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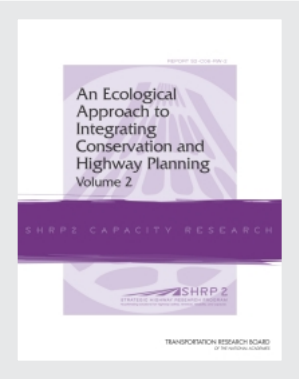

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The Second
STRATEGIC HIGHWAY RESEARCH PROGRAM

SHRP 2 REPORT S2-C06-RW-2

An Ecological Approach to Integrating Conservation and Highway Planning

Volume 2

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The need for SHRP 2 was identified in *TRB Special Report 260: Strategic Highway Research: Saving Lives, Reducing Congestion, Improving Quality of Life,* published in 2001 and based on a study sponsored by Congress through the Transportation Equity Act for the 21st Century (TEA-21). SHRP 2, modeled after the first Strategic Highway Research Program, is a focused, time-constrained, management-driven program designed to complement existing highway research programs. SHRP 2 focuses on applied research in four areas: Safety, to prevent or reduce the severity of highway crashes by understanding driver behavior; Renewal, to address the aging infrastructure through rapid design and construction methods that cause minimal disruptions and produce lasting facilities; Reliability, to reduce congestion through incident reduction, management, response, and mitigation; and Capacity, to integrate mobility, economic, environmental, and community needs in the planning and designing of new transportation capacity.

SHRP 2 was authorized in August 2005 as part of the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU). The program is managed by the Transportation Research Board (TRB) on behalf of the National Research Council (NRC). SHRP 2 is conducted under a memorandum of understanding among the American Association of State Highway and Transportation Officials (AASHTO), the Federal Highway Administration (FHWA), and the National Academy of Sciences, parent organization of TRB and NRC. The program provides for competitive, merit-based selection of research contractors; independent research project oversight, and dissemination of research results.

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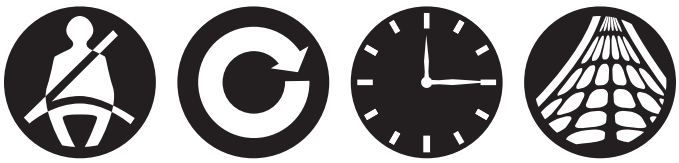

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FOREWORD

Stephen J. Andrle, *SHRP 2 Deputy Director*

This report is intended to help transportation and environmental professionals apply ecological principles early in the planning and programming process of highway capacity improvements to inform later environmental reviews and permitting. Ecological principles consider cumulative landscape, water resources, and habitat impacts of planned infrastructure actions, as well as the localized impacts. The report introduces the Integrated Ecological Framework (Framework or IEF), a nine-step process for use in early stages of highway planning when there are greater opportunities for avoiding or minimizing potential environmental impacts and for planning future mitigation strategies. Success requires some level of agreement among stakeholders about prioritization of resources for preservation or restoration. This implies long range environmental planning as a companion to long range transportation planning so that there is a basis and methodology for prioritization. This report provides a structured collaborative way to approach these issues. It does not address environmental mitigation and permitting actions required by current law or regulation.

The report provides technical background on cumulative effects assessment, ecological accounting strategies, ecosystems services, and partnership strategies, along with a summary of the available ecological tools that are most applicable to this type of work. The appendices document three pilot projects that tested the approach during the research.

The Framework details steps to enhance ecological considerations and efficiency in the early stages of planning highway capacity projects. Transportation professionals must routinely interact with numerous agencies in the course of planning highway expansions. These materials are intended to help each stakeholder better understand the missions and responsibilities of the other stakeholders and provide a structured and repeatable framework for interaction, thus allowing for agreement on ecological priorities. Use of the Framework can streamline the delivery of highway projects and improve water resources and habitats.

The research from SHRP 2's Capacity Project C06 produced two volumes of reports and a companion guide. Volume 1 (forthcoming) covers institutional issues and provides examples of techniques such as banking and programmatic agreements that can be used in the highway planning process. The guide (forthcoming) provides step-by-step information to help practitioners use the Framework. Essential content from the C06 project is available on the Transportation for Communities: Advancing Projects through Partnerships website (www.transportationforcommunities.com).

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Executive Summary

The nine-step Integrated Ecological Framework (the Framework or IEF) is designed to support and promote integrated transportation and conservation planning while expediting transportation project delivery. The report addresses the scientific and technical processes needed for this integrated approach. A step-by-step cumulative effects assessment and alternatives (CEAA) process provides the foundation. New regulatory assurance, environmental accounting, and crediting methods were developed that can be applied within the CEAA process. The entire CEAA process and supporting tools, methods, and case studies needed to use it will be available to transportation planners and resource agencies through the Transportation for Communities: Advancing Projects through Partnerships (TCAPP) website, developed by the SHRP 2 C01 project (ICF International and USR Corporation forthcoming). The team's research results are also incorporated in *An Ecological Approach to Integrating Conservation and Highway Planning, Volume 1* (Marie Venner Consulting and URS Corporation forthcoming).

The vision underpinning this research was to develop a scientifically supported, outcome-based approach that would facilitate efficient and effective transportation planning, regulatory decision making, and capacity development while maximizing opportunities for the long-term conservation and enhancement of ecosystem functions at multiple scales. New methods were researched to prepare up-to-date wetlands maps and create inductive models to predict where sensitive species are most likely to be located and where they are unlikely to occur. These new tools will allow transportation planners to more easily avoid such problems early in the planning process and be more confident of citing projects where impacts will be minimized. If impacts are unavoidable, the use of new environmental accounting tools, such as ecosystem credits, from planning through the site-level project delivery can improve conservation outcomes and speed permitting decisions.

The tight budgets faced by government at all levels make it vital that every dollar spent on environmental mitigation and restoration in transportation project development is well spent. The hope is that this new Framework and the supporting scientific and technical tools will foster agreement between transportation and resource agencies on conservation priorities and mitigation requirements where new transportation projects are planned, improving transportation project delivery and conservation results.

The Framework

Using the steps in the Framework (Table ES.1), state transportation agencies (DOTs), metropolitan planning organizations (MPOs), and resource agencies work together during long-range planning to identify strategic transportation program needs and their potential environmental impacts and conservation opportunities. The Framework allows programmatic tools to be used to increase regulatory predictability during project development while furthering regional conservation goals. The Framework is a comprehensive, dynamic process designed to promote the integration of regulatory and nonregulatory authorities and better environmental outcomes.

