

A Sustainable Chesapeake

BETTER MODELS FOR CONSERVATION

Edited by David G. Burke and Joel E. Dunn

THE CONSERVATION FUND



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Green Infrastructure Design and Benefit-Cost Optimization in Transportation Planning

Maximizing Conservation and Restoration Opportunities in Four Southern Maryland Watersheds

A team of natural resource and conservation experts has developed a powerful set of analytical tools that represent the next generation of green infrastructure planning for transportation applications and beyond.

CASE STUDY SUMMARY

Population growth along the US Highway 301 corridor near the town of Waldorf, Maryland, has created worsening traffic headaches, particularly for those commuting from bedroom communities in Charles County to employment centers in the Washington, D.C. area. The Maryland State Highway Administration (SHA) has been exploring transportation improvement options for US 301 in the Waldorf area including construction of a bypass or upgrading the existing road. SHA is also evaluating natural resources in four watersheds in Charles and Prince George's counties that could potentially be impacted by construction. The watersheds include: Piscataway Creek, Mattawoman Creek, Port Tobacco Creek, and Zekiah Swamp, as shown in the map of US 301 study area watersheds.

The State Highway Administration adopted environmental stewardship in its US 301 transportation planning process, with the goal of creating a

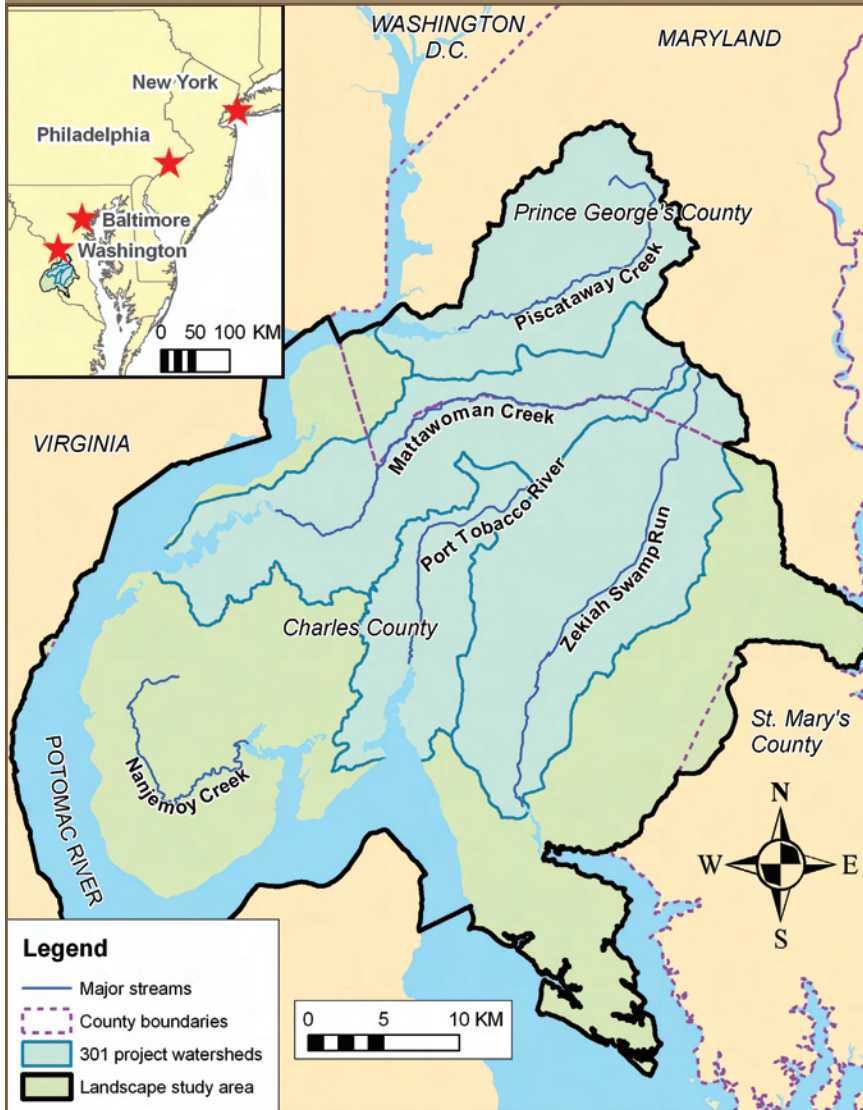
net benefit to the environment. This approach is innovative among transportation agencies because it goes above and beyond compensatory mitigation required by the National Environmental Policy Act (NEPA) to offset impacts from construction and related activities. In 2007 SHA asked The Conservation Fund, the Maryland Department of Natural Resources (DNR), and the U.S. Fish and Wildlife Service (FWS) to convene a Natural Resources Work Group (NRWG) to objectively identify and evaluate environmental stewardship needs and opportunities.

