A Practitioner's Handbook: Optimizing Conservation and Improving Mitigation Through the Use of Progressive Approaches

NCHRP 25-25, Task 67

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final report

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1.0 Introduction

When proposed for permitting under the terms of the Clean Water Act (CWA) §404 and Endangered Species Act (ESA) §7 and §10 programs, many transportation, infrastructure, and development projects would cause impacts to wetlands, streams, and the habitat of sensitive species. In these cases, state and regional transportation agencies work with Federal and state regulatory agencies to avoid and minimize adverse impacts to aquatic resources and habitat. After impacts to aquatic resources and habitat are avoided and minimized as much as possible, transportation agencies are commonly required to compensate for unavoidable impacts to these resources. Compensation, or compensatory mitigation, can be an important method of maintaining healthy, economically valuable ecosystems.

In this handbook we provide an overarching view of the ecosystem and economic benefits and cost savings associated with progressive approaches to the Clean Water Act or Endangered Species Act compensatory mitigation and compare these benefits and savings to traditional mitigation approaches. We then highlight several empirical examples of transferable tools, models, and frameworks used for innovative compensatory mitigation in use throughout the United States. We highlight innovative tools, methods, and frameworks that focus on landscape or watershed analysis of ecosystem functions only, as well as progressive approaches that include the valuation of ecosystem services provided by compensatory mitigation. Finally, we lay out tangible steps for transportation agencies, policy-makers, and the research community to facilitate and implement progressive mitigation programs. More detailed information about some important technical terms are provided in call-out boxes throughout the handbook, and a glossary of terms is provided in Section 6.

1.1 What is Progressive Mitigation?

Offsets for damage to wetlands, streams, or habitat of sensitive species may consider the **ecosystem functions** or **ecosystem services** associated with a mitigation site.

Ecosystem functions are the biophysical processes conducted by ecosystems. **Ecosystem services** are the economic or social values of these functions to society.

There are a range of approaches that can be applied to the process of selecting and designing compensatory mitigation sites. These different approaches offer a wide variety of ecosystem and economic outcomes. The different approaches to compensatory mitigation site selection and design can generally be grouped into one of three categories: traditional, "midway," and progressive.

Traditional approaches to compensatory mitigation are those that allow a permit applicant or the entity conducting compensatory mitigation (e.g., a mitigation bank) to propose compensation sites on a project-by-project basis, usually based on best professional judgment and with little or no analysis of landscape or watershed functional needs. Sites selected using traditional approaches to compensatory mitigation are generally chosen opportunistically to minimize costs to the permittee, rather than maximize environmental outcomes.[1]

Midway approaches are those that use some sort of evaluation of landscape setting, but do not include holistic watershed- or landscape-scale planning. Examples of these approaches generally undertake single-priority analysis, such as watershed plans that assess just one aquatic resource function or service. The midway category also includes the use of qualitative mitigation guidelines that describe the types of compensation projects that resource agencies prefer, and decision-making frameworks to handbook the selection of appropriate locations for compensation projects, but neither use detailed analyses of watershed or landscape needs to select compensatory mitigation sites.[2]

[1] For more on these approaches see: NCHRP 2010a, pp. 6-7. 34-47; NCHRP 2010b, pp. 8-9, 12-20; NCHRP 2011, pp. 16-23, 30-33.

[2] For more on these approaches see: NCHRP 2010a, pp. 6-7. 34-47; NCHRP 2010b, pp. 8-9, pp. 20-26; NCHRP 2010c, pp. 23-36.

Wetland, Stream, and Conservation Banks

Mitigation banks are a mechanism to provide compensation for lost wetland, stream, and endangered species habitats. Private entities or public agencies invest in the purchase of land, undertake mitigation activities (restoration, recreation, enhancement or preservation), and then sell the credits they earn from their investment to third parties in need of mitigation credits.

In-Lieu Fee Mitigation

With in-lieu fee mitigation, the developer pays a stipulated sum into a fund, usually managed by a public agency or by a non-profit organization, the proceeds of which are used to undertake compensatory activities. In-lieu fee mitigation arrangements have been used in both the wetlands and endangered species contexts.

Progressive approaches to compensatory mitigation are those that seek to use a strategic, analytic approach to compensation site design and selection that relies on a robust analysis of a suite of data on the watershed/landscape in which the compensatory mitigation project is being proposed. These approaches, whether applied through a mitigation or conservation bank, in-lieu fee program, or another compensatory mitigation mechanism, seek to characterize a watershed/ecosystem's functional needs in order to site and design compensatory mitigation projects that will improve the overall condition of a hydrologic or ecological unit. These holistic planning approaches consider multiple ecosystem functions or services. In the case of watershed planning, they address the entire suite of aquatic resource functions or services. Landscape planning efforts address the habitat needs of multiple species. These watershed- or landscape-scale evaluations allow permittees to move beyond project-by-project compensatory mitigation site selection; more comprehensive analyses of impacts from infrastructure and development are merged with conservation planning to proactively identify priority areas for ecological and economic investment.[3]

Progressive mitigation programs that use a multi-resource evaluation of the ecological functions and the economic benefits provided by ecosystems present a way to maximize investments in ecosystem restoration, creation, enhancement, or preservation. Transportation agencies are in a unique position to implement progressive mitigation programs, as infrastructure development plans are generally known in advance of impacts, as opposed to alternative forms of

[3] For more on these approaches see: Task 1, pp. 6-12, 34-47; Task 2, pp. 6-9, pp. 26-36; Task 3, pp. 23-36.

development, which generally do not require as much advance planning and don't offer as much certainty.

1.2 Moving from Traditional to Progressive Approaches

Since 1990, there have been many efforts to improve compensatory mitigation, including the development of guidelines and delivery of trainings to support a watershed, habitat, or ecosystem approach to evaluating and selecting mitigation sites (Venner 2010b; Venner 2010c). Many tools, frameworks, and methods have been developed in the intervening years to support improvements in the selection, design, and assessment of mitigation sites. In addition, there are many published case studies that document on-the-ground implementation of these progressive approaches across the country.

Clearly, there is not a one size fits all approach to the assessment and selection of compensatory mitigation sites. But given that over $3.3 billion is spent annually on compensatory mitigation under the CWA and ESA (ELI 2007) and that environmental permitting can encompass 3 to 59 percent of mitigation or road construction costs (Louis Berger and Associates, Inc. and BSC Group 1997), many opportunities exist to maximize the conservation and economic outcomes of transportation-induced aquatic resource and endangered species habitat offsets.

The following sections discuss the benefits and cost savings of different approaches to compensatory mitigation, provide examples of current agency approaches, and outline next steps to further advance effective mitigation.

2.0 How Progressive Approaches to Mitigation Support Economic and Ecosystem Benefits and Cost Savings

The high level characteristics and benefits of traditional versus progressive approaches to compensatory mitigation are outlined in Table 2.1 below, and explored in more detail in this section of the handbook. Each characteristic listed has an economic and/or ecosystem benefit or cost saving. As discussed in more detail below, innovative mitigation approaches can provide ecosystem and/or economic benefits or savings in two significant ways. First, a progressive approach to compensatory mitigation can yield more ecologically effective results and contribute to conservation priorities identified in a region, and in many cases provide society with economically valuable ecosystem services. Second, a progressive approach to mitigation lends itself to more coordinated and consolidated administrative and decision-making processes, introducing significant time and resource efficiencies for transportation and natural resource regulatory agencies. In addition, as discussed in Section 3, many of the innovative approaches to compensatory mitigation reviewed provide more transparency, repeatability, and performance measures than traditional approaches, thereby contributing to better accountability and ability to measure success.

Table 2.1 outlines some of the key characteristics of traditional and progressive approaches to compensatory mitigation. Traditional approaches tend to happen opportunistically – focusing on replacing the impacted resource by using another similar site in close proximity to the impact. In contrast, a progressive approach would entail selecting a site from a suite of already identified high-priority sites in the region – not only replacing the impact but contributing to an overall strategy to improve the condition of important watersheds and landscapes, and supporting conservation goals. When using a progressive approach to compensatory mitigation, sites are identified for conservation or restoration based on the results of a regional ecological assessment process that contributes to the identification of sites with a richer, healthier mix of species and/or a higher potential for sustaining the restoration of a site and resulting in a high level of ecosystem services. Utilizing an opportunistic approach to selecting a compensatory site tends to replace the single resource that was impacted, whereas a progressive approach provides the opportunity to select a site that not only replaces the impacted resource but other resources that occur in preidentified high priority sites for conservation or restoration. In addition, progressive approaches tend to utilize quantitative scientific information that is needed to conduct a scientifically rigorous ecological assessment process, and can in turn contribute to the selection of sites with a higher potential for better environmental outcomes. Similarly the use of this quantitative scientific information in combination with expert opinion, rather than expert opinion alone, will contribute to more standardized, repeatable decision-making processes, and can lead to more accurate assessments and therefore the selection of higher quality mitigation sites. In addition to the potentially better ecological and ecosystem benefits that a progressive approach can bring, working strategically can support more consolidated decision-making and administrative processes such as the selection of one larger mitigation site to offset impacts at many sites located throughout a watershed. Although a traditional approach to compensatory mitigation can replace impacts, the strategic, quantifiable, scientifically based elements of a progressive approach are more likely to result in sites that are higher in biodiversity, produce more ecosystem services, and are more likely to sustain these better ecological outcomes over time.

Table 2.1 Characteristics and Benefits of Traditional versus Progressive Compensatory Mitigation

Traditional	Progressive
Opportunistic	Strategic
Project-by-project impact analyses	Watershed/landscape-scale impact analyses
Single-resource approach	Multiresource approach
More reliance on qualitative information	More reliance on quantitative information
More reliance on expert opinion	More reliance on scientifically based information in combination with expert opinion
Replacement of impacted resources may result in partial replacement	Contribution to broader hydrologic and ecological conservation priorities
Investments bring lower level of ecological and ecosystem benefits	Investments bring higher level of ecological and ecosystem benefits
Repeated project-by-project decision-making and administrative processes	Consolidated decision-making and administrative processes
Nonstandard, difficult to replicate decision-making process	Potential for more standardized, repeatable decision-making process

2.1 Ecosystem and Economic Benefits of Innovative Mitigation

In this section the ecosystem and economic related benefits that can result from using innovative mitigation approaches are explored – describing how progressive approaches to mitigation provide ecosystem and economic benefits, and what these benefits include.

Innovative mitigation approaches address the role of wetlands, streams, habitats, or other land uses in a geographically broader context of biophysical production and functions. Biophysical inputs (such as polluted water inflow) are environmental features or conditions that are converted, via natural processes, into enhanced environmental features or conditions (such as pollutant-reduced filtered water). These converted environmental features or conditions are the outputs of biophysical processes. We refer to biophysical processes that transform inputs into outputs as biophysical production functions. When these broader systems of biophysical or ecological production functions are appreciated and taken into account, mitigation is more likely to deliver better ecological outcomes (NCHRP 2011, NRC 2001).

Traditional compensatory mitigation emphasizes replacement of the same ecosystem functions that have been lost and emphasizes that the replacement should occur on lands adjacent to the project site. However, a narrow focus on replacing on-site functions may fail to take into account broader ecosystem needs and goals. In addition, if compensatory projects are not viewed in the context of the larger landscape, off-site factors that can have a significant effect on the production of ecosystem outcomes at the compensation site can determine the success or failure of that site. For example, many of the progressive wetland and stream mitigation site selection methods (Kramer and Carpenedo, 2009, Strager et al, 2010) utilize a watershed approach, and include criteria that factor in the importance of the proximity of a mitigation site to a conservation priority or otherwise protected area. Having a compensatory mitigation site located in close proximity to conservation or protected lands can contribute to increasing a created, enhanced or restored wetland's success in compensating for losses by increasing its connectivity, size, and overall contributions to wetland functions in that watershed (Kramer and Carpenedo 2009). On the contrary, if a site that provides a high level of ecosystem function is selected, but the surrounding lands are undergoing significant infrastructure development, there is a high likelihood that the site will degrade over time and not support the long-term compensation goals of that site. Furthermore, innovative mitigation approaches use information about biophysical systems and consider multiple resources to evaluate the site and determine which are most likely to yield the highest number of ecologically valuable outputs (NCHRP 2010c). Thus, successful mitigation is dependent on the evaluation of on-site functions in the context of the broader ecological goals they support, as well as the spatial placement of the mitigation site within the landscape. Furthermore, using consolidated, off-site compensation options, supported by many innovative mitigation approaches described in Section III, may provide ecological economies of scale like the increased protection afforded to species by larger, unfragmented habitat patches (Schwartz 1999; Murcia 1995; Drechsler and Watzold 2009).

Ecosystem production functions as described above translate into ecosystem services or ecologically based outputs that are valued by society. Since progressive approaches to compensatory mitigation can support higher levels of ecosystem production function than traditional approaches, these progressive approaches can result in greater ecological-based benefits to society in addition to the inherent ecosystem benefits. Currently, the societal value of ecosystem production functions is rarely taken into account in the selection and design of compensatory mitigation projects (NCHRP 2010a, Ruhl and Gregg 2001), even though they provide valuable services to nearby human populations (Engel et al. 2008). For instance, in addition to traditionally valued ecosystem services such as timber and fish production, wetlands are well-known for their ability to, among other things, filter excess pollutants and nutrients, reduce flood hazards, absorb storm surge, and provide unique recreational or scientific opportunities (Mitsch and Gosselink 2000; Zedler 2003). Protection for endangered species supplies additional value for human populations (Loomis and White 1996). Species are often valued "for their own sake" particularly when threatened with extinction (so-called "existence value"). In some cases species are commercially valuable when caught or harvested. In other cases, recreational benefits (from hunting and angling, birding, hiking) are dependent on the existence and abundance of particular species. More ecologically effective mitigation can contribute to the preservation of these tangible values provided by terrestrial and aquatic resources, and their dependent imperiled species.

> Because many ecological outcomes are socially valuable, progressive approaches that consider ecosystem services will yield compensation projects with greater social and economic value than those where ecosystem service production is not taken into account (Boyd and Wainger, 2003).

Traditional and most progressive approaches to compensatory mitigation do not evaluate ecological outcomes and benefits in a way that includes mitigation's effect on the production of ecosystem goods and services. To do this it is necessary to evaluate ways in which site-specific gains/losses interact with the broader context of biophysical production. Measuring ecosystem functions, the spatial scales on which they operate, and their subsequent social value is a difficult and tenuous task (Kremen and Ostfield 2005). However, even rudimentary methods of assessing the social value of various ecosystem functions can help to integrate the economic benefits of compensatory mitigation projects into policy-making and regulatory decision-making (e.g., See MnRAM example in Section 3).

