above.

## **State boundaries (statesNer.shp)**

### Description

This GIS product represents boundaries of the 13 states plus Washington, DC, comprising the Northeast region.

### Considerations for Using Data Layer

This layer is included for the purpose of displaying the state outlines as an overlay to the other landscape design products.

### GIS Formats and Definitions

ESRI shapefile (polygons); attributed as follows:

- FID = ESRI assigned unique number to each polygon.
- Shape = ESRI assigned feature type = "polygon".
- state = name of the state.
- id = sequential numeric id (1-14) assigned to each state.

**HUC 6 watershed boundaries (huc6Ctr.shp)**

Description

This GIS product represents boundaries of the two HUC6 watersheds (or basins) in the Connecticut River watershed. Note, HUC6 watersheds were used to scale the core area selection indices in order to provide an even distribution of core area between watersheds.

Considerations for Using Data Layer

This layer is included for the purpose of displaying the HUC6 outlines as an overlay to the other landscape design products.

GIS Formats and Definitions

ESRI shapefile (polygons); with numerous attribute.

**HUC 8 watershed boundaries (huc8Ctr.shp)**

Description

This GIS product represents boundaries of the 14 HUC8 watersheds (or subbasins) in the Connecticut River watershed. Note, HUC8 watersheds were not used in any capacity to derive the landscape design products.

Considerations for Using Data Layer

This layer is included for the purpose of displaying the HUC8 outlines as an overlay to the other landscape design products.

GIS Formats and Definitions

ESRI shapefile (polygons); with numerous attribute.

**Hillshade (hillshade.tif)**

Description

This GIS product represents boundaries of the 14 HUC8 watersheds (or subbasins) in the Connecticut River watershed. Note, HUC8 watersheds were not used in any capacity to derive the landscape design products.

Considerations for Using Data Layer

This layer is included for the purpose of displaying the HUC8 outlines as an overlay to the other landscape design products.

GIS Formats and Definitions

Geotiff raster (30 m cells); cell value = hillshading index; ranges 0-254 based on 315 degree azimuth angle of the light source and 45 degree altitude angle of the light source above the horizon; consequently northwest slopes receive higher values and southeast slope receive lower values.