Recognizing the importance of landscape and watershed contexts, the NRWG followed a green infrastructure approach to identify and prioritize natural resources in the assessment area. Additionally, the NRWG designed a benefit-cost optimization tool to help SHA identify the set of stewardship projects that will maximize natural resource benefits within given budget constraints. The combined use of green infrastructure network design and benefit-cost

optimization constitutes the first known use of this powerful analytical approach in a real world application for development of grey infrastructure and conservation of natural resources. This new approach may well become the standard for future conservation planning—ensuring maximum ecosystem benefits for every dollar spent on conservation or restoration actions. A widely accepted definition of green infrastructure is strategically planned and managed networks of natural lands, working landscapes, and other open spaces that conserve ecosystem functions and provide associated benefits to human populations.¹

Webster's New World Dictionary defines infrastructure as "the substructure or underlying foundation, especially the basic installations and facilities on which the continuance and growth of a community or state depends."² Just as "grey infrastructure" – built structures like roads, water mains, and power lines – is needed by society, green infrastructure provides essential services like clean air, clean water, stormwater

► US 301 Study Area Watersheds



control, food and fiber, and recreation opportunities. Protecting and restoring our natural life-support system is a necessity, not an amenity. Green infrastructure provides a systematic and strategic framework for conservation, restoration, land use planning, and sustainable management practices.

To identify environmental stewardship needs, the NRWG reviewed pertinent studies, analyzed existing natural resource conditions, convened community focus group sessions, and delineated a green infrastructure network. Within the green infrastructure network, the NRWG identified top priorities for conservation and

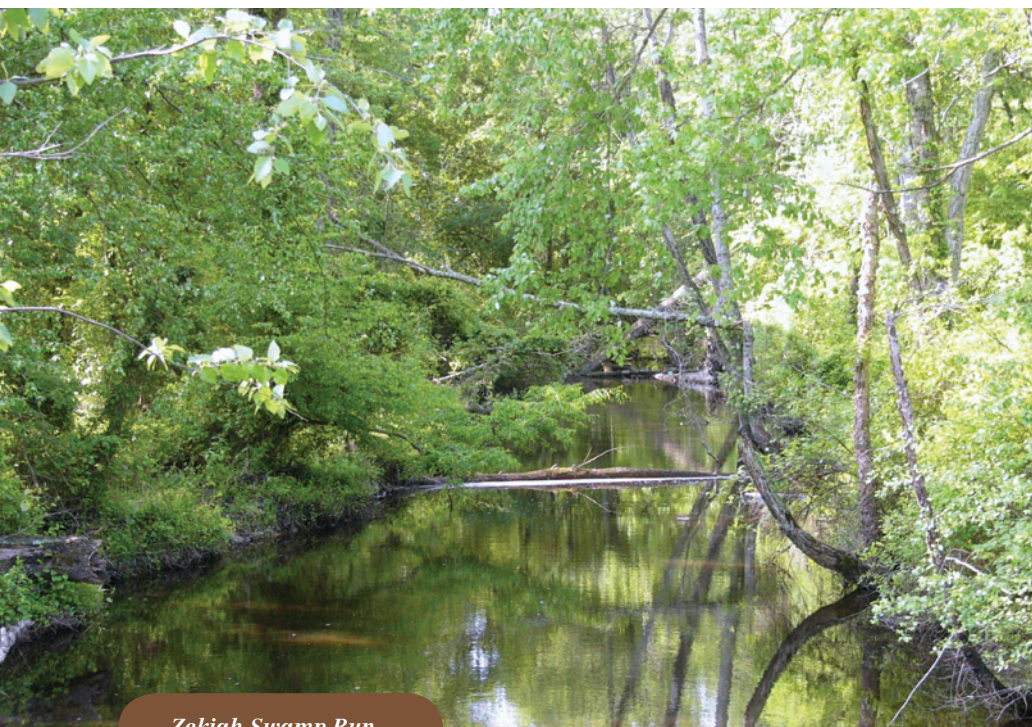
restoration. The NRWG developed technical field protocols and assessed priority areas on the ground, assigning resource values and estimating the costs of land protection and restoration, if needed. SHA's proactive environmental stewardship, the green infrastructure approach and analyses, and the use of benefit-cost optimization are all concepts that can be adapted and improved in future efforts to identify natural resource priorities, minimize impacts of transportation improvement projects, and select projects that provide the greatest environmental benefits under a given budget.

RESOURCE MANAGEMENT CHALLENGE

The four watersheds examined by NRWG for conservation and stewardship opportunities contain some of the state's most important natural resources, including high-quality forests, wetlands, streams, and biological communities. Mattawoman Creek and its wetlands are among the most productive finfish spawning and nursery streams in the entire Chesapeake Bay watershed.³ Mattawoman Creek is recognized as "an exceptional anadromous fish spawning and nursery ground that presently exhibits one of the highest densities of anadromous juveniles and the healthiest trophic fish assemblages in the Chesapeake system."⁴ In a study of eight tidal Chesapeake tributaries, scientists reported that anadromous juveniles in Mattawoman Creek were 40 times more abundant per unit effort than the other seven combined. They also found that Mattawoman Creek "represents as near to ideal conditions as can be found in the northern Chesapeake Bay, perhaps unattainable in the other systems, and should be protected from overdevelopment."⁵

The Smithsonian Institution described Zekiah Swamp as "the largest natural hardwood swamp in Maryland and one of the most important remaining ecological areas on the East Coast."⁶ Zekiah Swamp is the highest ranking watershed in Maryland for freshwater stream and riverine biodiversity,⁷ and is designated a Wetland of Special State Concern, a Natural Heritage Area, a Rural Legacy Area, and part of a State Scenic River. This watershed contains high quality wetlands, forests, and streams in both the swamp and many of its tributaries.