From an economic perspective we can make several broad statements about the value of ecosystem goods and services:

- The scarcer an ecological feature, the greater its value.
- The scarcer the substitute for an ecological feature, the greater its value.
- The more abundant a complement to an ecological feature, the greater its value.

- The larger the population benefiting from an ecological feature, the greater its value.
- The larger the economic value protected or enhanced by the feature, the greater its value.

For example, the value of irrigation and drinking water quality depends on how many people depend on the water – which is a function of where they are in relation to the water. Flood damage avoidance services are more valuable the larger the value of lives, homes, and businesses protected from flooding. Species important to recreation (for anglers, hunters, birders) are more valuable when more people can enjoy them. Economic valuation studies have found that wetlands also can generate aesthetic benefits (Mahan et al. 2000) contributing to an increase in property values (Doss and Taff 1996); thus wetlands in close proximity to larger housing communities have increased economic value.

A number of case studies have demonstrated surrogate goods and services, that are more easily measured, that can be used to generate approximate ecosystem service values (e.g., Costanza et al. 1997; Sutton and Costanza 2002). Nonetheless, we do not have a precise ecological understanding of the many natural benefits provided by an ecosystem; nor do we have a widely applicable, easy, and inexpensive methodology for measuring the value of ecosystem services (Kremens and Ostfield 2005). However, a number of emerging tools are attempting to fill this void by allowing decision-makers to identify the value of ecosystem services and the specific populations they serve in an effort to better target restoration or preservation (Waage et al. 2008). Several ecosystem service valuation tools are available or currently in development that may be useful to practitioners in resource agencies or transportation planning. These tools may help decision-makers prioritize natural resources based on the quality of their ecosystem services – either through avoidance, minimization, or compensation – and in so doing, will allow for mitigation decisions to provide the most economic value to society. Section III below outlines the emerging tools and methods that can be used in innovative mitigation efforts, and specifically assist in ecosystem service valuation.

2.2 Cost-Saving of Innovative Mitigation

The cost savings that can result from using innovative mitigation approaches versus traditional approaches are explored in this section.

Progressive approaches to compensatory mitigation expand the spatial and temporal scope of decision-making, supporting the consideration of multiple options to replace ecosystem functions and ecosystem services lost at an impact site (National Research Council 2001). It has been demonstrated that the cost of mitigation varies according to land value as well as the direct cost of restoration and creation. Innovative mitigation approaches that utilize regional, quantitative-based analyses provide more mitigation options to consider and therefore can provide cost savings related to land acquisition, restoration, construction, water right acquisition and opportunity costs (Louis Berger and Associates, Inc. and BSC Group 1997; Drechsler and Watzold 2009). Innovative mitigation supports more coordinated, efficient decision-making among transportation and regulatory resource agencies, as well as consolidation of regulatory permitting processes, and other administrative and transactional processes related to mitigation. For example, progressive approaches to compensatory mitigation encourage increased use of consolidated, off-site compensatory mitigation sources, such as mitigation banks, conservation banks, or in-lieu fee programs, presenting opportunities to capture economies of scale and reduce compliance costs for permittees (U.S. Department of Defense and U.S. Environmental Protection Agency 2008; U.S. Fish and Wildlife Service 2003). In two study areas in California, (Thorne et al. 2009) researchers observed a decrease in parcel price per hectare as potential mitigation sites size increased. Large-scale wetland and stream restoration projects may additionally capitalize on scale advantages by reducing the restoration planning, design, construction, and operation costs (Silverstein 1994; Sapp 1995). In addition, interagency collaboration and regulatory consolidation expedites mitigation permitting, reducing transportation project delays, and their associated costs. As an example, in Montana, cost- and time-savings are anticipated from having transportation and resource personnel address multiple projects concurrently, lowering the possibility of encountering significant obstacles to road expansion late in the project, and reducing regulatory time for permitting (Hardy et al. 2007).

As cited in *Eco-Logical: An Ecosystem Approach to Developing Infrastructure Projects*, utilizing holistic innovative mitigation planning in advance of impacts, can afford additional cost savings through the early acquisition of land, especially as the price of land rises over time (Brown 2006, Thorne et al. 2009). Many state departments of transportation (DOTs) confirm generating substantial cost-savings through consolidated mitigation planning, increased flexibility in site selection, and advance purchase of valuable mitigation parcels (NCHRP 2010a). In fact, late evaluations of the environmental impacts of road project development are the leading cause of expensive holdups in road construction (Transtech Management, Inc., 2003).

Programmatic mitigation utilizes processes that support a collaborative, landscape-scale approach to mitigation. These collaborative, holistic, landscape-scale approaches allow transportation and resource agencies to eliminate redundant investments, share data, and identify potential mitigation sites more effectively. This, along with the use of consolidated, off-site compensation, can reduce field site visits and time spent approving and monitoring ecosystem restoration. Collaborative, ecosystem-scale approaches to mitigation also lower overall financial expenses by establishing regulatory assurances and thus reducing vulnerability to litigation or punitive damages, while also allowing transportation agencies to more accurately forecast expected project costs and their associated environmental compensation components. (NCHRP 2010a, Brown 2006). In states with programmatic permitting processes and a statewide mitigation program that focus on achieving multiresource, multibenefit outcomes, research has demonstrated that many benefits can be achieved, including improved impact avoidance, and earlier identification of enhancement opportunities and permit needs – supporting efficiencies, and more accurate cost estimates and schedules (NCHRP 2010a). There are many examples of transportation programs that have adopted a streamlined, ecosystem-based approach to infrastructure planning and experienced substantial transaction cost- and time-savings as compared to traditional, project-by-project compensatory mitigation. In 2001, for example, the NCDOT reported that 55 percent of its transportation developments were delayed by wetland mitigation requirements; after ramping up streamlined transportation planning and mitigation through their Ecosystem Enhancement Program (EEP), there were no delays in Transportation Improvement Projects associated with EEP. (Venner 2010a).

2.3 Net Benefits and Cost-Savings: Traditional versus Progressive Approaches

Innovative mitigation planning involves more and better information and analyses, therefore the upfront costs of these progressive approaches will be more expensive than traditional approaches. However the ecosystem and economic benefits of innovative mitigation planning, combined with the potential cost savings, as described above, are likely to outweigh the additional (and upfront) analytical costs necessary to establish a progressive approach to compensatory mitigation planning (NCHRP 2011). These higher up-front planning costs are very likely to yield significant, long-run cost savings.

Progressive planning can constrain the location of acceptable mitigation projects by identifying which options may yield the greatest ecosystem and economic benefit. Ideally, progressive planning favors sites with the greatest *net* benefit, meaning land acquisition costs, as well as restoration and creation costs, are taken into account. However, it is possible that the cheapest lands will not yield the largest net benefit, which implies that acquisitions costs may be higher under a progressive planning approach. Nevertheless, with a net benefit approach to site selection that takes into consideration the benefits of improved ecosystem services, the gains from progressive planning will likely always be greater than any additional land acquisition costs.

Overall there is compelling evidence that if transportation and natural resource agencies continue to work together in developing a progressive, landscape-scale approach to the compensatory mitigation process using a combination of the methods and processes outlined in this handbook, significant ecosystem, economic, and societal benefits can be achieved.

The next section provides examples of tools and methods that can be used to support the type of progressive approaches to compensatory mitigation.

3.0 Examples of Tools and Methods Used in Progressive Approaches to Mitigation

Across the country, various systematic, progressive approaches are being taken to select priority sites for compensatory mitigation of aquatic resources and endangered species habitat. The potential ecosystem and economic benefits of these approaches are discussed in Section II. While a select few examples of these progressive approaches to compensatory mitigation currently assess the value of ecosystem services during site selection, most of the tools and methods utilized in these programs stop short of analyzing the social and economic benefits of compensatory mitigation projects. Instead, most innovative programs focus solely on watershed- or landscape-scale factors that affect the ecosystem function of a compensatory mitigation site. Tools and methods to evaluate a compensation site's potential functions may simply provide an overall metric for a particular aspect of a site's suitability as a compensation site, such as a generic wetland suitability rating, or may provide more specific metrics of a site's suitability for compensating for different ecosystem functions. But some of these innovative programs also incorporate consideration of more tangible economic benefits – e.g., economies of scale, advance purchase of compensation sites, and streamlined permit approval – into their site-selection methods.

Here we discuss a selected set of documented tools and methods used in existing compensatory mitigation programs that are representative of the present-day variation in holistic, multiresource approaches to choosing offset sites (midway and progressive as defined in Section I). First, we review innovative tools and methods used in programs that do not incorporate the value of ecosystem services into decision-making, including a few programs that have mitigation planning tools and methods that consider more tangible economic values in site selection (e.g., MARXAN). Second, we discuss other emerging tools and methods that also facilitate the economic valuation of ecosystem service outcomes as part of an innovative compensatory mitigation program.

3.1 Compensating for Ecosystem Function: Innovative Tools and Methods

Different conservation objectives and different levels of detail are utilized in current landscape-level approaches to siting compensatory mitigation projects. For instance, some innovative tools and methods focus on the establishment and analysis of green infrastructure plans or regional greenprints, which seek to identify habitat centers, corridors, and the relative contribution of a mitigation site to that network. Other plans primarily focus on the aquatic functions of wetlands and streams, such as management, riparian buffers, and fish dispersal corridors. In addition, while some methods identify aquatic resource or habitat offset priorities across an entire program area (e.g., a state, ecoregion, or 8-digit Hydrologic Unit Code (HUC)), others seek to identify priority watersheds or subwatersheds within their program area where compensatory mitigation protection or restoration projects can most effectively meet overall resource needs. The spatial scale of analysis also differs significantly among innovative site-selection methods; some projects operate within an entire state while other projects operate within particular counties or watersheds.

Currently, the most innovative tools and methods used to identify and prioritize compensatory mitigation options consider multiple hydrologic and ecological objectives. They holistically evaluate multiple ecosystem functions to support a diverse set of regulatory and nonregulatory programs; provide function-specific analyses of these various biophysical processes; are iterative and easily accessible to stakeholders and regulators, allowing for input and analysis of accurate, updated data; systematically consider land acquisition and restoration costs to maximize the use of available funds; and integrate projected development with conservation plans to identify ideal offset sites. For instance, the Maryland Water Resources Registry (WRR) provides a publicly accessible platform that analyzes specific ecosystem functions and suggests priority restoration projects that accommodate multiple regulatory or nonregulatory programs. Another example, the California Regional Advanced Mitigation Project (RAMP), concurrently analyzes ecological potential and economic costs of aquatic resource and habitat mitigation for use in diverse regulatory or nonregulatory settings. The Nature Conservancy's (TNC) Development by Design framework also promotes integration of development and conservation planning to identify priority areas for biodiversity offsets. This general framework of identifying priority areas for conservation and restoration is being utilized by other organizations and state agencies in California, Florida, Massachusetts, New York, Nevada, Virginia, Washington, and others. The central characteristics of innovative compensatory mitigation are embodied in these and the other programs highlighted below.

Other less innovative programs also perform watershed- or landscape-scale analysis of mitigation needs but achieve fewer of the progressive objectives discussed above. These approaches focus exclusively on requirements for one specific regulatory program; provide generic priorities for an offset's suitability instead of breaking down priorities by specific ecosystem functions; are only accessible to some regulators or researchers; are too technically demanding for most stakeholders; do not document consistent procedures for integrating restoration costs and land prices into decision-making; or solely evaluate conservation plans without consideration of projected development trends.

NatureServe Vista Integrated Assessment and Planning Tool

NatureServe Vista is a free ArcGIS extension that spans the breadth of assessment and planning processes for a range of ecosystem and cultural features and ecosystem services. NatureServe and the Colorado Natural Heritage Program (NatureServe's member program in Colorado) used Vista (in conjunction with other tools – see toolkit approach at end of this section) to conduct a cumulative effects and mitigation assessment to evaluate a range of alternative as part of the development of the Long Range Transportation Plans (LRTPs) and transportation improvement plans for the Pikes Peak Area Council of Governments (PPACG). The various alternative scenarios that were developed using NatureServe Vista incorporated existing land use, conservation areas, and future planned infrastructure. One product was the Conservation Value Summaries (an indexing feature of NatureServe Vista that summarizes the combined conservation 'value' of an area). These summaries were used to handbook development of a "conservation-focused alternative" that used avoidance to retain ecological values. Finally, a board-approved "preferred alternative" was assessed and forecasted impacts were addressed by locating offsite mitigation opportunity areas that had the same values and quantities forecast to be lost from new development and infrastructure.

The Conservation Fund's Green Infrastructure Network Methodology

To offset expected impacts to natural resources from a planned highway bypass and increase the cost-effectiveness of compensatory mitigation projects, the Maryland State Highway Administration (SHA) requested that The Conservation Fund (TCF), the Maryland Department of Natural Resources (MDNR), and the U.S. Fish and Wildlife Service (FWS) analyze natural resource mitigation opportunities in four watersheds in Charles and Prince George's Counties, Maryland. The project established a methodology for combining geospatial analysis and field site assessments to identify conservation and restoration priorities for forest, wetland, and stream offsets. To identify high-value compensation sites, the partners utilized a green infrastructure approach, which maps areas of core habitat, hub habitat surrounding core areas, and wildlife and plant dispersal corridors.

TCF, MDNR, and FWS developed a landscape ecological score for potential conservation sites based on a suite of environmental parameters; these parameters were compiled at six different spatial scales surrounding a mitigation site and they were weighted by their relative importance to determine the site's final landscape ecological score. These ecological scores were then integrated within the context of parcel boundaries to prioritize particular properties for preservation. Finally, the researchers performed field site visits at parcels over eight hectares in size to develop a field ecological score. Potential restoration sites were also analyzed in the context of the watersheds' green infrastructure and field visits to create a similar metric for restoration potential. Significant to the green infrastructure network approach is that restoration projects with the potential to fill internal gaps in the network are given the highest priority in the model.

Site selection methods for compensatory mitigation often choose the location of offsets based on ranking methods that adopt the projects with the highest individual benefits, without consideration of the comparative costs of other, cheaper compensation options that, when aggregated, provide better overall ecological results. In order to select the most cost-effective, ecologically valuable suite of conservation parcels, this project developed and utilized a benefit-cost optimization model that chooses mitigation sites based on a given budgetary constraint. Due to project funding constraints, this optimization model was only run for restoration sites.