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Table ES.1. Steps of the Ecological Assessment Framework

Step	Purpose
Step 1: Build and strengthen collaborative partnerships, vision	Build support among a group of stakeholders to achieve a statewide or regional planning process that integrates conservation and transportation planning.
Step 2: Characterize resource status; integrate conservation, natural resource, watershed, and species recovery and state wildlife action plans	Develop an overall conservation strategy that integrates conservation priorities, data, and plans, with input from and adoption by all conservation and natural resource stakeholders identified in Step 1 that addresses all species, all habitats, and all relevant environmental issues.
Step 3: Create regional ecosystem framework (conservation strategy + transportation plan)	Integrate the conservation and restoration strategy (data and plans) prepared in Step 2 with transportation and land use data and plans (long-range transportation plans [LRTP], statewide transportation improvement program [STIP], and transportation improvement program [TIP]) to create the Regional Ecosystem Framework (REF).
Step 4: Assess land use and transportation effects on resource conservation objectives identified in the REF	Identify preferred alternatives that meet both transportation and conservation goals by analyzing transportation and/or other land use scenarios in relation to resource conservation objectives and priorities using the REF and models of priority resources.
Step 5: Establish and prioritize ecological actions	Establish mitigation and conservation priorities and rank action opportunities using assessment results from Steps 3 and 4.
Step 6: Develop crediting strategy	Develop a consistent strategy and metrics to measure ecological impacts, restoration benefits, and long-term performance, with the goal of having the analyses be in the same language throughout the life of the project.
Step 7: Develop programmatic consultation, biological opinion or permit	Develop memoranda of understandings (MOUs), agreements, programmatic 404 permits, or Endangered Species Act (ESA) Section 7 consultations for transportation projects in a way that documents the goals and priorities identified in Step 6 and the parameters for achieving these goals.
Step 8: Implement agreements and adaptive management; deliver conservation and transportation projects	Design transportation projects in accordance with ecological objectives and goals identified in previous steps (i.e., keeping planning decisions linked to project decisions), incorporating as appropriate programmatic agreements, performance measures, and ecological metric tools to improve the project.
Step 9: Update regional integrated plan/ ecosystem framework	Update the effects assessment to determine if resource goal achievement is still on track. If goal achievement gaps are found, reassess priorities for mitigation, conservation, and restoration in light of new disturbances that may affect the practicality and utility of proceeding with previous priorities. Identify new priorities if warranted.

Cumulative Effects Assessment and Alternatives Process

The CEAA process is based on and supports the *Eco-Logical: An Ecosystem Approach to Developing Infrastructure Projects* (*Eco-Logical*) approach to infrastructure development (Brown 2006). The CEAA provides technical guidance to transportation and natural resource practitioners—helping them bring the right expertise, data, methods, and tools to the right stage of the transportation planning and project delivery decision-making process. The result should be better

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environmental outcomes through reduced impacts, identification of high-quality mitigation and enhancement opportunities, and accelerated permitting through proactive inclusion of resource considerations early in the process.

Rather than a radical new approach, the CEAA process brings together a variety of well-tested methods, data, and tools into a cohesive ecological assessment framework. It addresses several long-recognized needs: (1) the need to proactively consider ecological values early in planning processes for infrastructure and land use and preferably at a regional scale; (2) the need for spatially explicit and sufficiently precise cumulative effects assessment throughout a region to provide useful information to guide alternative development and mitigation planning; (3) the need for a collaborative structure for technical information development and maintenance to serve multiple planning purposes dynamically over time; and (4) the desire to obtain better ecological outcomes from mitigation investments while meeting planning objectives.

Specifically, the CEAA process guides a scientifically rigorous ecological assessment process that: (1) evaluates direct and cumulative effects on resources from any potential planning alternative or project; (2) assists in the identification or creation of alternatives; and (3) identifies the best mitigation and enhancement opportunities. It addresses several key questions in transportation and conservation planning and project development:

- What areas and resources will be directly affected by transportation development?
- How will those resources be affected cumulatively through the affected region?
- What areas could be used for mitigation?
- How can anticipated long-range regional mitigation needs be aggregated for maximum ecological benefit?

The CEAA is intended to be highly scalable to the time, resources, data, and expertise available and can be used at the regional, corridor, or project level. Undertaking a CEAA requires transportation and resource agencies and other stakeholders to work collaboratively to agree on targets and goals for an area of interest. This ensures that relevant expertise, data, tools, and methods are considered in the development of a Regional Ecosystem Framework (REF). The REF can then be used to assess and guide transportation decision making at all stages of transportation planning and development and allow impacts to be assessed and quantified early in the transportation planning and project delivery process.

Within this process, it is possible to begin at any transportation decision point and use the CEAA to help identify and incorporate the necessary questions, data, and analysis needed to support better environmental and transportation decision making. The online version includes references that provide in-depth reading on the concepts and case studies that illustrate real-life applications, as well as useful technical tools and data sources to support its use and implementation.

The major outputs of the CEAA are:

- Unified map of transportation, land use, conservation, and restoration priorities.
- Maps of each potential transportation scenario that show an assessment of direct and cumulative effects at a landscape level with supporting data.
- Identification of affected resources and the quantification of the cumulative effects for each transportation scenario being considered.
- Identification and evaluation of potential mitigation and enhancement areas within a region.

Regulatory Assurances and Ecological Accounting Strategies

Within the overall Framework and the CEAA process, two strategies are critical. First, transportation planners and project managers must address regulatory requirements, ideally as early in the transportation planning and development process as possible. Second, environmental accounting strategies can be used to reach agreement with regulatory agencies on project impacts

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and mitigation requirements. This project explored new approaches to regulatory assurances and environmental accounting and how they could be used within the overall Framework if transportation and resource agencies choose to do so.

Regulatory Assurances

Addressing regulatory requirements is an essential part of the decision-making process for all transportation projects. Obtaining complete regulatory assurances may be impossible; however, this report and the online database provide guidance on the information, tools, and processes that can lead to faster decisions with improved environmental outcomes. The team's focus was on regulations under the Endangered Species Act (ESA) and the Clean Water Act (CWA). The team identified the aspects of current decision making that raise the greatest concerns for regulators at the national, regional, state, and local levels, and developed tools and information to address them. Improved outcomes depend, first, on developing tools planners can use to identify potential impacts to regulated resources very early in the planning process—allowing them to avoid or minimize impacts as much as possible. Second, any mitigation that must occur due to unavoidable impacts must provide effective, measurable, and high-quality environmental outcomes for the affected resources.

The team found that, particularly for wetlands and endangered species compliance, regulatory conflicts and delays result primarily from transportation planners and regulators having insufficient, incomplete, or poor-quality data. Problems under Section 7 of the ESA, which requires consultation with the U.S. Fish and Wildlife Service or the National Marine Fisheries Service when federal actions may affect species listed under the ESA, result both from the lack of certainty about the probability and degree that a project may affect a listed species and the lack of certainty as to how to design meaningful mitigation measures. The team hypothesized that, if done correctly, specific improvements in threatened and endangered species data can improve transportation planning and species recovery efforts. Through research, the team found new methods of developing inductive species distribution models showing probable distribution of listed species, as opposed to traditional maps that show only known populations or highly generalized range for a species. The team found that developing inductive distribution models is feasible for all listed species and has the potential to radically improve regulator and planner interactions.