Piscataway Creek falls into the top tier of Maryland's watersheds for aquatic biodiversity and is a stronghold



Zekiah Swamp Run.

watershed for two species of greatest conservation need. The Port Tobacco watershed contains Hoghole Run, one of the Maryland Biological Stream Survey's sentinel sites, containing a reference-quality biological community and rare species.⁸ Brentland Woods, in the Port Tobacco water-

shed, is a large contiguous tract of forest that provides excellent habitat for forest interior birds and other wildlife.⁹

All four watersheds, especially Mattawoman Creek, which is in Charles County's development district, are

threatened by ongoing conversion of forests and farmland to low and medium density housing and other development. Over 10,000 acres of forest, over 2,000 acres of croplands, and almost all existing pasture are expected to be lost between 2000 and 2020 in the Mattawoman Creek watershed.¹⁰

The increase in development in these watersheds is affecting air quality, water quality and fish and wildlife habitat. Land use change due to human activity "is perhaps the single greatest factor affecting ecological resources."¹¹ When natural areas are converted to intensive human use, the population of species dependent on that habitat may decrease below the threshold needed for long-term persistence.¹² Fragmentation of formerly continuous habitat, especially by barriers like roads and buildings, reduces patch sizes, increases the edge to interior ratio, and restricts wildlife movement.¹³ Exotic plants invade fragmented forests and wetlands, and displace native species. As species are lost from an ecosystem,



Development along Mattawoman Creek.



those that depend on them for food, pollination, or other needs, also begin to disappear.¹⁴

All four watersheds in the study area contain tributaries with impaired biological communities and eroding stream banks. Stream condition is partly a legacy of past land use. The clearing of forests and poor agricultural practices eroded the sandy soils of southern Maryland, which accumulated in stream and river channels and valleys enough to impair navigation and cause the closure of ports on Mattawoman Creek, Port Tobacco River, the Patuxent River, and elsewhere.^{15,16} Further, many streams and wetlands were ditched or dammed to control flooding or drain areas for farming, and beavers were extirpated. Many streams are now incising through legacy sediments, and exporting these materials downstream.

Current land use practices, including agricultural and urban runoff, continue to impact the area's streams. Impervious surfaces (buildings, parking lots, roads, etc.) associated with development have adverse effects on streams and water quality. Studies in Maryland show that when a watershed exceeds 5-15% imperviousness, there is a rapid degradation of stream stability and aquatic habitat quality.^{17,18} Piscataway Creek, draining the most urbanized of the four watersheds, is deeply incised and has unstable banks. Another consequence of impervious surfaces is that as water is moved more quickly off the land, less of it percolates into aquifers.¹⁹ A study of watersheds in Charles County found that conversion of forests to development increases the discharges of water, nitrogen, phosphorus, and organic carbon, while conversion of forests to cropland increases the discharges of nitrate.²⁰ Stream Corridor Assessment surveys identified 218 potential environmental problem



Mature oak stand (unusually old for Southern Maryland) in a Prince George's County forest plot.

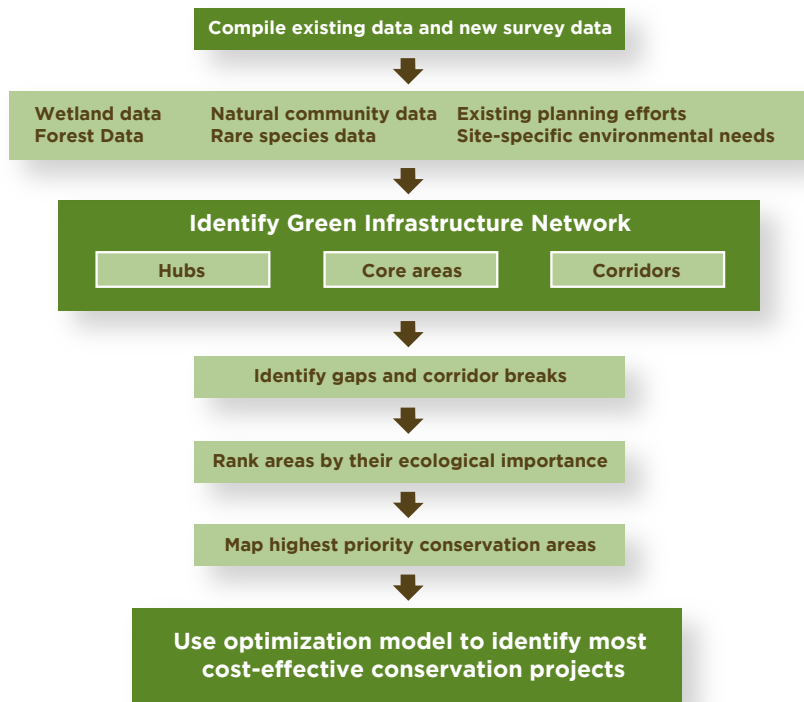
sites in the Port Tobacco watershed. The Maryland Department of the Environment also identified numerous wetland restoration opportunities throughout the study area.²¹

CONSERVATION VISION

While local governments ultimately control the area's development pattern, pace, and design, SHA was in a position to quantify its own impacts from the bypass and upgrade options it was analyzing and then go "above and beyond" that impact to

implement an ethic of stewardship in an environmentally sensitive area of the State. SHA also was intrigued by pioneering work undertaken by Dr. Kent Messer, a resource economist at the University of Delaware, and The Conservation Fund in applying the concept of optimization for conservation project selection.^{22,23} Optimization tools had been successfully designed and utilized in Baltimore County, Maryland, for agricultural land preservation, so SHA was well positioned to be good finan-

Green Infrastructure Planning Process



cial stewards by utilizing benefit-cost optimization to ensure they would get the most “bang for their buck.”