To select conservation sites, the optimization tool analyzed a parcel's area of green infrastructure, average landscape ecological score, field ecological score, distance to previously protected lands, and land costs. The ecological metrics were then used to create an overall parcel conservation score, which was compared with land costs to select conservation sites under hypothetical budget scenarios of $15 million and $5 million. The model run with a $15 million limitation was compared with a rank-based prioritization method, with the benefit-cost optimizer resulting in 15 percent more green infrastructure area and a 7 percent higher net ecological score. Under the $5 million budget scenario, the optimizer resulted in a 14 percent higher overall ecological score as compared with a ranking method, although it did result in 28 percent less green infrastructure area due to the enhanced ecological value of the selected parcels. The empirical model results were limited to conservation prioritization and did not extend to restoration, though the framework is established for such analysis by comparing restoration potential with cost (Weber and Allen 2010).[4]

While in theory, optimizing conservation for a suite of mitigation sites instead of selecting offsets based on individual site rankings is a more efficient approach to handbook land acquisition, this overall optimization approach may not be compatible with the realities of land acquisition. It is highly unlikely that compensatory mitigation providers will be able to acquire all potential compensation sites mapped in a green infrastructure model. Therefore, while the holistic optimization approach taken in this project is a useful theoretical exercise, transportation practitioners will likely need to choose offset sites through an iterative mitigation approach that maximizes conservation results from compensation sites that are actually available for acquisition.

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[4] Modeling optimal sites for restoration would also require consideration of estimated costs for restoration (e.g., site engineering, reforestation) and costs of conservation easements.

Maryland Water Resources Registry

A number of county, state, and Federal agencies, along with nongovernmental organizations, such as TCF, used the methodology discussed above as a starting point for development of a Watershed Resources Registry (WRR) in the same four watersheds. The registry database and tools have been expanded to cover the entire state of Maryland. The WRR developed in Maryland is a GIS-based mapping tool designed to support the development of watershed profiles by integrating information from various governmental and nongovernmental stakeholders. Watershed profiles generally characterize aquatic resource extent, quality, and types in a watershed to promote holistic analyses of watershed needs. The result of the WRR is a decision support tool that can easily help users identify priority resources and restoration objectives for water quality, habitat, stormwater management, land management, existing watershed plans, etc. By integrating information from multiple resource agencies and nongovernmental organizations into one system, WRR supports the identification of high priority resources for mitigation in Maryland and the development of conservation goals utilizing a standard, scientifically based and repeatable process that is encapsulated in the Registry.

The WRR includes information on resource type and quality, quantitative and qualitative descriptions of land cover, land use, soil types, wetlands, streams, forest hubs and corridors, endangered species, and critical birding habitat. Utilizing the information in the WRR, local scientific experts and conservation professionals document recommended actions in the watershed profile that support conservation goals in the watershed. The WRR maps those areas in the watershed that would benefit from the actions identified in the watershed profile. The WRR creates eight ecological maps that identify top opportunities for: 1) wetland preservation, 2) wetland restoration, 3) wetland enhancement, 4) riparian zone preservation, 5) riparian zone restoration, 6) upland preservation, 7) upland reforestation, and 8) stormwater management. The maps show areas that score high for each opportunity type, and importantly, can overlay these various maps to identify compensation projects that provide multiple ecological benefits. WRR utilizes widely available and accepted datasets like watershed layers developed by the U.S. Geological Survey (USGS), soils data maintained by the U.S. Department of Agriculture's (USDA) Natural Resources Conservation Service (NRCS), the U.S. Environmental Protection Agency's list of impaired waters (Clean Water Act §303(d) list), as well as locally developed priority areas. The WRR can easily identify areas that can provide multiple benefits if targeted for mitigation (Bryson et al. 2010).

The Trust for Public Land: Greenprints

The Trust for Public Land (TPL) utilizes Greenprinting – a case-specific process that fuses local community environmental objectives with GIS analysis – to produce interactive maps and tools that identify strategic conservation priorities for open space, recreational opportunities, water quality improvement, and wildlife and biodiversity protection. TPL gathers the input of local stakeholders, identifies local conservation priorities, and collects local geospatial and non-GIS data sources to inform Greenprint GIS models. Local input is generally gathered from a diverse set of stakeholders to consider impacts of growth on environmental, social, economic, educational, cultural, and recreational objectives. TPL data gathering also typically aims to establish baseline environmental conditions and when available, Greenprint models also use projected development patterns. TPL then analyzes local stakeholder input, priorities, and additional data sources in GIS models to identify and rank particular environmental projects that can maximize conservation investments. While Greenprints are generally not designed to locate compensatory mitigation projects, and indeed include little analysis of offset sites' restoration potential, their inclusion of local stakeholder input and identification of key conservation targets can provide a valuable context for mitigation site selection.

In order to direct development in Maine's Penobscot Valley, TPL worked with the Eastern Maine Development Corporation (EMDC), the Bangor Land Trust (BLT), the Penobscot Valley Council of Governments (PVCOG), and 12 municipalities to create a Greenprint for the Valley. Input from key stakeholders was collected through one-on-one interviews between TPL personnel and local leaders, public listening sessions with community members, and public opinion surveys of registered voters. Through its data gathering and outreach to key local stakeholders, TPL established six primary goals for the Valley's Greenprint: "Protect habitat and unfragmented natural areas; maintain scenic values and protect scenic vistas; protect working landscapes; protect water quality; establish areas for public access and recreation; and create multipurpose trails."

To create this regional Greenprint, TPL then created opportunity maps for each of these six regional environmental objectives. Greenprint opportunity maps categorize conservation project priorities into three broad categories: high opportunity, moderate-high opportunity, and moderate opportunity. Each of these maps used different data inputs and models to assign conservation priorities to particular areas – for instance, the Greenprint map with the designated goal of protecting water quality merged geospatial buffers around riparian areas, wetlands, shorelines, headwater streams, significant groundwater aquifers, public water supply protection areas, and flood zones to identify top areas for water quality protection. In addition to these six specific maps, TPL also synthesized these maps into overall urban and rural maps that display the suitability of sites for all six goals. The overall urban and rural greenprints used different formulas for ranking and identifying top conservation sites; for instance, the rural Greenprint places more emphasis on protecting habitat and unfragmented natural areas while the urban Greenprint maps places more emphasis on opportunities to preserve and promote public recreational opportunities. TPL also analyzed local funding to determine the feasibility of implementing various conservation measures, though these funding estimates only identified the amount of conservation funding available and did not focus on systematic consideration of land prices, economies of scale, or otherwise optimizing the use of conservation monies (TPL 2009).

The Nature Conservancy: Conservation by Design and Development by Design

Systematic conservation planning methods has been in use for over a decade by many conservation organizations. The Nature Conservancy (TNC) institutionalized these systematic conservation planning methods and applied them at multiple scales, from watershed to states to ecoregions and nations, in their Conservation by Design framework. This framework guided TNC conservation priorities and activities. Many states have also utilized these methods to develop up-to-date statewide priorities for conservation and land management, including California, Florida, Massachusetts, New York, Nevada, Virginia, and Washington. Some of these efforts were done under the State Wildlife Action Plan program. Conservation by Design is the driving framework for the recently approved Virginia Aquatic Resources Trust Fund (ARTF).

TNC's Conservation by Design framework first focuses on development of ecoregional assessments that set long-term objectives for natural resource conservation in particular ecoregions; these ecoregional assessments also identify priority locations for restoration or conservation of biodiversity/aquatic resources. Then, based on ecoregional assessments, TNC establishes conservation action plans within individual ecoregions that identify strategic actions to promote particular conservation objectives. TNC's framework then targets implementation of these strategic actions, measures the status of biodiversity in particular ecoregions, and measures the ecological success of TNC's specific restoration and conservation projects (TNC 2009).

The Virginia ARTF uses similar methods in its implementation of Conservation by Design to select priority sites for aquatic resource compensatory mitigation. Ecoregional assessments are performed to assess threats to aquatic resources functions in each of the ARTF's geographic service areas; these assessments are based on a compilation of existing geospatial data, field measurements, and expert input used to assess the size, condition, and landscape context of various aquatic resources. Geospatial data utilized in ecoregional assessments for aquatic resources include land use data, conservation lands, water quality data, aquatic habitat assessments, and data on aquatic and terrestrial species distribution and assemblages. More detailed measures of natural resource viability are then considered to ensure that a site can meet conservation/restoration goals and that threats to the site's ecological objectives can be overcome. ARTF then uses an ecoregional portfolio that it developed based on its conservation goals for species/aquatic resource abundance and spatial distribution of aquatic resources to "select a set of areas of biodiversity significance which most efficiently and effectively conserve the biodiversity of an ecoregion." For instance, in Virginia's freshwater ecoregions, ARTF's portfolio was refined for medium and large river/stream systems by only including those resources that qualified as Tier 1 (good to excellent quality), Tier 2 (fair to good quality, in need of restoration), or Connector Only (highly degraded but provide important link in stream network) (TNC 2009).

Clean Water Act §§ 303(d) and 319

Clean Water Act § 303(d): Section 303(d) of the Clean Water Act requires states, territories, and some tribes to create lists of impaired waters within their boundaries. Waters are considered impaired if they do not meet water quality standards established by the relevant state, territory, or tribe. The Clean Water Act requires these states, territories, or tribes to develop pollution reduction plans (Total Maximum Daily Loads, "TMDLs") for impaired waters under their jurisdiction.

Clean Water Act § 319: Section 319 of the Clean Water Act establishes the Nonpoint Source Management Program, which provides Federal grant money for state, territorial, and tribal projects that address specific nonpoint source pollution problems. Federal grants under §319 can provide "technical assistance, financial assistance, education, training, technology transfer, demonstration projects and monitoring to assess the success of specific nonpoint source implementation projects," and often utilize a watershed approach to address water quality pollution.

Sources: CWA 303(d), CWA 319, EPA web site http://yosemite.epa.gov/R10/WATER.NSF/TMDLs/CWA+303d+List and http://www.epa.gov/owow_keep/NPS/cwact.html.

A newer TNC framework – Development by Design – takes conservation by design one step further by integrating development priorities with conservation priorities to identify prime areas for compensatory mitigation. Selection of high-value compensatory mitigation projects is a secondary step in the Development by Design framework – this framework first melds conservation planning with the mitigation hierarchy (avoidance, minimization, compensation) to lessen impacts to existing resources that are rare and less easily replaced. Similar to Conservation by Design, Development by Design creates ecoregional assessments and strategically targets biodiversity conservation; however, Development by Design sets offset priorities in the context of known development priorities (Kiesecker et al. 2009).

Development by Design is reflected in TNC's documented biodiversity conservation scenario for oil and gas extraction in the Wyoming Basins ecoregion, which contains a number of rare and threatened species and also holds some of the larger oil and gas reserves in the Western U.S. Priority conservation areas were identified in an ecoregional assessment that was designed to meet the minimum viability needs of target species, as determined by collaborative work between TNC, other conservation organizations, universities, and state and Federal resource agencies. This ecoregional assessment resulted in a portfolio of sites totaling 3.5 million hectares, representing 27 percent of the ecoregion's area. Potential development was identified by mapping oil and gas potential in the ecoregion. By overlaying these two data layers, it was possible to identify potentially impacted natural resources and identify sites within the portfolio that could be used as offsets. Additionally, the conservation portfolio could be adjusted to focus high priority conservation and restoration in areas with low oil and gas potential as long as these areas could support the conservation goals of the impacted resources identified in the portfolio. This framework also identified "irreplaceable targets" that cannot be "replaced" through any offsets and therefore impacts to these resources would have to be avoided or minimized (Kiesecker et al. 2009).

Virginia Mitigation Catalog

The Virginia Department of Conservation and Recreation's Natural Heritage Program created a Wetlands Restoration Catalog (WRC) in 2008 that prioritizes wetland and stream restoration and conservation opportunities within 11 subwatersheds that drain into Virginia's Pamunkey River. The WRC is now being expanded to cover the entire state of Virginia. Restoration and conservation opportunity areas are selected based on their potential biodiversity and water quality functions. The WRC uses a combination of national- and state-level ecological and hydrologic data to categorize potential wetland and stream compensation projects by their restoration potential. Data inputs to WRC's analysis are divided into wetland source layers that portray existing wetland and stream resources, data helpful for predicting unmapped wetlands (e.g., National Wetlands Inventory (NWI), National Hydrography Dataset (NHD), Digital Flood Insurance Rate Map (DFIRM), and Soil Survey Geographic Database (SSURGO)), and priority source layers that "were used to prioritize for mitigation the features in the wetlands map." These priority source layers include geospatial data such as the Natural Heritage Program's biodiversity data and ecological core and corridor habitat maps, Clean Water Act §303(d) waters, and existing mitigation banks, and are analyzed to provide overall restoration ratings for potential wetland and stream offset sites. The WRC results in four principal outputs: a map with individual aquatic resources grouped into 5 categories based on their restoration potential rating, a map with parcels grouped into 5 categories based on the restoration potential of aquatic resources within their boundaries, a table that provides a wetland or stream's overall rating, restoration potential category (1-5), surrounding parcel(s), and surrounding subwatershed(s), and a table that provides a parcel's overall rating, wetland(s) and stream(s), surrounding subwatershed(s), and restoration potential category (1-5) (Weber and Bulluck 2010).

North Carolina Ecosystem Enhancement Program

North Carolina's Ecosystem Enhancement Program takes a unique, watershed-based approach to prioritizing compensatory mitigation across the state. EEP's watershed analysis is unique because it narrows down specific drainage areas for focusing compensatory mitigation efforts rather than analyzing an entire program area at similar levels of detail. EEP's watershed analysis incorporates three core steps.

First, state watershed planners develop River Basin Restoration Priorities (RBRPs) for each of the State's 17 river basins (state-defined drainage basins). RBRPs entail analyzing geospatial data in each basin, field observations in particular watersheds within each basin, and input from state and local agency officials to identify aquatic resource problems, assets, and opportunities for each 14-digit HUC watershed within each river basin. Aquatic resource problems in each 14-digit HUC watershed are evaluated based on the percent of the 14-digit HUC that is impervious surfaces/developed land, agricultural land, non-forested land/disturbed stream buffers, and impaired waters; along with the number of animal operations, projected population change, and shellfish closures.[5] Aquatic assets in a 14-digit HUC include the percent of the watershed that is forested and wetland, conserved, or covered by significant natural heritage areas (or areas identified as high priority for conservation), the presence of a water supply to a watershed, high quality/outstanding resource waters or trout streams,[6] and the number of natural heritage element occurrences (or populations of species). Opportunities include a number of aquatic resources related factors, such as the number of dams, mitigation banks, EEP projects, or Clean Water Act §319 projects in a specific 14-digit HUC.[7]

In the second step of the EEP process, the problems, assets, and opportunities within each basin are then compiled to identify Targeted Local Watersheds (TLW) (14-digit HUCs) within each 8-digit HUC. TLWs are local watersheds "in which EEP restoration, enhancement, and preservation projects should achieve the largest functional benefit." A draft list of TLWs is then vetted with non-GIS information (e.g., state resource agency reports, local conservation plans), field verification of watershed conditions, and stakeholder input to yield a final list of target watersheds in the State.