Species distribution models using inductive modeling methods can create reliable maps that can be used by transportation planners early in the planning process, before significant investments have been made toward road design. The maps are also useful in identifying mitigation opportunities and assisting in recovery planning. The nature of the inductive maps makes updating them with new information relatively straightforward and can allow regulators, if they choose, to easily modify the maps to make them more conservative if needed for Section 7 consultations for a particular species. Natural Heritage Programs have created these maps for many endangered and at risk-species in New York, Oregon, Florida, Wyoming, and Virginia and have been working with NatureServe and the U.S. Fish and Wildlife Service (USFWS) to develop a strategy for creating these data for all listed species in the United States.

Improved information appears to be equally as important for improving transportation and conservation outcomes related to wetlands, streams, rivers, and other resources regulated under the CWA. Most transportation agency interactions with regulators were on Section 404 compliance, which protects wetlands, so the team focused on information needs for wetlands. In many areas of the country, data currently are lacking for avoidance and minimization of impacts to wetlands and for assessing wetland mitigation options.

For avoidance, transportation planners need access to digital wetland maps covering the entire United States. The National Wetlands Inventory (NWI) is the baseline database for the country designed for this purpose but covers only approximately 80% of the country digitally, and much of the NWI is based on imagery that is almost 30 years old (U.S. Fish and Wildlife Service 2012a).

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USFWS has been working to obtain the funding to complete this data set, but with current protocols and funding levels, it will be decades before the country has digital wetlands data sufficiently updated to be used by transportation planners and accepted by regulators as meaningful attempts at avoidance and minimization. The team's research looked at case studies to create digital data lacking from Oregon and to improve data from Michigan and Virginia. Methods, including collaboration between state agencies, a mix of funding from federal, state, and nonprofit sources, imagery analysis, and modeling, were used in these states to dramatically increase digital wetlands coverage, at times for much less than the estimated cost of $1.5 to 2 million per state. These proven strategies could be used to create wetlands data for avoidance for the entire country within 2 or 3 years.

The primary data need for wetlands mitigation is the identification of priority wetland areas requiring restoration, often called a wetlands restoration and mitigation catalog. To be effective, these catalogs need to identify mitigation needs for all watersheds and be preapproved by wetland regulators. The team's research identified methods for developing wetland catalogs based on an REF, piloted in Oregon and Virginia, focusing on methods that can be implemented widely in the near future. Building on existing data and developing partnerships between public agencies, universities, and nonprofit agencies can create results quickly and inexpensively. Similar efforts have been undertaken as a local watershed approach in many areas of the country, such as Maryland's effort to develop statewide priorities. Many methods appear to be promising, although ways to integrate wetland priorities with other water quality needs are only beginning to be explored. The development of a wetlands mitigation catalog can significantly improve conservation outcomes and dramatically improve transportation project implementation. Developing standards for implementing this approach nationally is a critical need.

Ecological Accounting Strategies

There are many ongoing efforts to improve ecological metrics and decision-support tools. However, adoption of these approaches in transportation decision making has been slow. As a result, the transportation industry has not taken full advantage of the opportunities that better ecological metrics and decision-support tools can provide. Transportation planning and permitting decisions require a clear measurement of impacts to understand available choices, but agreement on measurements to assess impacts and mitigation options can be difficult to reach. In addition, as decisions are made in resource-specific processes, silos are created around each natural or ecological resource being managed.

The team's research addressed measurements needed to meet existing regulatory concerns and measures that take advantage of emerging requirements and stakeholder concerns developing around the concept of ecosystem services. The Framework and CEAA process provide the ability to link and correlate ecological measurements at a landscape scale with measurements of similar resource issues at a site level. Applied in a transportation context, that means being able to broadly understand and plan around a resource at a regional scale, identify goals and desired outcomes for that resource, and measure specific outcomes for that resource at a site level that allow assessment of a project's effect on the resource. In practice, linking the measurement scales provides the following outcomes:

- A better ability to maintain continuity between early transportation planning and project-specific planning,
- Improved regional goal setting and a better ability to track the effect of specific projects on the progress toward those goals,
- A framework for understanding and presenting cumulative effects analyses,
- An improved understanding of the opportunity and need for using programmatic approaches in project planning and an improved ability to develop them.

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This approach to ecosystem metrics from the landscape scale to the site level, from alternatives analysis to outcome-based mitigation for specific projects, is addressed throughout the CEAA process. A separate step addressing the use of crediting systems is included in the Framework, providing specific guidance for transportation agencies on how to develop and use ecosystem crediting systems and markets.

Pilot Projects

The team tested the CEAA process and supporting strategies in three pilot projects in Oregon, Michigan, and Colorado. The objective was to see if the new approach would result in different decisions and outcomes or time and cost savings compared with the traditional transportation planning and project delivery system. The team also sought to test the usability of the new processes and found that the methodology produced results similar to those of traditional approaches in the evaluation and mitigation of direct impacts. The team's approach provided better results than the traditional approach for cumulative impact analysis and selection of mitigation options.

Dissemination

The Framework, including the detailed CEAA process and the supporting strategies for achieving regulatory assurances and using ecological accounting systems and credits, will be included in the TCAPP website. The team developed an interactive database to support transportation and resource agencies. It will be integrated into the TCAPP website, which includes a step-by-step guide with supporting documentation in the form of case studies, tools, data, expertise, and other resources to assist practitioners in using all or part of the proposed new approach.

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CHAPTER 1

The Project Approach

Relationship to the Collaborative Decision-Making Framework and Volume 1

The SHRP 2 Capacity program is charged to develop approaches and tools for systematically integrating environmental, economic, and community requirements into the analysis, planning, and design of new highway capacity. The foundation of this approach is the SHRP 2 C01 report, *A Framework for Collaborative Decision Making on Additions to Highway Capacity* (ICF International and USR Corporation, forthcoming). The Framework builds on the *Eco-Logical* framework (Brown 2006), allowing it to be integrated into that of TCAPP to provide the process and tools needed by resource agency staff, transportation planners, and transportation agency environmental specialists to integrate transportation and conservation planning.

C06 project report Volume 1, elaborates on decision points in the TCAPP Decision Guide that involve regulated and nonregulated environmental impacts, such as wetlands, water quality, endangered species, wildlife, habitats, and cultural resources, building on the *Eco-Logical* framework. The Volume 1 report also addresses the problem of getting regulatory agencies to accept transportation agency investments in environmental mitigation or restoration. Both Volume 1 and this report reflect the need for a close partnership between regulatory and transportation agencies in addressing the challenges of integrating transportation and conservation planning. This coordination between agencies should assure that the scientific and technical processes and strategies developed to support an ecological approach fit within existing and future institutional systems and address barriers to its wider adoption.