The Conservation Fund, DNR, and FWS hoped to provide a model for green infrastructure planning that strategically targets the best locations for environmental stewardship and ensures the best possible conservation outcomes from a transportation project that impacts the environment. In addition, they hoped the delineated green infrastructure network and associated data would provide valuable planning tools to county governments and state and federal agencies.

IMPLEMENTATION RESOURCES

The State Highway Administration provided funding from 2007-2009 for the NWRG’s work within the planning budget of the US 301 Waldorf Transportation Improvements Project. This was the first instance in the country of transportation planning funds being utilized directly for green infrastructure network design and

benefit-cost optimization. SHA also provided staff and consultants to assist field reconnaissance and data collection. DNR led the assessment of wetland condition, rare species and natural community analyses and collection of associated data. Coastal Resources, Inc. helped collect forest and stream data. The University of Delaware developed the benefit-cost optimization algorithms and software. DNR, SHA, Charles County, and Prince George’s County provided GIS data. Landowners granted permission for all field work. NWRG also successfully leveraged earlier green infrastructure planning efforts by DNR and The Conservation Fund by refining the methods from Maryland’s first statewide green infrastructure assessment²⁴ and recent planning work by The Conservation Fund in Baltimore, Cecil, and Talbot Counties, Maryland²⁵, and Kent County, Delaware.²⁶ FWS contributed essential expertise on characterizing stream stability, while the Fund and DNR contributed expertise in wetlands, forests, and natural

GREEN INFRASTRUCTURE NETWORK IDENTIFICATION PRINCIPLES

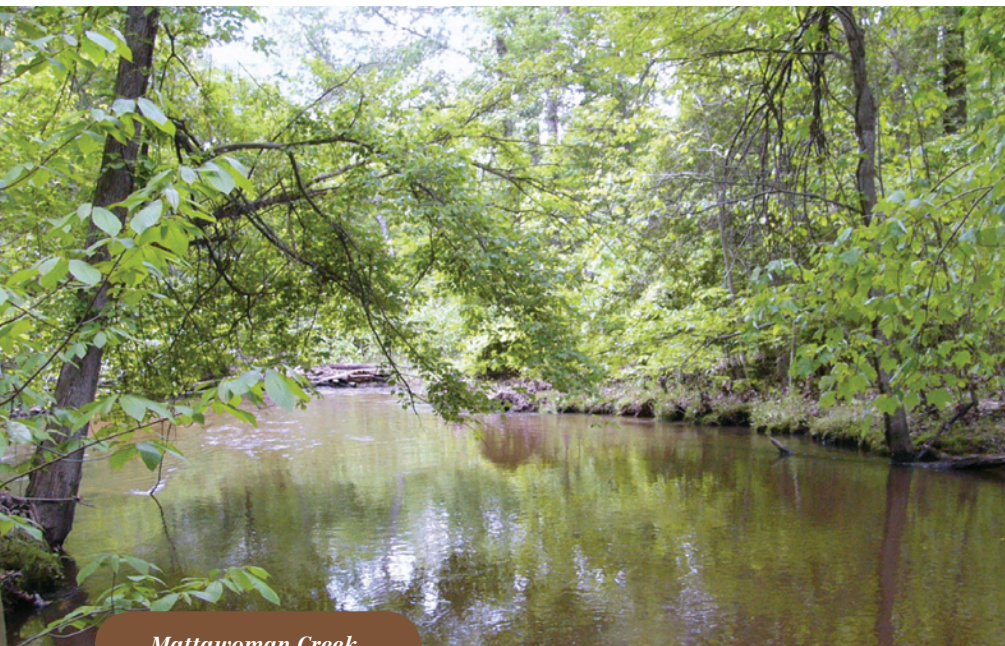
According to conservation biologists,^{26,27} a green infrastructure network should:

- ▶ Contain the best remaining examples of all native ecosystem types and the full suite of native biodiversity.
- ▶ Maintain viable populations of all native species in natural patterns of abundance and distribution.
- ▶ Maintain ecological and evolutionary processes, such as disturbance regimes, hydrological processes, nutrient cycles, and biotic interactions.
- ▶ Contain large blocks of contiguous habitat, with large populations of a species, rather than small fragmented habitat.
- ▶ Maintain connections between large blocks of habitat for gene flow and migration.
- ▶ Include habitat blocks with compatible buffers opposed to abrupt boundaries with development.
- ▶ Accommodate human activities compatible with goals of resource protection.

heritage resources. The Conservation Fund’s Conservation Leadership Network provided expertise in convening focus groups and soliciting stakeholder feedback.

CONSERVATION STRATEGY

Community Needs: Soon after beginning the project, The Conservation Fund facilitated four focus group sessions. Sixty four individuals, representing federal and state government agencies, local elected officials and staff, and various non-governmental organizations, participated in the four



Mattawoman Creek.

focus group sessions. Participants first discussed types of environmental stewardship activities most needed in the project area as well as the priority natural resources. The facilitators then provided a form to each participant, and asked them to allocate 100 points among four categories of stewardship activities and 100 points among eight categories of natural resources. Next, participants reviewed a list of available data and literature, and were asked to recommend additions. Finally, participants were asked to recommend specific projects or resource needs, writing a description, and marking their location on a map. The focus groups identified site-specific environmental needs in the study area. The input from these focus group sessions helped guide where field reconnaissance work took place for the existing conditions and green infrastructure network design and provided a preliminary look at potential environmental stewardship opportunities. The input also provided information to SHA that could be used in the prioritization of conservation projects through identification of priority natural resources and stewardship activities.