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[5] Shellfish closures in Eastern NC only.

[6] Trout streams in western NC and Piedmont only.

[7] Other data used to identify opportunities include the percent of the HUC-14 that is very poorly drained soils, NC Wildlife Resources Commission priority area, or Phase II stormwater area, the number of Clean Water Management Trust Fund projects, agricultural BMPs, and land trust conservation properties, surface water intake data, and the presence of a transportation improvement plan (TIP).

Finally, EEP develops local watershed plans in select TLWs. Local watershed plans result in three primary products designed to address leading watershed problems with specific compensatory mitigation measures: watershed assessment reports, project atlases, and watershed management plans. Watershed assessment reports review the aquatic resource functions in the smaller subwatersheds that make up each TLW to identify priority subwatersheds for wetland and stream mitigation projects. Project atlases compile site-level maps and assessment data for the highest potential compensatory mitigation sites within each TLW. Finally, watershed management plans provide suggestions such as specific BMPs or policy recommendations for addressing acute watershed problems. EEP has completed 41 local watershed plans to date (NC EEP; NC EEP 2010).

Hydrologic Unit Codes

The U.S. Geological Survey divides the country up into "hydrologic units" that are nested within each other. Each hydrologic unit is assigned a 2-12 digit hydrologic unit code (HUC), depending on the level of classification (i.e., a 2-digit HUC is assigned a 2-digit number and a 12-digit HUC is assigned a 12-digit number). The more digits the HUC, the smaller the hydrologic unit.

For example, the country is divided into 22 2-digit HUCs, which average 177,560 square miles and generally encompass the drainage area of a major river, such as the Missouri region, or the combined drainage areas of a series of rivers, such as the Texas-Gulf region. The 8-digit HUC, or subbasin, is a fairly standard unit used for a variety of watershed-based analysis and regulatory decision-making. There are 2,267 8-digit HUC subbasins in the country that average 703 square miles.

Sources: Lists and maps of the hydrologic units are available from the USGS. A text-formatted list of hydrologic unit names and numbers is available in the original format (http://water.usgs.gov/GIS/huc_name.html) or in tab-delimited format.

California Regional Advance Mitigation Planning

The Regional Advance Mitigation Planning (RAMP) effort in California's Central Valley was first applied in the Elkhorn Slough watershed and the Pleasant Grove study area, which was comprised of four watersheds. RAMP's methodology is spearheaded by researchers at the University of California-Davis, with support from Caltrans, the Corps' Sacramento District, FWS, EPA, NOAA, the Nature Conservancy, and state-level water resources, wildlife, and conservation agencies. RAMP analyzes a wide selection of data to locate and prioritize offset sites suitable for both aquatic resource and endangered species impacts. The RAMP methodology is current being scaled up for use in California's Statewide Advance Mitigation Initiative (SAMI) (Thorne et al. 2009; Erickson et al. 2010).

RAMP uses a standardized decision support tool to support the identification of regional ecological greenprints and priorities for compensatory mitigation sites within the greenprint. The tool – the MARXAN reserve selection algorithm – is used to incorporate ecological concerns and economic costs of parcel acquisition to determine top mitigation options. This progressive approach was used to estimate potential future impacts to resources by developing a "footprint" of projected transportation impacts, using this footprint to identify impacted resources, and then developing a method for identifying sites that could offset these particular impacts in a way that contributes to regional conservation priorities.

The project team began by developing a list of the species and habitat types that would potentially be impacted in the region. The locations of these species and habitats were mapped across the region and overlaid with additional data layers (e.g., ownership, land cover, species habitat, minimum viable size of a habitat, priority conservation areas) to evaluate each parcel's contribution to restoring potentially impacted ecological components. The MARXAN decision support tool was first used to select parcels that contributed most to the region's ecological quality. This analysis yielded a regional greenprint, which was then used to identify properties with the highest potential for compensatory mitigation. The project team then used the tool to create two outputs that support distinct approaches to prioritizing mitigation site selection: the first was an overall suite of mitigation sites that maximized overall conservation goals at the lowest cost, while the second provided individually ecological scores used to rank each parcel's suitability for providing transportation offsets. The RAMP project was used to identify compensatory mitigation priorities for a range of regulated habitats and species, including vernal pool complexes, giant garter snakes, and burrowing owls (Thorne et al. 2009).

Michigan Wetland Mitigation Site Suitability Index and Michigan DOT Property Selection Tool

In Michigan, the state Department of Transportation (MDOT) has developed a Wetland Mitigation Site Suitability Index (WMSSI) that combines with a property selection tool to expedite selection of ecologically suitable mitigation bank sites to offset transportation-related impacts. Input data for the WMSSI is relatively straightforward, and includes data that are generally available in most states. These data include land cover/land use data, topographic maps, soil moisture index maps, hydrology data (e.g., depth to water table), and maps of presettlement wetlands.

The WMSSI generates a map of potential offset sites based on their relative suitability for wetland restoration across a selected MDOT study area. Wetland mitigation suitability data are then evaluated against a set of criteria for evaluating the suitability of specific properties for acquisition. These criteria include parcel size, parcel adjacency to roads, maps of existing wetlands, and Michigan Department of Natural Resources (DNR) lands. MDOT then uses the wetland suitability and parcel analysis to select sites for further field investigation. The agency estimates that these tools save significant field staff time by eliminating consideration of less promising compensation sites (Brooks et al. 2008). MDOT now receives approval for around 95 percent of its proposed mitigation sites following a first site visit. MDOT has been able to achieve economies of scale via off-site, consolidated wetland mitigation sites. The agency estimates that per-acre compensation costs have decreased from an average of over $100,000, and generally $75,000- $150,000 per acre, to a present-day average cost of $25,000-$30,000 per acre (Venner 2010a).

These varying approaches used to holistically evaluate the ecosystem functions being lost and replaced through environmental offset projects represent the broad range of currently implemented tools and methods. These tools and methods incorporate varying amounts and types of data, use different methods to optimize use of available funding, provide varying levels of specificity in their offset suitability ratings, and are targeted for different regulatory or nonregulatory audiences.

A more contemporary approach acknowledges the complexity of assessment and mitigation and uses a "tool kit" to address these needs. For example, in the NatureServe Vista PPACG example above, the project team also incorporated NOAA's N-SPECT software to model changes in water runoff and non-point source pollution by exporting scenarios from Vista to N-SPECT then importing the N-SPECT results back into Vista for ecological effects modeling. For the mitigation portion, the team used Vista's wizard for working with Marxan to export the Vista database into that tool, generated optimal spatial solutions for conservation, and then brought the results into Vista to generate more spatially refined results and evaluate these for residual mitigation needs.

We now consider how existing innovative tools and methods used to evaluate the ecosystem function of compensatory mitigation sites can be updated to consider the social and economic values of ecosystem services.

3.2 Transitioning from Ecosystem Function-Based Approaches to Tools and Methods that Consider Ecosystem Services

Some of the existing tools and methods used to identify and prioritize high-value aquatic resource or endangered species compensatory mitigation opportunities are more adaptable to ecosystem services valuation than others. Finding the economic and social value of ecosystem services first requires knowledge of the quality and geographic extent of the different biophysical functions that can be provided by a particular offset site, and only then can these ecosystem functions be integrated into their social surroundings to determine their economic value.

The distinct ecosystem functions produced at a compensation site will generally produce different ecosystem services with different values, and so a general metric for restoration potential is less helpful for ecosystem services valuation than specific metrics for the different ecosystem functions that a compensation site can produce.

In particular, tools and methods with the capacity to provide detailed analyses of the particular functions provided by offset sites (e.g., Maryland's WRR) are likely to most accurately and readily incorporate economic valuation of these offsets into site selection. Innovative compensatory mitigation methods that already provide accurate, specific depictions of biophysical functions can incorporate geospatial data on beneficiary populations for ecosystem services, scarcity of particular ecosystem services, the presence of protected or enhanced property values, and complements to and substitutes for ecosystem services to find these functions' economic value.

One option for integrating ecosystem services valuation into these innovative, function-specific compensation tools and methods is to add analysis of ecosystem benefit indicators (EBIs) – countable features of the physical and social landscape that relate to and describe the value of the ecological changes induced by environmental impacts and offsets (NCHRP 2011). EBIs can usually be derived easily from existing geospatial datasets. For instance, function-specific compensatory mitigation analyses can measure water quality improvement services by incorporating estimated functions for nutrient and sediment removal with an EBI such as the percentage of wetland cover locally and across a watershed to measure the service's scarcity. Nutrient and sediment removal functions could then be mapped in relation to downstream, beneficiary populations and properties to estimate their potential societal benefits. However, in the absence of tools and methods that measure a compensatory mitigation project's specific functional improvements, accurate analyses of the value of ecosystem services are generally precluded.

Below we highlight two innovative programs that have incorporated the social or economic value of ecosystem services into their compensatory mitigation site selection methods. The first – which combines Minnesota's Wetland Restoration Strategy (WRS) and Routine Assessment Method (MnRAM) – allows regulators or mitigation providers to use GIS maps or site visits to rate wetland offset sites based on their potential to provide specific ecosystem services. The second, which includes multiple, overlapping projects in Oregon's Willamette Basin, pilots a decision support tool to model the economic value of ecosystem services in the Basin under different development and conservation scenarios.

3.3 Compensating for Ecosystem Services: Innovative Tools and Methods

Minnesota Wetland Restoration Strategy

Minnesota has several innovative plans, tools, and regulations in place that could support the incorporation of ecosystem service considerations into compensatory mitigation site selection and design. In 2009, several state agencies joined together to release a unified Wetland Restoration Strategy. Societal values of ecosystem services are a central component of the strategy, though the strategy does not provide specific methods to incorporate the value of ecosystem services into mitigation site selection.

Minnesota has also completed a Restorable Wetlands Inventory (RWI) in the State's prairie pothole region and uses GIS terrain analysis in the remainder of the State. The RWI is a collaborative effort between numerous state, Federal, and local partners to geospatially delineate drained depressional wetlands based on country soil surveys and hydric soils data, USDA Farm Service Agency compliance slides, USGS topographic maps, and NWI maps. However, RWI and the State's other efforts to prioritize wetlands for restoration do not explicitly incorporate consideration of offset sites' economic benefits (MN BWSR 2009).

Minnesota also has a comprehensive freshwater wetland permitting program that explicitly encourages the selection of compensation sites based on landscape-scale consideration of watershed needs and ecosystem functions. Much like the 2008 Federal Compensatory Mitigation Regulations (U.S. Department of Defense and U.S. Environmental Protection Agency 2008), Minnesota's wetland regulations specify that compensation projects must consider "landscape position, habitat requirements, development and habitat loss trends, sources of watershed impairment, protection and maintenance of upland resources and riparian areas, and provide a suite of functions" (Minnesota Wetland Conservation Act 2010). The regulations also specify upland buffer requirements for all wetland replacement projects. Finally, Minnesota requires that wetland compensation follow detailed siting procedures based on an impact's minor watershed, major watershed, county, bank service area, and metropolitan area; these siting requirements vary based on the percent of pre-settlement wetlands intact in a county/watershed. Minnesota's regulations support selection of higher-quality compensatory wetlands by explicitly requiring consideration of a suite of landscape features that influence wetland function and by promoting offsets that occur in high-needs watersheds or counties (Minnesota Wetland Conservation Act 2010).

In addition to the tools discussed above, Minnesota has in place a state-specific wetland rapid assessment method (MnRAM) that allows for more detailed field-based measures of a wetland's functional and economic value. MnRAM allows regulators to provide subjective ratings of a compensatory wetland's value for ecosystem services such as flood and stormwater storage, downstream water quality protection, shoreline protection, habitat value, and recreational and commercial uses.[8] MnRAM is utilized both in assessing potential wetland compensatory mitigation sites and in subsequent evaluation of mitigation sites for regulatory compliance with performance standards. The main wetland restoration prioritization tools and methods used in Minnesota (i.e., the Wetland Restoration Strategy and state regulations), however, seek to handbook wetland protection and restoration projects to previously drained wetlands and do not specifically institute more detailed consideration of specific ecosystem functions or services that can be evaluated using MnRAM (Fennessy et al. 2004).

Oregon's Willamette Basin

Overlapping projects in Oregon's Willamette Basin directly encourage the protection and restoration of ecosystem services by utilizing planning products and decision support tools that model the economic value of natural processes under different development/conservation scenarios. The Willamette Basin is the most advanced and detailed effort to date to integrate the economic values of ecosystem services into multiple regulatory programs requiring compensatory mitigation.

The Willamette Partnership is a diverse, collaborative nonprofit initiative focused on developing markets that use detailed accounting procedures for multiple types of ecosystem service credits to promote environmental stewardship. Perhaps the most defining characteristic of the Willamette Basin Partnership is development and application of science-based ecosystem service accounting protocols. These protocols are designed to measure and register the functions and values associated with improvements and impacts to separate ecosystem services. The Partnership currently is developing protocols for measuring improvements and damages for wetland habitat, prairie habitat, salmonoid habitat, nitrogen and phosphorus loadings, and thermal pollution offsets.

[8] MnRAM provides on-site measures useful for evaluating wetland mitigation performance criteria as well as off-site measures of a wetland's surrounding landscape. MnRAM is particularly conducive to social benefits analysis and, in fact, includes some metrics that incorporate judgments of the value or opportunity associated with a particular function. MnRAM allows regulators to assess a site's performance for the following categories of functions/values: "vegetative diversity and integrity, maintenance of characteristic hydrologic regime, flood and stormwater storage/ attenuation, downstream water quality protection, maintenance of wetland water quality, shoreline protection, management of characteristic wildlife habitat structure, maintenance of characteristic amphibian habitat, aesthetics/recreation/education/ cultural/science, commercial uses, groundwater interaction, wetland restoration potential, wetland sensitivity to stormwater input and urban development, and additional stormwater treatment needs" (Fennessy 2004). However, MnRAM only facilitates subjective rankings of a compensatory wetland's capacity to perform particular ecosystem services and does not attempt to place a monetary value on compensatory wetland services.