Approach

The team began work by developing a vision for integrated transportation and conservation planning (see Chapter 2). The team reviewed the literature and did detailed reviews and evaluations of existing ecological assessment tools and environmental accounting tools. The results of this work were included in the interim report and are included in the interactive database developed for inclusion in TCAPP. The CEAA process was developed and integrated into the overall Framework. State and federal regulators were interviewed to identify and address technical issues associated with obtaining regulatory assurances early in the transportation planning and project delivery process. State and local transportation agencies were interviewed to help develop step-by-step strategies for improving use of outcome-based environmental accounting and crediting systems. Once the CEAA technical guidance and supporting regulatory assurance strategy were developed, they were tested in three pilot states.

The team's approach integrated well-vetted and tested concepts from the disciplines of systematic conservation planning (Groves 2003), cumulative effects assessment, and mitigation hierarchy (avoidance, minimization, mitigation, compensation). While integrating scientific concepts from these disciplines, the team developed technical guidance drawn from spatial analyses and decision-support practices. The intent was to develop a detailed hierarchy of integrated steps and steps to guide practitioners through the CEAA process that was flexible enough to be used with specific geographic information system (GIS) platforms, available capacity, and financial resources.

Development of the Framework

The Framework was developed in collaboration with the team developing Volume 1. It was developed to closely follow the *Eco-Logical* framework and make this framework easier to implement by providing additional detail. These additional details were described in a hierarchical fashion with detailed technical levels to include the CEAA component. The team revised the Framework several times based on review by

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practitioners and experience conducting the pilot projects. The CEAA built on work done on another TRB research project (Paulsen et al. 2010) on regional cumulative effects assessment. The original work was modified to fit the Framework and provide further detail in the components of mitigation and alternatives development and ongoing adaptive management.

Ecological Assessments Tool Survey and Utility Analysis

Scientists have developed many methods for assessing ecosystem function over various geographic scales and timeframes. The challenge is to identify the methods that are most useful at various stages of the transportation planning and project delivery process to know what resources and functions are important, how impacts to them can be avoided and minimized, and if impacts are unavoidable, how they can be mitigated most effectively. To identify methods appropriate for use at key decision points in transportation planning and development, the team developed a tool survey protocol.

The tool survey protocol included the methods for searching for tools, evaluating tools for their relevance and utility, and characterizing tools in a database suitable for long-term use in an interactive database. The survey built on considerable existing knowledge regarding tools available to conduct ecological assessments, including cumulative effects analyses. It also drew on tool surveys by the Ecosystem Based Management (EBM) Tools Network. The EBM Tools Network supplied the team with characterizations of 171 tools that were already integrated into an online database (NatureServe 2012), some of which were included in the team's survey. The team's database was built by reviewing the tools documented in the EBM Tools Network, reviewing the tools that were referenced in many of the articles and research cited in the literature review, and by using the team's knowledge to evaluate the tools.

The tool evaluation database consists of decision-support tools, ecological- and conceptual-modeling tools, transportation-sector–specific tools that have broad applicability, and state-specific ecological and conservation data query tools. Some tools listed are best described as methods to organize information or integrate certain steps into a larger planning process.

Each tool in the database was evaluated within the context of the overall Framework and the process tasks and key decisions included that support the Framework. There is no ecological assessment *supertool* capable of conducting all computerized analyses necessary for regional ecological and cumulative effects assessment; therefore, the team developed a toolkit that combines multiple tools to support an information workflow through all levels of transportation planning and project delivery. The following assessment criteria and questions were developed against which potential tools were assessed for their utility at various stages of the transportation planning and project development process:

1. *Was sufficient information available to correctly characterize a tool?*
   For some tools, adequate information could not be obtained to describe it adequately.
2. *Is the tool documented?*
   Documentation can take many forms, but it should be clear and readily accessible. It should clearly state who created the tool (the originator), what the tool was designed to do, whether it was created for a particular focal ecosystem, what information or inputs the tool needs, and how the tool creates useful outputs for the user(s).
3. *Was the tool developed by a credible source?*
   Most tools encountered online come from well-known governmental, private, or nonprofit institutions. The existence of a user community for a tool adds to its credibility.
4. *Is the tool maintained?*
   Too often tools are created and released but not maintained over time. Because technology and methodologies change, tools can quickly become obsolete. Some of the documented methods were older but applied more generally to well-established planning processes (such as the National Environmental Policy Act [NEPA]).
5. *Has the tool been used in the field?*
   Ideally, all tools have been used in a planning process and contributed to a successful outcome. However, some tools lack any type of field testing, so the outputs of these tools are unknown. In some cases, there was no information on how particular tools have been used.
6. *Is the tool useful for integrated conservation/transportation planning?*
   If the tool did not appear to add value to an integrated ecological assessment method in the transportation context, it was eliminated.

If the tool did not meet all criteria, it was eliminated from the database. Forty-two tools are included in the database of a total of approximately 70 tools surveyed (see the TCAPP for the list of the tools). In the final evaluation stage, the team defined and cross-walked information about the tools using key steps in the overall Framework.

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Regulatory Assurances and Data Quality

Transportation practitioners seek methods for identifying potential impacts to regulated resources as early as possible in the planning process so that impacts can be avoided or minimized. They also share the desire of regulatory agencies to assure that any mitigation required because of unavoidable impacts provides effective, measurable, and high-quality environmental outcomes for the impacted resources. Through the planning and project development process, transportation planners seek to avoid conflicts and delays caused by disagreements with regulatory agencies about project impacts and mitigation requirements. For wetlands and endangered species regulation, the literature and the work described in Volume 1 show that insufficient, incomplete, or poor quality data usually are at the root of the problem.

Data Quality Issues: The Clean Water Act

To address wetlands regulators' concerns, the team consulted with state and federal wetland managers to determine what types of regulatory certainty can be provided in states with widely differing quality of wetlands digital data. The team diagramed a workflow with data and tools that integrate the USFWS's nationally available NWI database with a process for refining and augmenting that information to assure the digital data are complete enough for regulators to feel confident that transportation planners can avoid all important wetlands (see Appendix A).

The result of this work was to develop a method for identifying Wetland Mitigation Priority Areas, or a Wetland Restoration and Mitigation Catalog. Such a catalog can then help direct the locations of mitigation banks and allow transportation agencies to expedite approval of mitigation options. The team also evaluated other aspects of the CWA, particularly those related to water quality, including nonpoint sources, runoff, and total maximum daily loads (TMDLs); however, the team's work in this area was limited to potential (secondary) improvements to water quality from wetlands restoration and enhancement.

Data Quality Issues: The Endangered Species Act

Most information on listed species locations currently exists in the form of observations, rather than habitat or predicted distributions. Rare species occurrences are highly sensitive and, as a result, not readily shared with transportation agencies or the public. The project tested the possibility of transforming these highly sensitive maps showing precise known locations of federally listed species into slightly more generalized, public domain maps showing places where these species are likely to occur or where their habitat needs to be protected using inductive modeling methods.