Resource Conditions: A key element of the conservation strategy involved the NRWG's survey efforts. FWS surveyed streams throughout the project area, assigning a rating of stable, unstable, or recovering. FWS and The Conservation Fund compared observed stream stability to their geomorphic setting and catchment conditions, finding that stable streams generally had low gradients and were in catchments with low imperviousness and high percentages of mature forest, or were artificially controlled by beaver dams or human engineering. FWS extrapolated these relationships to assign stability ratings to all the streams in the project area, which were used to identify potential locations for restoration activities. In addition, stable streams were considered "core" streams and therefore conservation priorities if they also provided high-quality fish habitat.

DNR and The Conservation Fund collected wetland data from each of the four watersheds, and used this to predict presence of high-quality wetlands. DNR also performed rapid assessment surveys to characterize nontidal wetlands for conservation

potential and the amount of effort and resources required for restoration.

The Conservation Fund collected forest plot data throughout the project area, and used this to identify and calibrate parameters modeling high-quality forest. They also compared the forest plot data to LIDAR (light detection and ranging) canopy height data processed in Charles County, historic aerial photos in Prince George's County, and other data such as land cover, slope, stream proximity, wetlands, and floodplains, and developed a predictive model of forest age. This analysis helped identify core forest areas in the green infrastructure network.

The Department of Natural Resources' Natural Heritage Program performed surveys of rare species and natural communities, updating their existing inventory. DNR identified and characterized Ecologically Significant Areas that contained rare species habitat, and grouped ecological communities according to species similarities. This information helped delineate and prioritize the green infrastructure network and environmental stewardship opportunities.

Green Infrastructure Network Design:

The next step in developing the conservation strategy was to identify the green infrastructure network. The basic building blocks of a green infrastructure network are core areas, hubs and corridors. Core areas contain naturally functioning ecosystems and provide high-quality habitat for native plants and animals. These are the nucleus of the ecological network. Hubs are slightly fragmented aggregations of core areas, plus contiguous natural cover. Hubs are intended to be large enough to support populations of native species, and serve as sources for emigration into the surrounding landscape, as well as providing other ecosystem services

like clean water, flood control, carbon sequestration, and recreation opportunities. Corridors link core areas together, allowing wildlife movement and seed and pollen transfer between them, and thereby promote genetic exchange.

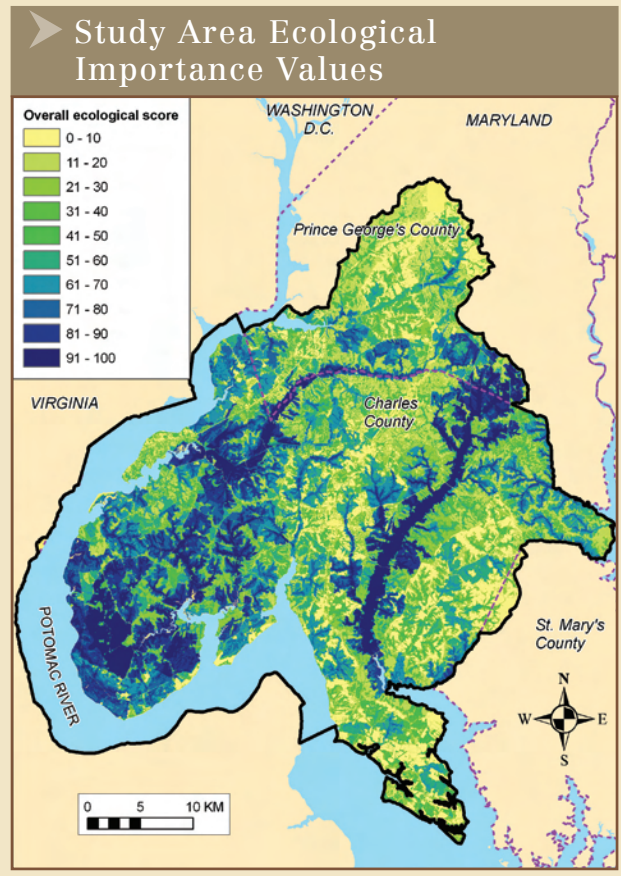
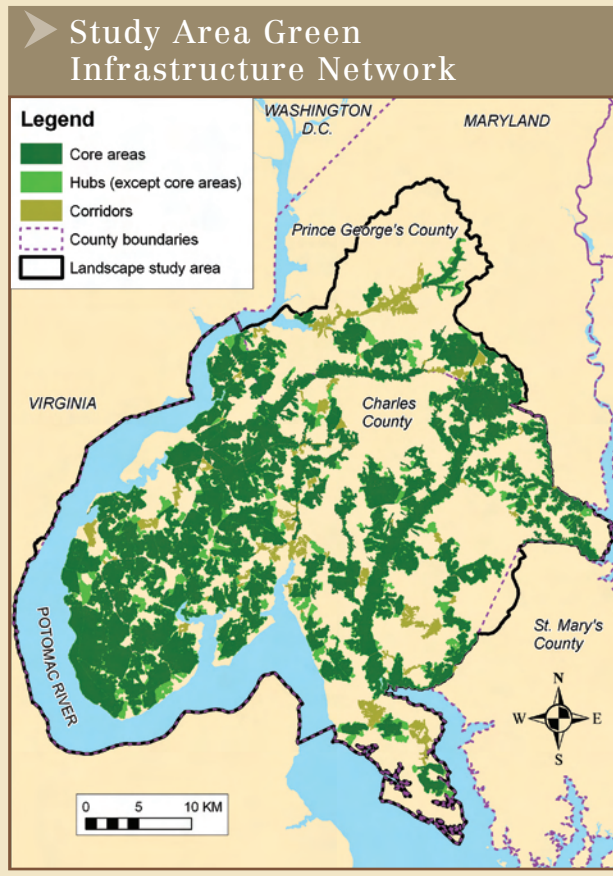
The types of landscapes and ecosystems incorporated into a green infrastructure network depend on the region's topography, climate, geology, historic and current species composition, present configuration, and other factors. The first step in developing a green infrastructure network is to identify species and natural communities occurring in the study area, and then identify their habitat preferences and requirements, home range sizes, dispersal abilities, suitable landscape features for dispersal, barriers to dispersal (e.g., highways or development), and the species role in ecosystem function. "Umbrella"