Several site-based calculation methods already have been approved, including those for salmon, prairie, wetlands (the Oregon Wetland Assessment Protocol, or ORWAP), and water temperature.

The Partnership's General Crediting Protocol, which provides the procedures for using these ecosystem service accounting procedures, references priority areas for ecological improvements to salmonoid habitat, prairie habitat, wetland habitat, and water temperature impairments. The Partnership identifies priority rivers and streams for improved salmon habitat based on National Marine Fisheries Service (NMFS) data, priorities for investment in prairie habitat and thermal pollution mitigation based on the Willamette Basin Synthesis Map, and priorities for wetland mitigation based on the wetland priorities identified in the Synthesis Map or areas surrounded by high-function wetlands as determined by Oregon's rapid wetland assessment method, the Wetland Assessment Protocol (ORWAP) (Willamette Partnership(a)).

The Synthesis Map was produced through a partnership of conservation groups, academics, and government agencies, including Oregon State University, the Oregon State Institute for Natural Resources (INR), and the Willamette Partnership. It identifies priority terrestrial and freshwater sites for conservation and restoration within each subwatershed of the basin. In order to include wetland restoration and protection priorities, the partners needed to update the wetlands dataset for the basin, which was a significant undertaking.

The two major components of the map are 1) probable species distribution maps for three endangered plants and an endangered butterfly that occur on wetlands and upland prairies in the Willamette Valley (Achterman et al., in press); and 2) data developed in support of the recovery efforts for threatened fish in the basin, most notably salmon.

Since the primary wetland compensatory mitigation activity is wetlands restoration, the project also developed a Wetlands Restoration Planning Tool (Oregon State University 2010) that helps users identify the most appropriate sites and wetland types to target for restoration. Datasets used in the tool include the statewide wetland layer, rare wetlands, restoration targets based on 8-digit HUCs, locations of wetland mitigation banks and Wetland Reserve Program sites, wetland priority sites for the Willamette Valley, and hydric soils.

The Natural Capital Project, a joint research initiative between Stanford University, the University of Minnesota, TNC, and the World Wildlife Fund, aims to develop and promote tools to integrate the value of ecosystem services into environmental decision-making. The project has evaluated ecosystem service values throughout the Willamette Basin and has produced one of the first published applications of a spatially explicitly modeling tool that places a monetary value on ecosystem services valuation, the Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST) (Nelson et al. 2009).[9]

It is worth noting that the Willamette Partnership was funded primarily with NRCS Conservation Innovation Grant dollars meant to help create markets for ecosystem services. Mitigation activity and planning were thus driven by a "markets" approach, which tends to demand both transparent criteria for measuring environmental improvements and damages and an assessment of benefits associated with alternative mitigation outcomes. Stream and aquatic habitat restoration efforts are being coordinated by the Freshwater Trust along with the Willamette Partnership.

3.4 Ecosystem Services Valuation: Additional Tools

Five leading ecosystem service valuation tools are available or currently in development which may be useful to resource or transportation agencies. These tools help natural resource managers and transportation practitioners to prioritize environmental offsets, either through avoidance, minimization, or compensatory mitigation, that in addition to being ecologically viable, are most economically beneficial to society. In particular, compensatory mitigation programs which already prioritize selection of offset sites based on specific ecosystem functions may be able to integrate their current outputs with GIS-based models such as ARIES, InVEST, or MIMES to obtain a more accurate picture of the economic value of natural processes provided by potential offset sites. An introduction to each tool is provided below.

- Artificial Intelligence for Ecosystem Services (ARIES): A joint project of University of Vermont's Ecoinformatics Collaboratory, Conservation International, Earth Economics, and Wageningen University. Despite its complex foundation, ARIES is a user-friendly, web-accessible tool. The ARIES model is a "decision-support infrastructure to assist decision-makers and researchers by estimating and forecasting ecosystem services provision and their correspondent range of economic values in a specific area" (Artificial Intelligence for Ecosystem Services).

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[9] The paper uses the Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST) to assign monetary values to ecosystem services in the Willamette Basin. While the paper does not model the economic value of ecosystem services associated with a particular compensatory mitigation program, the researchers modeled three stakeholder-defined scenarios of land cover change in InVEST, one of which was a "conservation" scenario. A second paper published by Natural Capital further expounds how use of modeling tools such as InVEST can inform natural resource management (Tallis and Polasky 2009).

- Ecosystem Services Review (ESR): Designed by the World Resources Institute (WRI), the Meridian Institute, and the World Business Council for Sustainable Development (WBCSD), ESR is primarily targeted at corporate users and is the most experienced of these tools in the corporate environment. ESR is "a sequence of questions that helps managers develop strategies to manage risks and opportunities arising from a company's dependence on ecosystems" and supplies guidance on ecosystem service valuation (World Resources Institute).
- Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST): InVEST was developed by the Natural Capital Project. InVEST is "a decision-making aid to assess how distinct scenarios may lead to different ecosystem services and human well-being related outcomes in particular geographic areas." InVEST developers are also progressing towards creating an ArcGIS extension version of the tool (Natural Capital Project (b)). As mentioned earlier, a tool kit approach often maximizes the function of the individual tools and brings better whole solutions. NatureServe and the Natural Capital Project tested an integration in Colombia using the scenario-mapping capabilities and policy-planning functions of Vista with the InVEST tool demonstrating that these tools provide complementary capabilities.
- Multiscale Integrated Models of Ecosystem Services (MIMES): MIMES is a product of the University of Vermont's Gund Institute for Ecological Economics; it is "a multiscale, integrated suite of models that assess the true value of ecosystem services, their linkages to human welfare, and how their function and value may change under various management scenarios." MIMES is open source and can provide valuation outputs of money, land area, or other metrics (University of Vermont (b)).
- Natural Value Initiative (NVI): The NVI is a project of Fauna and Flora International, the Fundação Getúlio Vargas Business School in Brazil, and the United Nations Environmental Programme Finance Initiative (Natural Value Initiative 2011). NVI is principally focused on use in the corporate and financial sectors, providing "an evaluation benchmark methodology for assessing biodiversity and ecosystem services-related risks and opportunities in the food, beverage, and tobacco sectors" (Waage et al. 2008).

Use of these tools, or other methods, to integrate the economic value of nonmarket ecosystem services into mitigation approaches can provide a more complete picture of the overall costs and benefits of a prospective transportation project and its environmental offsets.

4.0 Next Steps to Implementing a Progressive Approach to Mitigation

Our review of documented progressive mitigation programs indicates that as a whole, implementing progressive approaches to mitigation planning and implementation promotes significant economic and ecosystem benefits for transportation agencies, resource agencies, and society. This section of the handbook includes a discussion of concrete steps to assist transportation practitioners, policy-makers and regulators, and the research community in implementation of progressive approaches to mitigation.

4.1 Steps for Transportation Agencies

Moving from traditional, project-by-project compensatory mitigation procedures to adoption of a holistic, landscape approach which incorporates natural resource concerns into early stages of transportation planning presents many challenges. Barriers to implementation of these progressive mitigation strategies consist of resource constraints and institutional constraints. A brief summary of the primary barriers are listed below, since the institutional steps needed relate to overcoming the key barriers.[10]

Barriers

Resource Constraints

All transportation and resource agencies operate under budget constraints, and while progressive mitigation strategies present opportunities for long-term efficiencies and cost-savings, transitioning to more holistic approaches requires investment. Resource constraints may slow implementation of these innovative, streamlined programs. The primary resource-related constraints are limitations in available data and funding. These limitations often reflect short term budget problems, rather than long term savings which research has indicated may be available with progressive approaches.

[10] A more comprehensive discussion of barriers is included in NCHRP 2010a, pp. 25-32.

Data Limitations

Effective watershed and landscape analyses of natural resource conditions, along with subsequent identification of ecologically favorable compensation sites, are heavily reliant upon accurate, high-resolution, and current data. GIS studies are particularly adept for large-scale evaluation of the status and trends of ecological data. Thus, data restrictions, particularly for geospatial data, can serve as a key barrier to implementation of watershed and landscape approaches to compensatory mitigation. Indeed, the final results from the Transportation Research Board's Strategic Highway Research Program (SHRP) Capacity Program research project C-06 (SHRP II C06) (Institute for Natural Resources et al. 2010; URS et al. 2010) attribute many regulatory conflicts and costly delays in project delivery to poor-quality or incomplete natural resource data available during the planning phases of projects.

In the context of ESA §7, available data does not adequately depict how projects will impact listed species (Achterman et al, in press). For CWA §404 permitting, SHRP C06 recommends creation of a "wetlands mitigation catalog" similar to that developed in Virginia with identified, previously approved wetland replacement sites in each watershed. Data concerns, specifically regarding geospatial data needs, are an acute barrier identified by all resource agencies, most transportation departments, and local governments.

When surveyed, Federal resource agency staff generally mentioned encountering similar data-driven problems in implementation of an ecosystem approach. FWS and NMFS staff specifically identified the need for data prioritizing conservation objectives, Corps staff noted that geospatial data is often of inadequate resolution or specificity for evaluation of the impacts of a particular project, and EPA staff noted the need for higher-quality datasets, particularly for the National Wetlands Inventory (NWI) (Venner 2010a). Other common impediments noted by public resource agencies were lack of thorough, ecosystem-scale data, particularly for some important species, lack of digitized data, out-of-date datasets, low interagency data sharing, partially due to regulatory constraints, and an inability to prioritize use of the many available GIS data layers.

Funding

The need for significant funding is seen as a major deterrent for potential adoptees of landscape-level planning approaches. Transitioning resource agencies to new regulatory roles and transportation agencies to new planning procedures often requires upfront capital for database investment, staff training, staff time, collaboration, and adaptive management, among other priorities. In particular, there may be initial costs in identifying off-site wetland or endangered species mitigation sites, which to be an effective ecosystem-scale mitigation approach requires the development or adoption of a regional ecosystem framework (REF) or a watershed analysis. A REF, as defined by an interagency team that developed *Eco-Logical: An Ecosystem Approach to Developing Infrastructure Projects*, is defined as "an element of integrated planning that likely consists of an overlay of maps of agencies' individual plans, accompanied by descriptions of conservation goals in the defined region" (Brown 2006).

Institutional Constraints

Institutional barriers to early consideration of transportation-related impacts and mitigation are another leading obstacle to moving beyond traditional, project-by-project mitigation approaches. Collaboration between resource and transportation agencies with conflicting missions poses significant challenges, as does internal resistance to progressive approaches. Political pressures may also rush or modify alternative mitigation strategies and resource agencies may encounter difficulties in formulating substantively valuable input at early project stages.

Resistance, Conflicting Agency Missions, and Constraints

Internal resistance to implementing ecosystem approaches to compensatory mitigation is commonly identified as a significant impediment to progress. Cultural or institutional change in methodology is often resisted by agencies struggling to meet normal, day-to-day work objectives. SHRP C06A's survey also regularly identified the lack of adequate incentives or the presence of disincentives to modify regulatory or transportation planning practices as sources of agencies resistance. Agencies generally focus on managing the resources they oversee or manage, using their primary objectives to measure success. Real or perceived obligations for permit-processing or transportation planning, as imposed by law, regulation, or suggested in guidance, may limit an agency's ability or willingness to adopt watershed or landscape considerations into transportation projects.

Political Pressure

Political considerations have also hindered adoption of a holistic, ecosystem-based approach to mitigation. SHRP survey respondents noted that political pressures to quicken transportation projects and accelerate regulatory approval processes could prevent use of progressive approaches. In addition, FWS and the Corps noted that political demand to contain compensatory mitigation within political boundaries, specifically at the state, county, or municipality level, can prevent use of a landscape approach to identify compensation sites of the highest functional quality. At a local level, city and county governments mentioned that politicians may be disposed to allow losses of natural resources in exchange for increased local tax revenue.

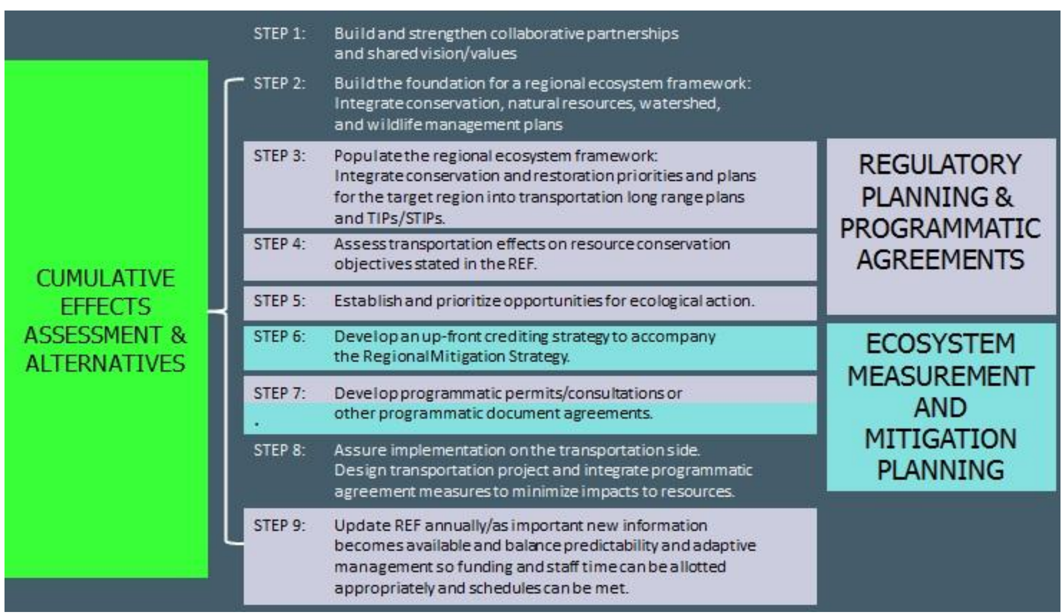
Other constraints include staff turnover, both at agencies and at regularly utilized consulting firms, and the lack of understanding of the values and methods of providing resource related information to transportation planners early in the transportation planning process.