Ecosystem Services Accounting and Crediting

More than 120 methods of accounting for and valuing ecosystem services were reviewed in terms of principles and criteria developed for transportation and conservation planning. No single method emerged as a readily available option for use in transportation planning and project delivery given the wide variety of resource types and ecosystems. To respond to this lack of a single tool, the project developed a step-by-step process for use by any transportation agency to self-diagnose needs, identify candidate tools, and develop custom tools if needed. The accounting strategy, and a first iteration of credit design, was tested with the pilot study agencies through a series of interviews in which participants were led through a focused discussion of the assumptions and structure of the proposed credit design. The accounting methods are included in the Framework, and the methods are included in the TCAPP website.

Pilot Projects

The team tested the technical guidance to see if using this new approach to assessing an area for project development would result in different decisions and outcomes, significant savings in time or funding, or additional refinement of process when compared with traditional methods. The team's pilots focused on testing the technical aspects of an integrated planning process, not on the collaboration building aspects of planning process. The team decided that testing the technical guidance on a transportation project, rather than a transportation plan, would yield a more quantitative and accurate comparison of these methods because a transportation project generally is more detailed and spatially explicit than a plan. But in two of the pilot states (Michigan and Colorado), it was critical to compare the pilot test results with the original results of planning efforts in the area to adequately test the guidance geared toward improving planning-level decisions.

In preparation for conducting the pilot tests, the team developed and documented the approach (see Appendix C) that would be used by all three teams in testing the technical guidance. This document also included the criteria used for selecting the projects or areas where the team would conduct the three pilot tests. In the proposal, the team suggested doing pilot testing in Florida, Oregon, and Virginia, but the

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Florida and Virginia DOTs could not participate in the project because of budget constraints. Oregon, Colorado, and Michigan were then selected because the team included staff from these states' agencies and the DOTs were interested in the research.

Initially the team met with key state and federal agency staff from the transportation and natural resource communities in Colorado, Michigan, and Oregon to introduce the initial research results. Using the team's selection criteria and input from the agency participants, the team selected a project in each state to test. The three projects that were selected were the I-25/US-85 project in Colorado, the St. Joseph County section of US-131 project in Michigan, and the Pioneer Mountain—Eddyville project in Oregon.

Symposium

The SHRP 2 C06 Capacity project teams held an invitational symposium on September 15–16, 2010, in Boulder, Colorado. The results of the team's research were presented to a group of 55 local, state, and federal transportation agency and resource agency officials experienced in integrated transportation and conservation planning. Resource agency officials also presented new approaches that they are using to integrate conservation planning and permitting and reflected on lessons they have learned in reference to the Framework. Breakout sessions provided feedback on the Framework and suggestions for implementation actions. These discussions informed the final report, especially the conclusions.

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CHAPTER 2

The Ecological Assessment Process in Transportation Planning

Introduction

The advantages of an ecosystem approach to sustaining and restoring ecological systems and their functions have long been recognized (Brown 2006; U.S. Council on Environmental Quality 1995). Transportation agencies and the FHWA have worked with resource agencies throughout the last 2 decades to use this approach in planning and delivery of new transportation facilities. Unfortunately, it has not been as broadly adopted as it should be, given its benefits for project streamlining and environmental outcomes.

The FHWA Report *Eco-Logical: An Ecosystem Approach to Developing Infrastructure Projects* (*Eco-Logical*) provides the basic framework for using an ecosystem approach in transportation planning and project delivery across individual agency jurisdictions and encourages an outcome-based approach to conservation (Brown 2006). However, *Eco-Logical* does not provide the tools needed to implement these principles. This project fills that gap by providing the tools needed for the ecological approach. Volume 1 identifies existing barriers to adopting the integrated ecosystem approach and opportunities for future implementation, as summarized in Table 2.1.

Volume 1 identifies three key scientific and technical barriers to using the *Eco-Logical* approach:

- Lack of integrated and agreed-upon conservation priorities across agencies;
- Lack of accepted data standards and geospatial data and lack of access to environmental data and plans; and
- Lack of agreed-upon methods to quantify the impacts of transportation projects on ecosystem functions.

The research addresses these barriers by developing a new Framework supported by enhanced information about regulated resources and improved ecological accounting methods.

Vision for an Integrated System

The vision underpinning this research was to develop a scientifically supported, outcome-based approach that would facilitate efficient and effective transportation planning, regulatory decision making, and capacity development while maximizing opportunities for the long-term conservation and enhancement of ecosystem functions at multiple scales.

The team envisioned an ecological assessment and crediting approach that would: (1) Provide transportation agencies the toolkit they need to collaborate with resource agencies, local governments, nongovernmental organizations (NGOs), and others to simultaneously meet conservation and transportation goals and priorities during the decision-making process; (2) Provide the data and tools needed to develop environmental regulatory assurances that resource and regulatory agencies and transportation agencies can use to make earlier decisions and investments in the transportation planning and project delivery process; and (3) Integrate regulatory compliance within and across agencies.

The team envisioned a specific, yet flexible, approach that could be customized and embraced by transportation and resource agencies and would result in sustained institutional change that encourages transportation agencies to adopt environmental stewardship policies enhancing ecosystem and hydrologic functions and maximizing the benefits of their investments.

The approach focused on regional ecological priorities, multiresource ecosystem measurement and accounting systems, and achieving improved, measurable environmental outcomes. It is linked to the key decision points in TCAPP's Decision Guide through guidance relevant to environmental regulatory compliance processes that identify policy questions; data development and management needs; analytic tools; case studies and best practices; and references. It is scalable, flexible, regionalized, and compelling to agencies,

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Table 2.1. Barriers and Opportunities

Barriers	Opportunities
Inability to access other agency and nongovernmental organization (NGO) environmental data and plans	New tools for publishing data and harvesting data from other agencies and organizations.
Lack of integrated and agreed-upon conservation priorities across agencies	New methods for integrating conservation priorities in the Great Lakes, Chesapeake Bay, the Willamette Valley, Oregon, Virginia, and Colorado.
Lack of local, regional, and national geospatial data for environmental data and plans	Potential for new standards and funding to develop regional and national environmental data.
Inability of transportation and regulatory agencies to agree on the scientific validity and adequacy of planning level analysis in providing regulatory predictability at the permitting stage	New models for predicting the locations of listed threatened and endangered species with capacity to expand these nationwide. New spatial data, tools, and knowledge to map wetlands and identify wetland priorities. New models for identifying potential water quality implications for road development projects very early in the planning process.
Ability to quantify the anticipated impacts of transportation projects	New decisions support tools to look at cumulative impacts of developing in watersheds or ecoregions.
Lack of agreed-upon measures to quantify ecosystem functions important to transportation planning and development	Environmental Protection Agency Ecosystem Services Partnership, USDA Office of Ecosystem Services and Markets, and programs such as the Natural Capitol Project, the Bay Bank, and the Willamette Partnership interested in developing measures. Scientific interest in developing pilot models and algorithms for attributing areas with these values.
Lack of transparent and integrated scientific peer review of metrics, methods, and protocols	Ecosystem Commons peer review process drawing upon university and agency research capacity.

regardless of their experience with environmental management systems. Finally, it is designed to maximize the likelihood of beneficial environmental outcomes from all stages of transportation planning and project development.