and "keystone" species native to the area are used to determine size, connectivity, and other thresholds in the green infrastructure network design. Umbrella species are a species or group of species whose habitat needs overlap those of other animals and plants. For example, the habitat needs of forest interior breeding birds overlap those of many other plant and animal species, including large mammals, many wildflowers, wood frogs, and wild turkeys. When sufficient habitat is protected to sustain a diverse assemblage of forest birds, important components and microhabitats of the forest will also be encompassed and be protected.²⁹ Keystone species are those with an important role in ecosystem function, such as pollinators, seed dispersers, hydraulic engineers (beavers), and top carnivores. Habitat preferences of umbrella and keystone species

help identify core areas and hubs. Connectivity requirements of less mobile species (e.g., amphibians and small mammals) are used to model corridors.

The Conservation Fund reviewed available literature concerning the project area and native wildlife species. Wildlife habitat requirements and movement obstacles helped parameterize green infrastructure core areas, hubs, and corridors.

For analysis purposes, NRWG divided ecosystems into three broad types: forests, wetlands, and aquatic systems. NRWG did not include grasslands (before European colonization, a rare and ephemeral ecosystem in the project area) because surveys showed that available remotely sensed data could not accurately identify grassland habitat.



CORE AREA CRITERIA

Core Forest: Blocks of forest containing at least 250 acres of mature interior (at least 100 meters from the nearest edge) deciduous or mixed forest. Criteria were derived from habitat requirements of forest interior breeding birds.

Core Wetlands: Relatively unimpaired wetlands with adjacent forest or water. These included large blocks (at least 250 acres) of interior broadleaf forest along natural perennial streams, large blocks of mature interior swamp or floodplain forest with standing water, unpolluted wetlands (at least seasonally flooded) and vernal pools with at least 215 meters of surrounding forest, and unimpaired and well-buffered marsh at least 12 acres in size. Criteria were derived from habitat requirements of several species of birds, amphibians, and reptiles.

Core Streams: Stable perennial streams with continuous riparian vegetation and not impounded or channelized. Core aquatic areas included adjacent forests and wetlands. Criteria derived from habitat requirements of native fish and mussels.

ECOLOGICAL RANKING FACTORS

- Rare species presence, viability, and habitat extent
- Aquatic biological condition and importance
- Forest maturity and extent
- Wetland and stream condition and context
- Distance from roads and development
- Proximity to other core areas or hubs
- Connectivity potential and importance in the overall network
- Type of neighboring land uses

NRWG defined core areas using criteria derived from the habitat requirements of keystone animal species in the three focal ecosystem types (see text box).

NRWG defined hubs as aggregations of core areas, other habitat, and other natural land, divided by major roads or gaps greater than 328 feet (100 meters) and at least 250 acres in size. Not all core areas, other habitat, or other ecological features fell within hubs, if they were isolated and below the size threshold. The Conservation

Fund used least cost path analysis to identify optimal linkages between core areas, and added adjacent suitable land to delineate corridors.

Finally, the NRWG identified potential buffers around core areas, hubs, and corridors. These buffers – natural land, pine plantations, fallow fields, or agriculture – could protect the green infrastructure from high-intensity disturbances associated with urban development.

NRWG then evaluated and ranked areas within and outside the green

infrastructure, using a set of factors at multiple scales, to help distinguish their relative ecological rank (see text box). NRWG used the resulting relative ecological rankings to identify the highest priorities for conservation efforts, shown here in the map of ecological importance values. These included the highest ranking unprotected forests, wetlands, and streams in the green infrastructure network that were adjacent to existing protected land, and were developable. NRWG considered the Zekiah Swamp mainstem and Mattawoman Creek floodplain too wet to develop, and subject to regulatory protections. All other privately owned land without conservation easements were considered at-risk for development or sand and gravel mining, although the immediate risk varied.

The State Highway Administration mailed letters to all landowners with at least 20 acres in these priority areas. Where permission is granted, work group and SHA will assess the conservation values of key properties, as well as restoration needs and costs. NRWG developed standardized methods for evaluating potential conservation and restoration projects in the field.