Institutional Steps to Advance Progressive Approaches

To implement a progressive approach, there are a set of institutional steps which best overcome these identified barriers. A nine-step framework was identified in the SHRP C06 project to integrate conservation planning with transportation planning, the basis of progressive mitigation approaches (Institute for Natural Resources et al, 2010). However, only a subset of these is related to mitigation. All decision points for transportation planning, including the framework steps from the CO6, are included in the TRB Transportation for Communities web site (Transportation for Communities). In particular, transportation agencies and Metropolitan Planning Organizations (MPOs) have three steps identified which are critical to implementing a progressive mitigation approach (see Figure 4.1):

- *Step 3:* Populate the regional ecosystem framework; integrate conservation and restoration priorities and plans for the target region into transportation long range plans and transportation implementation plans.
- *Step 6:* Develop an up-front strategy for defining the value of offset credits and a regional mitigation strategy.
- *Step 7:* Develop programmatic permits or consultation structures and other programmatic document agreements.

Figure 4.1 Framework Steps for Implementing an Eco-Logical Assessment Process for Highway Capacity Projects



Source: Achterman et al, in press.

Most of the barriers identified above refer to these three steps in the C06 framework, but currently there are opportunities available to overcome most of the barriers. In particular, both the data limitations and funding limitations, which appear to be the most overwhelming (Venner 2010b; Venner 2010c), can be overcome by characterizing and taking advantage of the long and short term cost-savings that can be obtained by the use of progressive methodologies.

Populate a Regional Ecosystem Framework (Step 3)

Addressing how to populate a regional ecosystem framework (Step 3) is the first barrier to be overcome. To some extent, coming up with the upfront investment required in data analysis and planning is a policy problem, rather than a transportation or regional planning issue. Cost benefit studies in Oregon, Florida and elsewhere have shown that even paying for upfront data development costs and all the costs of developing a programmatic agreement can provide significant economic returns if an agency plans significant transportation investments in developing new projects or updating existing projects (Oregon Department of Transportation 2008). In addition, there is significant potential for regional and national data development funded by either Federal Highway Administration (FHWA) or the American Association of State Highway and Transportation Officials (AASHTO) to support this work. Currently, the data development work is occurring regionally and often without significant involvement from regulatory agencies. Creating the data using national standards at a larger scale certainly would provide reduced marginal costs and greater acceptance, although this will probably have to be done through FHWA or AASHTO (Venner 2010a). Previous work funded through the TRB and FHWA Eco-Logical research programs has identified the promise of new data development. However, additional acceptance is required to remove additional data development from the research realm to allow cost-benefit analysis to determine if national funding can be obtained.

There are clearly a large number of methods which have been identified in the previous section of this report that can support development of the regional ecosystem framework and development of the crediting and state or regional mitigation strategies. Investing resources up front to develop these strategies will allow transportation practitioners to do an overall 'estimate' of the potential regional and statewide impacts as they develop their long-range transportation plans as well as shorter-term improvement plans (STIPs and TIPs). For transportation agencies and MPOs, selecting the methods to adopt or create a REF or a crediting and mitigation strategy should be based on partnerships available in a state or region, as well as the availability and acceptance of REFs or Watershed Assessments. Assuring that regulatory agencies are invested in the REF is the best way to assure the resultant mitigation strategy or list of mitigation priorities will be accepted (Achterman et al, in press).

As with all projects, in developing alternative mitigation strategies, it is more efficient to take advantage of existing tools. For example, State Transportation Infrastructure Improvement Plans required under SAFETEA-LU facilitate progressive mitigation approaches and advanced mitigation by requiring five-year forecasts of transportation-induced impacts. As mentioned above, regulatory planning can occasionally utilize and often build on existing conservation/watershed plans.

Develop an Upfront Crediting Strategy (Step 6)

Developing an upfront Crediting Strategy, or Step 6, is probably the most complex piece, and in some contexts probably not critical. Including a crediting strategy can both expand the case for progressive mitigation, and provide additional economic and social incentives for the work (NCHRP 2011). Yet under U.S. Federal law, the only environmental markets that are likely to require (through a regulatory mechanism, rather than a voluntary one) offsets for damages to aquatic resources and habitat fall under the CWA (§§ 303, 402, 404) and ESA (§§7, 10). State and local laws and regulations, however, may stipulate additional regulatory requirements for environmental offsets. Accordingly, aquatic resource and habitat impacts must be dealt with in a regulatory context, so a multiservice crediting framework may be optional.

For states where efforts exist to build ecosystem service markets and make them available to landowners for restoration and conservation purposes, there may be external resources available to transportation agencies to develop these markets. Without these resources, it may not be possible to immediately implement a program with a crediting system built on multiple ecosystem service crediting. Currently, programs exist within the U.S.D.A. Office of Environmental Markets (OEM) to facilitate the development of ecosystem markets, and programs exist at the state level that can take advantage of these markets, and to help focus Farm Bill restoration projects. Regionally, programs exist in the Pacific Northwest (Willamette Partnership (b)), in the Chesapeake Bay (Pinchot Institute for Conservation), and in the Ohio River Valley (Electric Power Research Institute). There are a number of universities and centers doing extensive research on ecosystem services and accounting. There are institutes that may be able to provide local guidance on these protocols in Vermont (University of Vermont(a)), California (Natural Capital Project(a)), and a number of other states, including Colorado, Florida, New Hampshire, New Mexico, and Wyoming.

Developing a regional mitigation strategy can be effective even without a crediting protocol. The Watershed Resource Registry (U.S. Environmental Protection Agency) in Maryland or Virginia's Wetland Restoration and Mitigation Catalog both include functional wetland assessments in developing priorities for mitigation sites. Other models from California, Oregon, North Carolina and other states strategically identify priority compensatory mitigation sites, although the Maryland and Virginia methods are the most integrated into the needs of Clean Water Act regulators, regarding both §404 and §401 permitting (Weber and Bulluck 2010; Bryson et al. 2010).

Develop Programmatic Agreements (Step 7)

The final, critical step is to move from a mitigation plan and prioritized mitigation sites to programmatic agreements between transportation agencies and water quality, wetland and endangered species regulatory agencies in your watershed, state, or ecoregion. As mentioned above, a progressive approach to mitigation will allow transportation practitioners to have an overall estimate of potential impacts that can be assessed and incorporated during the development of long-range plans and/or STIPs and TIPs – supporting the development of more detailed and effective programmatic agreements. If the regulators were involved in the creation of the mitigation strategy or catalog, this should be relatively straightforward, although requirements for each of the regulated resources will have to be characterized. Also, if done correctly, progressive mitigation sites often will provide the potential for crediting of multiple resources, such as water quality, wetlands and endangered species, and the programmatic agreements will need to assure restoration and mitigation activities are not double-counted (see, for example, Kane 2009).

4.2 Steps for Policy-Makers

Steps to Support the Progressive Approach

Section II of this report outlines significant benefits of progressive mitigation approaches. Aside from the improved environmental and economic outcomes which research indicates are likely to occur, there are a number of specific benefits which can be outlined from the use of the approach. These include:

- Water quality threats addressed;
- Drinking water quality services delivered;
- Flood threats addressed;
- Flood protection benefits delivered;
- Species abundance threats addressed;
- Species abundance benefits delivered;
- Increased recreational opportunities; and
- Increased land values for properties adjacent to new natural areas.

The relationship between improvements in abundance or biodiversity and proximity to recreators can be assessed using the following types of data:

- Location of public lands, including parks, beaches, forest, and navigable waters;
- Proximity to forms of access, including trails, roads, boat ramps;
- Usage rates and populations within walkable, drivable distances of the resource; and
- Proximity to residential areas and population density with visual or recreational access to the species.

If the social and economic value of ecosystems – not just acreage or functions – is to be preserved, then sites' relative ability to generate benefits must be understood by policy-makers as well as regulators and transportation decision-makers. Data and methods already exist to foster appreciation of landscape characteristics that contribute to the quality of ecosystem functions and services produced at a particular offset site. If applied, these data and methods are likely to yield compensatory mitigation projects that produce greater ecological and social benefits.

The most critical step for policy-makers is to assure that an acceptable watershed/landscape –scale mitigation plan is adopted and that this plan is a structural part of the REF or watershed plan, or at least is consistent with the REF. These are different from the detailed, site mitigation plans that the Army Corps of Engineers requires for mitigation site designs. It is important that the following six factors be considered when creating the regional or watershed mitigation plan:

1. Standardized Methods

Whenever possible, conservation plans should be developed using standardized methods. National decision-makers should attempt to standardize methods for creating a national conservation 'blueprint'. This would greatly facilitate local efforts to adopt a watershed/landscape–scale mitigation plan, which is the critical step towards prioritizing compensatory mitigation sites.

This can only be done by policy-makers. One of the greatest problems related to implementing standards for general, multiple resource conservation planning is that there are usually no clear authorities for these standards at the state and Federal levels. State and Federal Agencies are generally given a legislative mandate to focus on a particular resource. As such, no agency generally has the authority to evaluate multiple resources, such as water quality, water quantity, wetlands, endangered species, and biodiversity. In addition, when creating an integrated REF or Watershed Strategies, some communities will choose to include access to parks, recreational opportunities, lands for new development, or other potentially competing land uses in their conservation strategy. While these are perfectly valid considerations in a land use plan, they can make it more difficult to create a REF that will address the critical needs of regulated resources. Standard procedures for conservation planning can assure that resources spent on planning create implementable, transferable strategies.

2. Sufficient Potential Mitigation Sites

It is essential that sufficient areas be identified so there are always locations in which to work. In order to support identification of an adequate quantity of potential mitigation sites, policy-makers should remove static preferences for on-site/in-kind compensatory mitigation. Regulators often are sensitive to moving compensatory mitigation too far from the losses, fearing that the resulting restoration will not be "in kind" or "in place." However, obtaining poor quality, small wetlands or habitat adjacent to highways or shopping centers often provide low ecological benefits. Moving restoration to areas in the same watershed where meaningful restoration and conservation can occur may provide better ecological outcomes.

An additional potential policy solution to increase alternatives for mitigation sites is to grant larger geographic service areas to mitigation providers that utilize progressive mitigation approaches. Mitigation banks, conservation banks, or in-lieu fee programs with increased geographic flexibility will have more options for sites to choose for aquatic resource or endangered species offsets. In addition, granting larger geographic service areas to mitigation providers that utilize innovative mitigation approaches increases the marketability of their credits and may promote financial investment in these progressive approaches. However, larger geographic service areas allow relocation of mitigation far from losses, which may lead to systematic geographic transfers of natural resources, as happens with urban-to-rural migration of wetland offsets. While larger geographic service areas do not necessarily encourage higher quality compensatory mitigation, they will inevitably increase the number of potential locations for mitigation (Womble and Doyle, in press).

The method used in the Maryland Water Resources Registry and Virginia Wetlands Mitigation Catalog to assure that sufficient mitigation and restoration opportunities exist is to evaluate and rank all potential mitigation sites based on the quality of their different potential ecosystem functions. As a result, every potential mitigation site can be ranked and the various services it can generate can be evaluated. When this type of comprehensive information is available and vetted by (or in this case created by) regulatory agencies, policy-makers should institute enough regulatory flexibility to allow mitigation providers to choose high-priority offset locations. If EPA expands the Watershed Resources Registry across the nation, it should be relatively straightforward to integrate into a regulatory framework.

3. Regulatory Agency Involvement

The mitigation plan must be able to include local and key regulatory inputs, to assure that it can obtain regulatory approvals. If the regulatory agencies are involved in the development of, or at least have significant input in the review of the watershed/landscape-scale mitigation plan or strategy, approvals are easier to obtain, and converting the plan into a programmatic agreement can occur fairly rapidly. If not, the plan or strategy will require redundant development.

Programmatic Agreements and Decision Support Tools

Programmatic agreements, and the use of decision support tools built on these agreements, need to be developed. The implementation of a programmatic agreement to institutionalize a holistic mitigation strategy is critical, and – as most transportation planners and regulators know – can be long and difficult processes to develop. These should be easier to develop using a progressive mitigation strategy (Institute for Natural Resources et al. 2010). Once these agreements and the strategies are developed, decision support tools can significantly improve transportation and land use planning in the watershed or the region, reducing the cost of the planning, and likely improving ecological outcomes. These benefits can promote the development of programmatic agreements, and perhaps simplify their implementation.

Incentives for Coordination

Agencies need to reduce disincentives and provide support for coordination with other agencies and the public, and invest in joint data development and conservation planning efforts. Currently, the process of creating a programmatic agreement can often be very time consuming and difficult. As a result, transportation and regulatory agencies often choose not to take advantage of the fact that programmatic agreements can provide both economic and ecological benefits in the long run. Policy-makers must address this issue, both by providing initial support for the development of the data to move progressive approaches forward and to provide support for transportation agency staff and regulatory agency staff to pursue programmatic agreements.

Support for Updated and Iterative Decision Support Tools

An additional challenge is to create incentives for making decision support tools iterative, so data can be updated and new information incorporated. Complex decision support tools built on programmatic agreements are difficult to modify (NCHRP 2011). Currently, there are few incentives available for any entity that has created a decision support tool, such as Florida's ETDM, to modify the tool in light of new types of data. ETDM, like most well designed decision support tools, was created to allow for updated versions of the key data layers that were used in its design. However, if a critical data layer, such as observations of state and Federally listed species can be replaced with a more useful but very different coverage, such as a geodatabase of likely distributions of state and Federally listed species, the ETDM would need to be modified. The problem with any modifications of the ETDM related to regulatory resources is that the programmatic agreements may need to be renegotiated. The time and expense of any negotiations with regulatory agencies creates a major disincentive for any significant changes in decision support tools, even if they are done to improve outcomes to the regulated resources. Because iterative decision support tools are difficult to establish and maintain, agencies are not going to be inclined to change current processes, especially if they appear to be working well. Policy-makers can institute new incentives to allow agencies to promote acquisition of these flexible, iterative decision support tools.

4.3 Steps for the Research Community

It is important to understand mitigation's implications (via effects on ecosystem services) for households, communities, and other stakeholders. Social evaluation of ecosystem service outcomes requires two basic things: 1) ecosystem service outcome or evaluation measures that allow for social, economic, and policy interpretation, and 2) the application of economic valuation or evaluation methods to assess the benefits of a change (gain or loss) in ecosystem services. Research in the following areas will support further advancements in effective mitigation.