The team's approach strives for expedited transportation development, cross-agency understanding, and incorporation of conservation goals and priorities early in the transportation decision-making process, reduced legal challenges and costs, and sustainable and systematic ecosystem restoration and mitigation outcomes.

The Need for Integrated Conservation and Transportation Planning

The key objective of this research is to develop a workable ecological assessment method that can and will be used by transportation planners working in diverse physical environments with varying existing data availability. Although there is a large body of research on all of the themes, this project focuses on the integration between the existing models, tools, and processes needed to use them effectively in transportation decision making from long-range planning through project permitting.

Since passage of the NEPA in 1969, transportation agencies developing projects with federal funds have been required to consider the impacts of their projects on the environment. New transportation facilities must also meet the requirements of dozens of other federal, state, and local environmental and land use regulatory requirements (Bearden and Luther 2003; Dale et al. 2000; Phelan and Phelan 2007). Two key issues developed as transportation agencies implemented these regulatory requirements for new capacity projects: (1) determining when in the transportation planning and project development process to prepare required environmental analyses and apply for permits; and (2) determining how to avoid duplication of effort and inconsistent requirements under different laws and regulations.

Traditionally, environmental resource and permitting agencies have little involvement in the transportation planning process when alternatives are developed and compared; instead, such agencies wait until a specific project solution has been selected before becoming involved. As a result, planning decisions are often questioned and revisited in the NEPA process and in project permitting, which delays delivery and adds cost. This problem was recognized as early as 1975 by the National Cooperative Highway Research Program (NCHRP) (Manheim et al. 1975). The 1975 NCHRP report also recognized the disconnection between the level of data analysis and impact predictions at the systems-level planning stage versus the project development stage.

At the heart of the suggested reforms is the idea that an environmental review process that runs concurrently with or at least overlaps with transportation agency planning processes

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would increase efficiency and provide better information for planning and less litigation as a result of greater opportunities for public participation (Tripp and Alley 2003). The former head of the Council on Environmental Quality, James L. Connaughton, strongly supported this approach, noting the need to share documentation and maintain databases of information from prior environmental reviews (Connaughton 2003). Such an integrated approach is expected to move beyond traditional approaches of avoiding, minimizing, and mitigating impacts of transportation projects to use ecosystem approaches to provide environmental benefits and promote ecosystem sustainability (Brown 2006).

Amekudzi and Meyer (2005), in NCHRP Report 541, surveyed state transportation agencies and metropolitan planning agencies to assess how they consider environmental factors in their system planning. Survey respondents indicated that only some of the data types needed for considering environmental factors in transportation planning were available. Respondents also noted a lack of appropriate planning analysis tools. Reviewing the various types of tools (geospatial databases, remote sensing, impact modeling, decision analysis, and simulations), the authors concluded that new tools should be able to provide more and better information to decision makers at the planning level to protect environmentally sensitive areas. They developed a conceptual framework of transportation systems planning and project development to show where environmental factors could be incorporated to improve the process, overcoming the past disconnection between the planning and project development stage. The study showed that environmental considerations can be included throughout system planning and project development.

Eco-Logical (Brown 2006), builds on the earlier 1995 interagency Memorandum of Understanding on ecosystem management (U.S. Council on Environmental Quality 1995). *Eco-Logical* presents an integrated planning framework that incorporates an ecosystem approach to environmental mitigation agreements and adaptive management through performance measures. The team's research builds from *Eco-Logical* to provide the scientific and technical procedures and methods needed to support use of the new integrated Framework.

Cumulative Effects Assessment and Alternatives

The CEAA process is tightly coupled with and fully integrated into nearly all steps of the Framework. The CEAA provides a hierarchy of steps for implementing relevant components of the Framework. They are further supported by: (1) literature citations providing references to peer reviewed and other works for additional reading on the steps; (2) case studies and examples from real-world applications of the concepts to illustrate how they have been accomplished; and (3) tools, focusing on software for spatial modeling and assessment that can be used to streamline the application of the steps in a GIS.

The CEAA steps are described in the Framework (see Chapter 3) and further described in the online database (see Chapter 5). A brief description of the key processes and products of the CEAA is provided below along with a discussion of challenges and suggestions for successful implementation.

CEAA Goal and Products

The goal of the CEAA is to support all types of transportation and land use planning by conducting thorough ecological cumulative effects assessment and development of alternatives that reduce resource impacts and assist in achieving regional conservation goals. The key products for achieving these objectives are:

1. Regional Ecosystem Framework (REF) consisting of:
   a. A database of viability requirements and responses to a variety of land uses, transportation features, and other disturbances as well as conservation practices for each resource or priority conservation area, and
   b. A map that synthesizes existing achieved conservation areas and identified, but not yet achieved, conservation priority areas from accepted sources. The map can be supplemented as needed with individual resource distribution maps to provide complete coverage of the list of resources.
2. Transportation alternatives assessment and refinement consisting of:
   a. Quantitative assessment of the impacts of alternatives individually and cumulatively with other land use and conservation actions and
   b. Support for developing alternatives that meet both transportation and conservation objectives.
3. Mitigation support consisting of:
   a. Quantification of resource impacts for all alternatives and
   b. Identification of compensation sites that can provide for the required mitigation and provide the greatest contribution to regional ecosystem objectives.
4. Adaptive planning and management consisting of:
   a. A partnership structure for dynamic information sharing and
   b. A technical approach for integrating new resource information and status with project development decisions for dynamic updating of the status of conservation objectives.

Intended Applicability of the CEAA Process

Recent advances in data quality and decision support systems and computing power enable NEPA-level assessment at all

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stages of the transportation planning and design process when transportation improvements can be characterized spatially (whether coarsely or at fine scales). This process should be applicable to long-range transportation plans (LRTPs), corridor plans, and project design. The team's emphasis and intended application is LRTP in keeping with study objectives for moving resource consideration and mitigation planning to the long-range planning phase, as opposed to putting it off until project design. The team thinks this technical guidance is applicable for all DOTs and their MPO partners, but acknowledges that many agencies, especially many smaller MPOs and many state resource agencies, currently lack the capacity to implement the template in its ideal form.

Relationship to NEPA

This technical guidance will provide support for creating environmental assessments (EAs) and environmental impact statements (EISs) consistent with guidance for a tiered EIS process developed by the FHWA through their Legal Guidance on Integration of Planning and NEPA Processes (U.S. Department of Transportation and FHWA 2005). The team's process seeks to move analysis traditionally conducted at the project phase of the transportation development process to the planning phase to streamline project delivery by identifying and mitigating expected impacts much sooner. This CEAA process provides several outputs useful for NEPA processes and products. First, it identifies environmental resources and environmentally sensitive areas, existing natural resource conservation areas, and the outputs of natural resource planning efforts. It also explicitly and quantitatively conducts cumulative effects assessments for plan alternatives by incorporating all reasonably foreseeable actions in the area, such as regional and local growth and development plans and projections and other cumulative effects factors. The guidance assumes that analyses of environmental effects at the planning stage will not be sufficiently current or detailed for NEPA, but fully implementing the CEAA steps can produce sufficient analyses if desired. The CEAA process also supports decisions and documentation for eliminating alternatives and generating plan alternatives to avoid impacts as much as practicable. It enables assessment results and comments to be used to create a preferred alternative, quantify impacts, and if necessary, mitigate resource impacts.