Restoration Targeting: Restoration includes a wide variety of activities to improve ecological functions, such as reforestation, wetland creation or restoration, stream restoration or stabilization, invasive species removal, stormwater management, construction of fish passages, ditch removal, road underpasses, and abandoned road or railroad removal. “Gaps” are areas within the green infrastructure that do not currently have natural vegetation, such as agricultural, barren, or lawn areas. Revegetation of these areas with natural land cover would strengthen the integrity of hubs and corridors, decrease negative edge effects, ease wildlife movement,



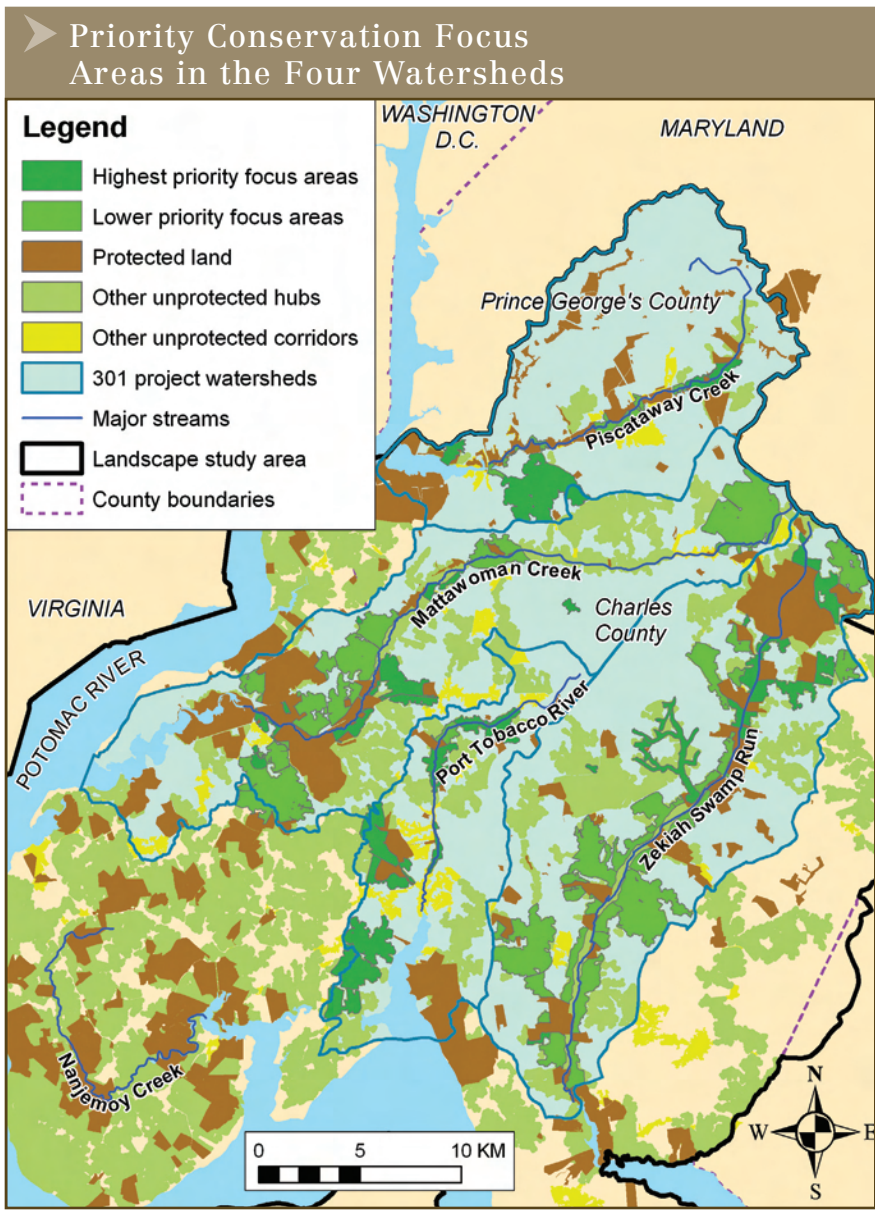
and decrease opportunities for invasive plants. The NRWG identified gaps within hubs and corridors that could be restored to natural cover by planting native species and, if needed, restoring soils or hydrology. NRWG identified corridor breaks and stream buffer gaps as high priorities. Internal gaps (entirely within a hub or corridor) were deemed higher priorities than gaps on the periphery of the network. The NRWG also identified unbuffered stream reaches outside the green infrastructure, but upstream of core aquatic areas.

In addition to reforestation, the NRWG examined opportunities for stream stabilization, wetland restoration, and invasive species control. Because restoration projects would require permanent protection from land conversion, the highest priorities were within priority conservation areas. Further, restoration projects within the green infrastructure would benefit the network as a whole, and the restoration project would be more likely to succeed over the long term. For example, wetland restoration within a green infrastructure hub, especially near existing core wetlands, could benefit from nearby sources of

native species and a relatively natural hydrology. Restoration projects in urban or agricultural areas, although they may provide benefits like stormwater retention and flood attenuation, often become dominated by exotic species and may be subject to hydrologic impairments and influxes of pollutants. Similarly, stream restoration in a hub, especially where the watershed is mostly forested, may benefit from a more stable baseflow and storm flow, and may be linked to more diverse populations of fish and benthic organisms.

Optimization: Effective conservation and mitigation require both sound science and sound economics, yet the most common technique used to select conservation projects can be quite inefficient. This selection technique, a “rank-based model,” selects the projects with the highest benefit scores with little consideration of the relative project costs. In situations where numerous high quality projects go unfunded due to budget constraints, the rank-based approach ensures only that the available resources are spent on the highest ranked projects; however, the model frequently misses opportunities to spend the money in a cost-effective way by funding low-cost, high-benefit alternatives that would maximize overall conservation benefits.