Identify the Right Ecosystem Service Measures

The centerpiece of ecosystem service-oriented mitigation policy is the definition, measurement, and evaluation of *ecological endpoints*. Biophysical production function studies should relate wetland mitigation actions to a specific, consistent set of outcome measures we refer to as "ecological endpoints." Ecological endpoints are a distinct subset of the larger universe of biophysical outcome measures. By definition, ecological endpoints facilitate evaluation that can be expressed in social, economic, and policy terms. Ecological endpoints are biophysical outcome measures that require little further biophysical translation in order to make clear their relevance to human welfare. These endpoints are the essential bridge between biophysical and economic assessment.

Progressive planning and assessment requires us to measure ecosystem service outcomes whose value or importance can be meaningfully debated by stakeholders or detected by social scientists. In practice, this means choosing outcomes that are comprehensible and meaningful to non-scientists. Unfortunately, many of the most common mitigation outcome and assessment measures in current regulatory use do not directly facilitate or allow for economic evaluation. Outcomes like biotic integrity indices, chemical water quality concentrations, hydrogeomorphic classifications, and biological productivity are of scientific interest, are related to ecosystem services measurement, and establish the scientific basis for accurately modeling ecosystem functions and services. But without more intuitive, and tangible, measures of these benefits, stakeholders cannot evaluate and communicate their social value.

Monetary Valuation Methods

Economists use a range of methods to calculate the economic value of wetlands and ecosystem services.

"Revealed-preference" studies look at the price people are willing to pay for marketed goods that have an environmental component. From those prices, inference can be drawn about the environmental benefit. For example, real estate near wetlands or other aesthetically desirable ecosystems is often more expensive. The price premium that reflects the value of the environmental amenity can be measured via "hedonic analysis."

"Travel cost studies" measure the time and money spent traveling to parks, beaches, and other natural resources associated with recreation and tourism. Benefit estimates are derived from travel expenditures, based on the principle that the benefits of the natural resource must be at least as great as the costs born to enjoy the resource.

"Avoided cost studies" base benefits on the cost of replacing ecosystem services with built infrastructure that serves a similar function – such as water treatment facilities, dams, and levees.

"Stated-preference" methods survey people, in a highly structured way, about their willingness to pay for a set of environmental improvements or their preference for ecosystem services versus a commodity whose market value is known.

Many common ecological outcome measures in practice today, however, do not satisfy the characteristics of ecological endpoints. In other words, their relationship to economic welfare is unclear, ambiguous, or qualitative, rather than quantitative in nature. In order to undertake economic assessment of ecosystem service priorities and delivery, economic and social science analysts need new data and modeled relationships that translate existing outcome measures into ecological endpoints suitable for economic and social evaluation. Socially meaningful endpoints are sometimes, but not always, obvious. Because endpoints are the focal linkage between biophysical and economic assessment, they should be chosen deliberately and based on empirical assessment.

In order to assess mitigation's ability to produce (and maximize) ecosystem service benefits, it will be necessary to 1) monitor ecological endpoints, and 2) relate them to ecological measures that already are routinely collected. Methodologically, this requires analysis that "translates" known outcomes (e.g., hydrogeomorphic classifications, biotic integrity and habitat equivalency scores) into their subsequent implications for endpoint changes.

Support More Economic Valuation Studies

Economic and social evaluation is built around analysis of biophysical production – more specifically *changes in* biophysical production. If ecological evaluation can describe the relationship between mitigation interventions and the suite of subsequent changes, the economic benefits (or costs) of those endpoints changes can be evaluated. By design, endpoints are meaningful to decision-makers and society generally. This means that changes in those endpoints can more easily lead to economic evaluation. There are several ways to approach economic analysis of endpoint changes. Economic studies derive monetary benefit estimates using hedonic, travel cost, contingent valuation, and other econometrically sophisticated methods. Nonmarket valuation techniques fall into two general categories: revealed and stated-preference methods.

The environmental economics profession has produced hundreds of such studies. But there are relatively few that value wetlands specifically. And far fewer that evaluate wetland's production of "off-site" ecosystem services. Progressive mitigation planning would benefit from new valuation studies designed to capture benefits that arise from mitigation's contributions to off-site ecosystem services delivery.

Develop "Benefit Transfer" Capabilities and Data

It is usually not practical for mitigation planners to conduct original, site-specific studies of a wetland's economic value. Such studies are expensive and time-consuming, and require special statistical skills. A cheaper alternative is to conduct "benefit transfer" studies.

The benefit transfer method takes the results of preexisting valuation studies (conducted by academics, agencies, nongovernmental organizations) and applies the dollar estimates to new environmental contexts. For example, if existing studies show that certain wetlands are worth $500/acre, benefit transfer studies ask whether wetlands in a new context are worth more or less than $500/acre. The challenge for benefit transfer methods is that the value of wetlands (and the ecosystem services they provide) is highly dependent upon the physical and social context in which they arise. Note that this is the primary motivation for pursuing the progressive mitigation concept. For the analyst, benefit transfers requires methodological and conceptual sophistication. In order to judge the relevance of a particular study to a new site, it is necessary to know how comparable those sites are. Like any benefits, environmental benefits are a function of scarcity, substitutes, and complements. In order to transfer benefit estimates to new sites, it is necessary to adjust for these kinds of factors.

Accordingly, additional research to develop standardized ecosystem service endpoints and other variables would facilitate agencies' ability to deploy benefit transfer methodologies. Some of this data will be biophysical, some demographic and economic. This kind of data would also be applicable to nonmonetary evaluations of mitigation, which is discussed as follows.

Research on Nonmonetary Approaches to Social Evaluation

Monetary valuation requires the use of methods that substantially add to the planner's assessment burden. Most decision-makers also find econometric tools excessively complicated. This can undermine trust in economic assessment and limit the application of economic arguments in certain decision contexts. An alternative approach is the use of quantitative ecosystem benefit indicators (EBIs).

EBIs are quantifiable features of the physical and social landscape that can be used to evaluate ecosystem serve benefits and thereby relate to and describe the value of endpoint changes. They can usually be derived easily from existing geospatial datasets. EBIs relate ecological endpoints with data on the endpoint's scarcity, substitutes, and complements and with rough measures of the populations and economic activities they support.

Specific examples include the population or number of properties affected by flooding, number of households drawing drinking water from an aquifer, or number of visitors to a park. All else being equal, the larger the number of these beneficiaries, the more valuable is the wetland that contributes to their ecosystem services. Linked to specific ecological endpoints, these measures can quickly inform decision-makers and allow for more comprehensive evaluation of multiple goods and services given limited budgets for analysis.

EBIs are also relevant to the benefit transfer methods described earlier. The translation of a preexisting monetary study to new geographic contexts requires economic analysts to describe differences in the sites, the ecological systems to which they are connected, and the populations they benefit. EBIs can be thought of as the data, or variables, that describe these differences in the ecological and social landscape. They thus will facilitate studies designed to transfer dollar-based valuations derived in one location to other locations affected by mitigation. Accordingly, EBIs should not just be thought of as a standalone approach to evaluation, but also as an important complement to conventional monetary benefit estimation.

The application of EBIs to the planning and evaluation process may provide progressive mitigation planners with a cheaper, more practical alternative to monetary benefit estimation.

Summary

It should be emphasized that economic evaluation of ecosystem goods and services affected by wetland, water quality, or endangered species mitigation is entirely dependent on the underlying biophysical science. If there is a single research priority, therefore, it is to develop the biophysical production relationships that quantify mitigation's effect on off-site ecosystem goods and services.

If social and economic evaluation is ultimately the goal, ecosystem service production – and the science used to quantify it – should be expressed in terms (ecological endpoints) that are amenable to social evaluation. Once those relationships are quantified, economic tools can be deployed to weight the relative importance of endpoint changes triggered by mitigation scenarios.

5.0 Conclusions

There are many progressive approaches that can assist with various aspects of carrying out an ecosystem and/or watershed scale 'progressive' compensatory mitigation program. Although there are upfront investments of time and resources necessary to develop these progressive approaches, they may provide significant cost savings over time. In addition, they may support the improvement and preservation of natural resources that provide critical ecosystem services that contribute to the health and well being of humans.

Elements of a progressive approach to compensatory mitigation include consideration of:

- On- and off-site ecosystem impacts and functions;
- Statewide or regional ecological and impact assessments and goals;
- Multiple ecosystem functions and their resulting ecosystem services (i.e., consideration of wetlands and streams, multiple species, corridors, on-site and off-site wetland functions, etc.);
- Methods to measure the economic and social values provided by ecosystem services;
- Mitigation assessment and action in advance of impact (i.e., provides more flexibility and can lower land acquisition costs) ;
- Spatial context of mitigation sites (i.e., proximity to protected areas contributes to sustainability, proximity to human populations contributes to higher values ecosystem services);
- Consolidation of administration and decision-making processes within one or more regulatory programs (i.e., permitting, ecological assessments, site selection, land acquisition, etc.);
- Economies of scale (i.e., increased protection afforded to species by larger, unfragmented habitat patches, lower cost of consolidated land acquisitions, etc.);
- Collaboration across multiple agencies and organizations; and
- Standardized, peer-reviewed site selection frameworks that include some or all of the considerations listed above.

Implementation of one or more of the elements listed above using methods and tools similar to those identified in Section 3 of this handbook may contribute to significant ecological and economic benefits and cost-savings. Still, there are many challenges to achieving compensatory mitigation efficiently and effectively; especially ensuring that on-the-ground actions contribute to greater environmental benefits and ecological sustainability. The primary challenges are resource-based, process-based, and institutional, and include:

1. Current requirements and processes create disincentives to achieving better compensatory results.
2. Current funding, requirements, and processes restrict the time available to agency staff to implement additional processes that could support more progressive approaches.
3. Clear and standard methods are needed for evaluating and/or selecting areas that result in better restoration, establishment, enhancement, or preservation outcomes.
4. Insufficient data and/or analyses are available to support the implementation of progressive evaluation or selection frameworks (Venner Consulting and URS Corporation 2009).

Although it appears that there are now fewer regulatory impediments to implementing progressive mitigation approaches (Venner 2010a; Venner 2010b; Venner 2010c), it is less clear that sufficient incentives exist for transportation agencies to support these progressive approaches (NCHRP 2010a). The lack of incentives coupled with the initial implementation costs, and the additional agency and public coordination that may be required in implementing a progressive approach to compensatory mitigation, both need to be addressed to support better social, economic and ecological outcomes nationally. If policy-makers can encourage agencies to assess long-term impacts at the programmatic level, they can better compare the upfront implementation costs of individual projects, with the long-term benefits available through the progressive approach.

The recommendations in this handbook will help agencies implement progressive approaches to compensatory mitigation and assist in clearly demonstrating the benefits and costs savings of these approaches.[11]

Clearly, there is no single approach that should be used for the assessment and selection of compensatory mitigation sites. Although many of the published approaches to progressive compensatory mitigation have similarities, it would be beneficial to conduct more in-depth studies of the various technical approaches to the assessment and selection of mitigation sites in order to bring

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[11] The recommendations in this handbook were based on a literature review of progressive approaches to compensatory mitigation (NCHRP 2010a), which documents tools, frameworks, and methods that support progressive approaches to the assessment, selection, and monitoring of mitigation sites. This handbook also drew from the many published case studies that document on-the-ground implementation of these progressive approaches across the country. At least 14 states have documented their efforts to improve mitigation outcomes by utilizing a watershed, ecosystem and/or multi-benefit approach.

more understanding of and support in the use of the various approaches, and ensure more scientific rigor in the efforts to improve compensatory mitigation across the country.

While working in the right place is clearly a critical factor leading to ecological success and meaningful ecosystem services outputs, it also is essential that sufficient areas be identified so there are always locations in which to work.

In summary, we recommend the following:

1. Develop a progressive mitigation program utilizing one or more of the elements of consideration listed above.
2. Support development of regional and/or statewide ecological assessments and impacts and conservation goals to support landscape-scale mitigation.
3. Utilize recommendations provided in Section 5 of this handbook to include a way to measure the ecosystem and economic benefits and cost savings associated with a progressive approach to compensatory mitigation.
4. Conduct a more in-depth study of the various technical approaches to the assessment and selection of mitigation sites to further advance the use and effectiveness of compensatory mitigation across the country.
5. Improve incentives and training to support transportation agencies use of these progressive approaches.

Going forward, the best – and most practical – examples can and should form the basis for mitigation planning that targets the most socially, ecologically and economically beneficial mitigation locations. This handbook will support agencies who want to implement or have implemented progressive approaches in assessing the relative benefits and costs savings of these approaches – further supporting the refinement and sustainability of these approaches.

6.0 Glossary

Adaptive Management	An approach to management that involves monitoring the outcomes of an activity, project, or decision, and on the basis of the monitoring results, making changes that improve the way the activity, project or issue is managed.
Animal Feeding Operation	Facilities in which animals are kept and raised in confined situations. Clean Water Act regulations define animal feeding operations as those confining livestock or poultry for 45 days or more in a 12-month period in a facility that has no vegetative ground cover. When large enough, these facilities are designated as concentrated animal feeding operations (CAFOs) and they become subject to regulatory requirements to prevent point source pollution. (Source: Congressional Research Service 2005.)
Avoidance	In the context of transportation planning and compensatory mitigation, progressive planning as described in this report could assist in identifying high priority natural resources for conservation allowing avoidance of impacts.
Benefit	In this report it is used as shorthand for an ecological, ecosystem, and/or economic benefit.
Benefit Indicator	A nonmonetary measure based on economic theory and empirical evidence of value that indicates a relative magnitude of value for ecosystem services.
Benefit Transfer	Techniques to estimate values of ecosystem goods and services based on previously conducted valuation studies. Benefit transfer is conducted by either taking average values of existing studies or by using a transfer function to transfer values from primary studies (study sites) to new locations (policy sites). A transfer function is often developed through meta-analysis, which is a statistical (usually regression) technique to model differences in values among primary valuation studies. A transfer function allows values to be transferred from study sites to policy sites based on a set of independent variables that capture the degree of similarity between the study sites and policy sites. (Source: Wainger and Mazzotta 2009.)