Scale

This process is meant to be applied at any scale ranging from states and ecoregions to municipalities and corridors. Differences in scale suggest differences in information sources and levels of precision (e.g., data covering large regions is often coarser). Therefore, expectations for the level of precision of products from the spatial analyses should be consistent with the level of precision of the data inputs. In other words, expectations/needs for precision of results should be lower for larger regions compared with smaller corridor/MPO analyses. However, the advent of species distribution modeling, as described in Appendix B, and robust desktop computation capability are reducing the extent/precision effect and creating data that are applicable at multiple scales across broad extents. This does not eliminate the need for on-the-ground observation for project permitting but should narrow the scope of site surveys to the resources that have reasonable probability of occurring on the site.

Partnership Coordination

Because an REF by definition is a synthesis of the work of many contributors, many organizations should be involved in deciding how to create it. However, it is unlikely that the REF will be created and maintained without strong central coordination. The role of the coordinator is to identify the key sources of information and science needed to build and maintain the REF and to engage the responsible organizations in the REF partnership. Because the REF is developed initially for the transportation planning process (to be useful in many applications), it may be appropriate for an MPO or DOT to take the lead role. However, it may be more appropriate for a resource agency, such as the state wildlife action plan (SWAP) coordinator, to assume the lead role because of the REF focus on natural resources. Leadership and partner roles in conducting the CEAA, especially the creation and maintenance of the REF, generated considerable discussion at the C06 Symposium. Several participants suggested that larger MPOs would have the strongest motivation and coordination capability.

Regional Ecosystem Framework Guidance

This component of the CEAA process was drawn directly from *Eco-Logical.* It was described there as: "An REF consists of an overlay of maps of agencies' individual plans, accompanied by descriptions of conservation goals in the defined region" (Brown 2006). This definition could result in an incongruous product, by trying to combine both conservation and development plans and goals. For clarity, the REF is defined here as a spatial and nonspatial database of resources and scenarios with planning objectives and conservation criteria. The REF contains the spatial distribution of information that characterizes:

1. Current actual development, established conservation area, and their attributes.
2. The conservation priority areas of the resource partners (e.g., resource agencies and NGOs) with attributes that

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specify the individual resource (e.g., species) contained in those priority areas, individual resource distributions, and their conservation goals and requirements.
3. The development plans for action agencies (transportation and other infrastructure and land use agencies). These tend to be less certain and more dynamic given shifting agency and societal objectives and available implementation funding.

Resources the partnership considers important to represent in the REF may need to be represented by individual resource distribution maps, rather than encompassed in priority area maps. The resources component of the REF should be as objective as possible, based on quality mapping and robust scientific processes involving subject matter experts (SMEs) for the required resources. The REF process the team has developed keeps the three components (current situation, conservation priorities, and planned development) separate and intersects them when a cumulative effects assessment is needed to support decision making.

Limitations and Challenges in Using the CEAA Process

As with most innovations and activities requiring broad partnerships, the key challenges to adoption tend to be institutional, political, and financial rather than technical. Those issues are addressed in Volume 1. This volume focuses on the technical and scientific limitations and challenges of the CEAA and provides suggestions for overcoming them.

Data Availability and Quality

Lack of quality data is becoming less and less of an excuse for not doing good resource assessment. Although perfect data will never be achieved, more and better data are available every year. However, the perfect should not be the enemy of the good. The REF partnership process focuses on making the best use of available data while it develops the strategy and funding mechanisms to obtain better data. Frequently, the data from conservation NGOs is overlooked, but it may represent some of the best available information. Two specific data content and quality challenges are: (1) the scale and spatial specificity of SWAPs and (2) the lack of coverage for some important resources in conservation plans. The team's suggested solutions to these challenges follow.

The SWAP should be a key component of the REF. Sometimes SWAPs are nonspatial or too coarse to support transportation planning. As of this writing, most states seem dedicated to mapping priority areas for their SWAP and increasing the spatial resolution to support implementation. Other plans may exist to fill this role wholly or partially in the interim, such as work by large national or regional conservation NGOs and some natural heritage programs. When no conservation priority area plans exist at the needed level of resolution, the partnership should decide if it will be more efficient to downscale existing coarse-scale plans or create an interim product from existing data on individual resources. The SWAP and other partners' plans can still provide important guidance on the resources to be considered, resource priorities, general areas of conservation importance, and perhaps even resource retention goals. To create a more resolved spatial-priorities map, an alternative is to identify natural vegetation areas containing important resources by using existing high-resolution, natural landcover and habitat maps, such as those produced by the U.S. Geological Survey (USGS) Gap Analysis Program (U.S. Geological Survey 2012), with other natural resource data, such as the natural heritage program occurrences of imperiled species and ecological communities and state resource agency maps of important game species habitat.

Conservation priority areas do not cover some important resources and maps, for such resources often are based on incomplete observation points, in part because many SWAPs do not address plant species and many species distribution maps exist only as point observations. Techniques described here that address the omission of resources in conservation priority maps can also address this problem. Predictive distribution models can be used when there is a lack of complete geographic distribution maps for individual resources. The USGS Gap Analysis Projects produced moderate confidence models for most terrestrial and aquatic vertebrate species and some developed models for other species. Other projects in states or regions may have produced other higher confidence models for particular species. The REF program/partners may also be able to use contemporary tools and methods to create the necessary models that are achievable with much less effort than in the past, as discussed later.

Science and Subject Matter Experts

As with data, science is imperfect and incomplete. Few species have been studied sufficiently to provide empirical values for viability (e.g., retention goals, minimum required occurrence sizes), which form the basis in the CEAA for determining cumulative impacts. Thus, the team's process must rely on SME judgment. This reliance on expert judgment can present defensibility issues in the planning process even though it is frequently accepted in other resource planning processes subject to NEPA. SMEs need to be accepted by the partnership. They often are found in government agencies, academia, and NGOs and other organizations outside those providing plan inputs to the REF. U.S. Environmental Protection Agency NEPA guidance describes cooperating agency roles related to their

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expertise in the environmental issues being addressed (U.S. EPA, 2012b). The team followed this accepted approach but moved it forward into the spatial analytical age by including quantitative values for viability assessment. The NGO conservation community has been using this approach for many years. Sources for additional guidance are found in the CEAA online resource links. Although a fair amount of uncertainty around quantitative values exists and should be documented, the team thinks this approach provides more rigor and defensibility than typical approaches for conducting assessments at the planning level and likely also for project level assessments.