In contrast, an “optimization model” uses a mathematical technique called binary linear programming to identify the set of cost-effective projects that maximizes aggregate benefits. The optimization model uses data describing the resource benefits of the potential projects and relative priority weights that an organization assigns to each benefit measure, as well as estimated costs of each project and overall budget constraints. The optimization model evaluates each of the possible sets of available projects and selects the set that maximizes the



aggregate conservation benefits given a specified budget. The optimization model can help distinguish between the high-cost “Cadillac” projects, which can rapidly deplete available funds while making relatively small contributions to overall conservation goals, and the “best buy” projects, which individually may not appear as valuable, but when combined, provide significantly greater aggregate benefits. An alternative approach is known as Cost-Effective Analysis, which ranks benefit-cost ratios for each project from highest to lowest and then selects the highest ranked benefit-cost ratio until the budget is exhausted. Identifying the cost efficient set of projects generated not only helps organizations maximize their financial resources, but can also provide a science-based, economic rationale for identifying and prioritizing projects.

RESULTS

Inventory: The work group performed an extensive natural resource inventory for the project. They conducted a literature review of local environmental conditions, wildlife habitat requirements, the natural history of the area, and existing planning efforts; surveyed stability conditions at 163 stream reaches; collected forest data at 62 randomly selected plots; collected data at 27 wetlands; identified 30 locations of seven rare plant species; and collected data on 89 natural communities. In addition, stakeholders in the focus groups identified 328 site-specific environmental needs.

Development of new landscape characterization methodology:

To help characterize ecosystem condition, wildlife habitat, and help prioritize conservation decisions in the study area, two members of the work group created a new spatial model that uses remotely sensed data to estimate forest maturity.³⁰

This new methodology used LIDAR (light detection and ranging) data and innovative techniques to calculate tree canopy height and thus estimate forest age. After verifying their results with sample plots on the ground, the information was used to construct a spatial model to classify the forest in the four focal watersheds of the 301 project area into three age categories: young (<30 years old), intermediate (30–70 years old), and mature (>70 years old). Of all the GIS variables used to identify conservation priority, modeled forest age was the best predictor of highly valued conservation areas. The work group used the data from this ground-breaking model extensively to help develop the conservation network.

Green Infrastructure Network Design:

The study area encompassed 439,452 acres and the resulting hub-corridor network totaled 185,862 acres (42% of the area). The work group identified 141,362 acres of core areas, 172,289 acres of hubs (30,927 acres of this external to core areas) and 13,573 acres of corridors. They also identified gaps and corridor breaks, where restoration would improve network integrity. They ranked areas by their ecological importance and developed methods to evaluate conservation and restoration projects. Finally, they mapped priority conservation focus areas.

Optimization Study: By the end of 2009, the work group will provide a list of potential environmental stewardship projects, with estimated benefits and costs, for use in the selection of opportunities based on different road alignments and budget scenarios. The US 301 project serves as a model for holistically identifying natural resource needs and priorities, minimizing the impacts of transportation projects, providing a framework for strategic mitigation and a process

for project selection that addresses benefits and costs.

In a hypothetical modeling scenario involving a \$15 million budget and a maximum of 30 conservation projects (to simulate limited staff available for implementation), optimization outperformed rank-based selection by selecting projects with 7% higher aggregate ecological value and 15% more green infrastructure acreage for \$2 million less. The additional \$2 million could have been spent to protect even more land if there was additional transaction capacity. Comparable scenarios occur with other combinations of budget and transaction capacity and illustrate that ecological value, green infrastructure acreage, and other benefit measures can be maximized using an optimization decision support tool.

Citizen Involvement: The work group’s process included substantial public input because they assumed that public assessment of needs and priorities should be key factors in decision making and resource allocation. They also felt that it would bring major benefits to the process and lead to better decision outcomes that were supported by the public.

KEYS TO SUCCESS

The Conservation Fund offers the following recommendations on how best to integrate green infrastructure and benefit-cost optimization for conservation planning:

- **Establish a collaborative green infrastructure working group** with a clear work plan, quality control procedures, and regular communication.
- **Educate transportation proponents and resource agency staff** on green infrastructure principles to ensure all parties understand the concept and the vocabulary.



- **Convene meetings with the local community early** in the process to ensure that the full range of potential resources are identified and evaluated.
- **Design the network for multiple purposes.** While a green infrastructure network may be developed for a particular purpose (e.g. a transportation improvement project), the network can be designed so that it is useful for other purposes (e.g., municipal and county land use planning and decision making).
- **Design the network to facilitate restoration targeting** so that mitigation projects are more likely to be successful and provide tangible ecological benefits.
- **Develop methods, protocols, and evaluation systems that are replicable and transparent.**
- **Develop message points for each constituency that may potentially be involved in implementation of the network design** – remembering that the network design will cross public, private and non-governmental organization owned land.
- **Actively communicate that smart mitigation using a green infrastructure approach provides positive benefits to both green and grey infrastructure** – a win-win. If planned properly, green infrastructure and grey infrastructure should be viewed as complementary systems rather than competing systems.
- **Ensure all green infrastructure plans are provided to the State Department of Transportation (DOT)** as these plans will serve as valuable data layers in DOT planning processes.

PHOTOS AND FIGURES

All photos and figures by The Conservation Fund
 Page 117: Image, Google Earth
 Page 119: Figure, Joel Dunn



Box turtle (Terrapene carolina) in Charles County, a species that relies on connectivity between wetlands and forest, and is impacted by roads and development.

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