Benefit-Cost Analyses (Also Cost-Benefit Analyses)	A formal quantitative and sometimes qualitative evaluation of the benefits to be derived from a decision or action compared to the costs incurred by implementing that decision or action. Benefits and costs may include both market values and nonmarket values. Also see risk-benefit analysis.
Best Management Plans (BMPs)	A conservation practice or combination of practices designed to maintain productivity while reducing point source pollution and nonpoint source pollution. (Adapted from CRS 2005.)
Ecological (Or Biological) Production Function	A description of the type, quantity, and interactions of natural features required to generate outputs of functional ecological endpoints. For a simple example, the biophysical characteristics of a coastal wetland (flooding regimes, salinity, nutrient concentrations, plant species abundance, prey and predator abundances, etc.) can influence the abundance of a population of watchable wading shorebirds (the ecological endpoint). The outputs of ecological production functions, when combined with complementary goods and services and demand by humans, produce ecosystem goods and services. Also see ecosystem service production function. (Adapted from Wainger and Boyd 2009, Wainger and Mazzotta 2009.)
Biophysical	(adj.) Pertaining to the biological, chemical, and physical attributes of an ecosystem or environment.
Commodity	Generally, a physical substance – such as food, grain, or metal – that is interchangeable with another product of the same type, and which investors buy or sell. The price of the commodity is subject to supply and demand.
Compensatory Mitigation	For the purposes of this report, mitigation is defined, except where otherwise noted, as the third step of the three-step mitigation sequence: compensatory mitigation, or offsetting for lost habitat area or functions as required by a Federal or state regulatory program.

Connectivity	Connectivity refers to a functionally connected landscape that has an assemblage of habitat "islands" (the result of fragmentation) surrounded by "matrix" (less-preferred habitat, including clear cuts, agricultural land, and suburban sprawl). Because species vary in their willingness to pass through less preferable habitats, meaningful conservation planning and management projects must evaluate connectivity from the perspective of the individual target species. (Tabor, Gary M. and Meiklejohn, Katie, Connectivity 101, Landscope, July 2011. http://www.landscope.org/explore/natural_geographies/corridors_connectivity/connectivity_101.)
Conservation Banks (also Wetland Conservation Banks)	See call-out box on Page 1-3 of report.
Conservation Blueprint	In this report it is a term used to loosely define a map that identifies areas as high priority for conservation (preservation) and restoration of species and habitats. Craig Groves talked about this concept in detail in his book Drafting a Conservation Blueprint, although the term is used loosely and does not require a specific methodology or approach - currently many conservation and environmental organizations use this term to define the area they are targeting for their ecological assessments and management activities.
Conservation Planning	The systematic process of identifying areas important for conserving biological diversity. The result of this planning process is a network of lands that best conserves all elements of biodiversity within the planning area (sometimes called a 'conservation blueprint').
Conservation Targets	Species and habitats (or ecosystems) being targeted for conservation action.
Core Areas (also Habitat Centers, Hub Habitat)	Areas identified for conservation or restoration because they are critical to the long-term viability of species and habitats or ecosystems.
Credit	A single unit of trading that quantifies the provision (or right of use) of a regulated or nonregulated ecosystem service and that defines the changes in ecosystem condition that are equivalent to a unit of a service. (Adapted from Willamette Partnership.)

Decision-Makers	One of any social and mental processes leading to the selection of a course of action among several management options or alternatives. Also see decision/management alternative and decision/management option.
Decision-Making Process	One of any social and mental processes leading to the selection of a course of action among several management options or alternatives. Also see decision/management alternative and decision/management option
Decision Support Tool (or System)	An interactive computer-based system to aid decision makers in identifying and solving problems, and making decisions. These systems may use data from observations, output from statistical or dynamic models, and rules based on expert knowledge.
Development By Design Framework	A landscape-level mitigation planning approach called Development by Design, see details at: http://www.nature.org/aboutus/developmentbydesign/.
Dispersal Corridors	A dispersal corridor is a migration route that allows more or less uninhibited faunal interchange.
Ecological Benefit	The contribution to social welfare of ecosystem goods and services. In the ESRP, the term applies specifically to net improvements in social welfare that result from changes in the quantity or quality of ecosystem goods and services attributable to policy or environmental decisions. Synonymous with benefit, social benefit, and "ecosystem-derived benefits" as used in Wainger and Boyd 2009. (Modified from U.S. EPA 2006.)
Ecological Economies	The field of research and analysis that aims to address the interdependence and co-evolution of human economies and natural ecosystems over time and space. Compare with environmental economics.

Ecological Endpoints	A biophysical feature, quantity, or quality that requires little further translation to make clear its relevance to human well-being (i.e., "public-friendly" measurements). Ecological endpoints are the ecological inputs that, along with complementary goods and services inputs and demand by people, produce ecosystem services. For the ESRP, synonymous with "Boyd" endpoint. For example, a population of watchable birds is an ecological endpoint, that when combined with complementary inputs such as transportation infrastructure and demand by birders, produce the ecosystem service of recreational bird watching. (Adapted from: Boyd 2007, Boyd and Banzhaf 2007, Wainger and Boyd 2009, Wainger and Mazzotta 2009.)
Ecological Score	An index or score based on ecological attributes and metrics so that it can be understood in light of conservation goals and objectives.
Econometric Tools	Tools that support the provision of empirical content to economic relations.
Ecoregional Portfolio (also Conservation Portfolio)	The results of a systematic conservation planning process, an ecoregional portfolio provides an overview or profile of the natural resources conditions occurring within a ecoregion that are relevant to conservation and/or restoration activities. The information used to develop a portfolio result from an ecological assessment process. Ecoregional assessment is one of two methods that The Nature Conservancy uses with partners to establish priorities for its conservation actions. The process assesses relatively large geographic areas delineated by large-scale patterns of climate, geology, biodiversity, and other ecological and environmental patterns.

Ecosystem Functions (also Ecological Production Functions or Ecosystem Service Production Function)	A description of the relationship between quality-adjusted ecological endpoints and the provision of ecosystem goods and services. This term differs from ecological production function because it includes both the biophysical functions and the non-ecological assessments that are needed to demonstrate a service. ESPFs evaluate four things: 1) how ecological endpoints combine with complementary (non-ecological) inputs to generate goods and services; 2) whether the quality of ecological endpoints is sufficient to generate the service; 3) whether required complementary goods and services (trails, roads, homes) are available; and 4) whether demand exists for the service by location. For example, a quantitative or qualitative description of how a population of watchable birds (the ecological endpoint), when combined with complementary inputs such as transportation infrastructure and demand by birders, produces the ecosystem service of recreational bird watching, is an ecosystem service production function. Also see ecological production function. (Source: Wainger and Mazzotta 2009, with input from J. Boyd.)
Ecosystem Goods and Services	Outputs of ecological functions or processes that directly ("final ecosystem service" sensu Boyd and Banzhaff 2007) or indirectly ("intermediate ecosystem service") contribute to social welfare or have the potential to do so in the future. Some outputs may be bought and sold, but most are not marketed. Often abbreviated as ecosystem services. (Modified from U.S. EPA 2006.)
Ecosystem Services	Shorthand notation for ecosystem goods and services.
Environmental Economics	A subfield of economics that undertakes theoretical or empirical studies of the economic effects of national or local environmental policy. Particular issues addressed include the benefits and costs of alternative environmental policies to deal with air pollution, water quality, toxic substances, solid waste, and global warming. Compare with ecological economics. (Adapted from National Bureau of Economic Research.)
Green Infrastructure	Green infrastructure is a strategically planned and managed network of natural lands, working landscapes and other open spaces that conserve ecosystem values and functions and provide associated benefits to human populations.

Greenprints	Greenprint is a term used loosely by the conservation community to characterize a 'map' of high priority areas for conservation, preservation, and restoration. The Trust for Public Lands has a process called Greenprinting – a framework that utilizes GIS analyses and modeling in combination with a community-based process in order to define priorities for new parks and land conservation, identify lands to be protected, and plan networks of conserved land that meet public need.
Habitat Requirements	Requirements necessary for a habitat to be viable (e.g., the minimum area needed without fragmentation for a habitat to be viable), usually referring to an individual species needs.
Hydrogeomorphic	A land form characterized by a specific origin, geomorphic setting, water source, and hydrodynamic.
Hydrologic Unit Codes (HUC)	See call-out box on Page 3-11 of report.
Impaired Waters	All waters where required pollution controls are not sufficient to attain or maintain applicable water quality standards.
Imperiled Species	Generally, a term applied to species that are considered rare or in danger of becoming rare. Can include species that are listed under the U.S. Endangered Species Act as well as species that are considered rare or imperiled under other species 'ranking' systems such as the IUCN Red List and NatureServe's Global Conservation Status Ranks.
Impervious Surfaces	Impervious surfaces are mainly artificial structures--such as pavements (roads, sidewalks, driveways, and parking lots) that are covered by impenetrable materials such as asphalt, concrete, brick, and stone--and rooftops. Soils compacted by urban development are also highly impervious.
In-Lieu Fee Mitigation	See call-out box on Page 1-3 of report.
Minimum Habitat Size Viability Requirements	The size of an area required for the long-term viability of a species or habitat. Size requirements vary based on the individual needs and characteristics of the habitat.
Minimum Viability Needs	Requirements necessary for a habitat or species to be viable (e.g., the minimum area needed without fragmentation for a habitat to be viable).
Mitigation Bank	See Conservation Bank.

Monetary Valuation Methods	Defined on Page 4-12.
Natural Heritage Areas	NatureServe, a nonprofit conservation organization, focuses on providing the scientific basis (information, expertise, and methods) for effective conservation, and has member programs in every state in the U.S. that are commonly called natural heritage programs. These programs all use a standard methodology for mapping the locations of species (natural heritage element occurrences) and habitats as well as determining the conservation status of these elements. Natural heritage areas are areas that these programs have identified as critical to the long-term viability of rare and imperiled species and natural communities.
Natural Heritage Element Occurrences	See Natural Heritage Areas.
Offset(S)	A credit used to compensate for the unavoidable impacts on the environment. Used by companies, governments or other entities in compliance markets to comply with regulatory caps. Offset credits are often called mitigation credits. Also see credit. (Adapted from Willamette Partnership.)
Off-Site Compensation Options	A compensatory mitigation site that is not in close proximity to the impacted project site.
On-Site/In-Kind Compensatory Mitigation	A compensatory mitigation site that is in close proximity to the impacted project site, and is 'replacing' the same type of species or habitat that was impacted.
Performance Measures And Performance Standards	Performance standards are criteria that define particular objectives or outcomes to be achieved without prescribing the specific methods to be used to achieve the objectives. A performance-based standard describes and provides measures for the attributes of success to the extent practicable. The performance measures may be qualitative, quantitative, or a combination of the two. For example, "quantification of an ecological endpoint within 10 percent accuracy," without specification of the quantification methods to be used, could be a performance-based standard.

Programmatic Agreement	A programmatic agreement (PA) in this report represents a document containing the terms of a formal, legally binding agreement between a state Department of Transportation and other federal and state regulatory agencies, which establish a process for consultation and project review based usually based on a set of agreed upon actions. PAs for Clean Water Act and Endangered Species Act compliance are usually procedural as opposed to project-specific. These PAs often involve the delegation of environmental review functions from the FHWA to a state DOT, or from a Federal or state natural resource agency to a state DOT. These delegation PAs can address, for example, Categorical Exclusion reviews and Wetland Permitting.
Programmatic Mitigation and Permitting	Compliance with Section 7 of the Endangered Species Act can be accomplished through the use of programmatic consultations, resulting in the development of programmatic biological assessments, and programmatic biological opinions prepared by the U.S. Fish and Wildlife Service. These are not formal agreement documents per se, in the sense that this term is used in Section 106 compliance; rather, they are documents that handbook agency decision-making. The FHWA, state DOT and U.S. Fish and Wildlife Service use these programmatic assessments and biological opinions as guidance documents for future projects. When one of these projects is initiated, the agencies use these programmatic consultations to expedite and simplify Section 7 compliance, as opposed to completing a separate, formal Section 7 consultation.
Project Atlases	Compile site-level maps and assessment data to identify the highest potential for compensatory mitigation within a Targeted Local Watershed (TLW).
Regulatory Assurances	Assurances to environmental regulators of compliance to environmental regulations. With progressive mitigation the development of indicators of ecological health and performance measures associated with mitigation sites are critical to strong regulatory assurances.
Restoration	Physical modification of a site to reconstitute a pre-existing ecological condition, or range of conditions.
Risk	The likelihood that adverse ecological effects or human health effects may occur or are occurring as a result of exposure to one or more stressors. (Derived from U.S. EPA 1998.)

Scenario	As used in the ESRP, a set of driving conditions that will cause ecological and potentially human well-being change. Driving conditions can include the continuation of existing trends ("business-as-usual"), extrinsic changes (e.g., a change in the rate of population growth, a change in the rate of sea-level rise) or the introduction of hypothetical policies.
Sensitive Species	A term used loosely to characterize species that are considered to be at-risk of imperilment or imperiled. The U.S. Bureau of Land Management and U.S. Forest Service use this term to characterize species of high priority for conservation on their lands, and some states use this term to characterize species 'of concern' for conservation focus in their state.
Stakeholder	An individual, group, or organization with an interest in, or potentially impacted by, the outcome of a policy or management choice.
Targeted Local Watersheds (TLW)	Watersheds that are targeted as high priority for conservation or restoration using a process that compiles the problems, assets, and opportunities within a basin.
Valuation	Generally, the process of estimating the worth, merit or desirability of something. Specifically with respect to ecological benefits, the quantification of those benefits. (Adapted from U.S. EPA 2006.)
Value	Generally, the worth, merit or desirability of something. It can be expressed quantitatively (for example, in monetary terms) or qualitatively. Specifically with respect to ecological benefits, a quantitative or qualitative description of those benefits.

Watershed Management Plan	Equivalent to a watershed plan, this is a strategy and a work plan for achieving water resource goals that provides assessment and management information for a geographically defined watershed. It includes the analyses, actions, participants, and resources related to development and implementation of the plan. The watershed planning process uses a series of cooperative, iterative steps to characterize existing conditions, identify and prioritize problems, define management objectives, and develop and implement protection or remediation strategies as necessary. They often use a review of aquatic resource functions in the smaller subwatersheds of a Targeted Local Watershed (TLW) to identify subwatersheds that would be a priority for wetland and stream mitigation, and make management and policy recommendations to address acute watershed problems.
Watershed Profile	A watershed profile is an overview of geographic and social attributes within the watershed, and it summarizes current natural resource conditions that are particularly relevant to management of agricultural and natural lands.
Wetland(s)	An area of predominantly hydric soils that can support a prevalence of water-loving plants, known as "hydrophilic vegetation." Transitional between terrestrial and aquatic systems are wetlands typified by a water table at or near the surface, or the land is covered by shallow water at least part of the year. Types of wetlands are distinguished by water patterns (the frequency and length of flooding) and location in relation to upland areas and water bodies. Wetlands perform many functions including wildlife and fish habitat, storage and conveyance of flood waters, sediment and pollution control, and recreation. (Source: Congressional Research Service 2005.)

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