In the near term, the REF partnership needs to agree on the degree of scientific rigor acceptable for the REF applications. It may be reasonable to conclude that the bar for planning should be lower than for project assessment (full NEPA process), for which the number of considerations is fewer and more precise information can be collected and more rigorously analyzed. The objective is to provide a far better and more precise assessment at the planning phase than has been done in the past while not hamstringing it with impracticable requirements. Education of partners and stakeholders in the use and value of SME judgment will be needed to achieve the objectives of streamlining project delivery by moving considerations to the planning phase. Uncertainty in scientific knowledge also should contribute to agreements about triggers for additional analyses at the project phase. The partnership should agree on acceptable sources of scientific information and develop mid-term and long-term scientific research needs assessments and strategies to fill critical gaps.

Technical

Many of the technical challenges and limitations of the past have been overcome with improved computing power and creation of decision support tools to automate a considerable amount of the CEAA process. But technical challenges remain. Three are addressed here.

- Creating robust analyses understandable to decision makers and stakeholders: With the availability of more and better data and robust spatial analyses techniques and tools, analyses and products are becoming highly complex and more difficult to describe and explain. The team suggests a hierarchical form to the CEAA process products that starts with the binary presentation of "problem/not a problem" and then allows users to drill down through the information to additional detail, as needed. For example, a result from a cumulative effects assessment may indicate an incompatibility between a resource and a proposed action (there is a problem). Additional investigation may reveal the resource is not legally protected, but the action would prevent achieving the resource retention goal. Identification of the specific resource and the amount of area affected can then help identify possible on-site or off-site mitigation options that could be pursued with interested REF partners.
- Integrating and maintaining information from distributed sources: This can be a particular challenge for obtaining, integrating, and managing expert input on the resources. Such experts usually are distributed among many organizations and over wide geographic areas. Creation of a simple online location where their information can be entered and accessed can ease the burden on everyone for information collection and management. Using this approach makes everyone's information reusable for multiple applications.
- Integrating dynamic processes and information: Dynamic data can include data that are updated frequently or represent dynamic phenomena. Climate change study and modeling are increasing and beginning to produce large amounts of such data, which can affect the REF (species/ecosystem change and migration) and assessment of additional important resource stressors. The REF partnership should explicitly address what information should be included and how it should be used in updates to the REF and assessment.

Suggestions for Low-Capacity Agencies

Ideally, transportation planning processes will build the necessary partnerships and funding needed to conduct the CEAA process, ongoing updates, and adaptive management. If the transportation agency and REF partners lack capacity to implement the process, it is possible to use a significantly scaled back approach that can rely on SME involvement or be automated through a statewide system (existing or under development in a growing number of states). However, for the long term, scaled back processes ultimately may require more staff time if important elements are missed initially and may produce less reliable or defensible results. This approach also loses the opportunity to gather expert knowledge in a reusable database to apply to other plans and projects in the region.

An alternative process to that described in the CEAA process in its most minimal form entails overlaying (graphically with hard copies or through a GIS) proposed LRTP alternatives with the SWAP and or other spatial conservation priority maps for the resources of interest. Areas of potential conflict would be identified graphically, and SMEs would identify resources that might be affected and make an expert judgment about the significance of the impact and options for mitigation.

This approach currently is common in project assessments, and such functionality is supported through tools such as Florida's Efficient Transportation Decision Making (ETDM) online system for project evaluation (Florida Department of

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Transportation 2011). States could replicate this capability to assist low-capacity transportation organizations by providing a system that would contain all of the necessary resource layers and the capability to overlay maps. The only technical requirement for the transportation agency would be to provide their LRTP to the state system for assessment. This alternative approach would accomplish the rudimentary need for comparing the LRTP to the resources, but it falls far short of the suggested process in terms of ability to quantify cumulative effects and support a full cycle of LRTP option development, assessment, selection, mitigation, and implementation.

The lack of resource agency capacity can be mitigated somewhat by involving science-based NGOs, but in the long run, more capacity for resource agencies to routinely engage with transportation planning activities will be required for integrated conservation and transportation planning to succeed. This will require internal capacity building and training in methods and tools.

Regulatory Assurances

Addressing regulators' needs is an essential part of the decision-making process for all transportation projects. Although obtaining complete regulatory assurances may be impossible, the team focused on identifying the aspects of current decision making that provided the greatest concern for regulators at the national, regional, state, and local levels and then developing tools or information to address these concerns. Based on the research, the team thinks that, particularly for wetlands and endangered species, regulatory conflicts and delays result primarily from transportation planners and regulators having insufficient, incomplete, or poor-quality data. Transportation practitioners seek methods for identifying potential impacts to regulated resources as early as possible in the planning process so that impacts can be avoided or minimized. They also share the desire of regulatory agencies to assure that any mitigation required because of unavoidable impacts provides effective, measurable, and high-quality environmental outcomes for the affected resources.

The keys to success identified and addressed in Volume 1 are to: (1) Use the best data that can be obtained or collected early in the planning process; (2) Stay in touch with regulators—contact them early and often throughout planning and implementation; (3) Take advantage of existing conservation planning work completed by federal agencies, state agencies, universities, and conservation organizations; and (4) Link conservation planning with regulatory protection work but understand that regulators must focus on their specific resource of interest. The team developed new strategies for data integration and modeling that can be used in the CEAA process to improve the likelihood of obtaining regulatory assurances throughout the transportation planning and project delivery process.

Improving Wetlands Data

Section 404 of the CWA is the key national regulatory mechanism to assure wetlands are not lost. The program is also the primary mechanism used to replace lost aquatic functions. In a 2007 report, the Environmental Law Institute (ELI) estimated that private and public expenditures for compensatory mitigation under Section 404 of the CWA is about $2.9 billion annually (ELI 2007). These funds represent more than three quarters of all natural resources mitigation expenditures nationally and constitute the primary source of funds for restoring wetlands and watersheds across the nation.

Some progress has been made in restoring and compensating for the loss of aquatic functions, but to date much of the implemented mitigation has not led to the creation, restoration, or conservation of important wetland habitats, resulting in a system that does not completely avoid losses and that is largely unable to be proactive (Gardner et al. 2009). The current system also lacks sufficient emphasis on avoiding or minimizing project impacts. Some of these inefficiencies stem from a lack of practically accessible data, which regulators would consider sufficient for the proactive analysis and early commitments that could maximize DOT investments in conservation or restoration of significant areas, to help achieve watershed goals. Later decision making and suboptimal mitigation outcomes result when resource agencies can most effectively consider the resources in question since early in the process key information may be absent.

Major concerns of wetland regulators include:

- Assuring the most significant or vulnerable wetlands are protected.
- Being confident that the locations of most significant wetlands are known in advance so that they can be avoided if possible; and impacts are minimized if unavoidable.
- Assuring that high-quality and appropriate wetlands information is used in assessment tools.
- Having methods for addressing prioritization of sites for mitigation.
- Assuring that mitigation results in high-quality wetlands creation and/or measurable enhancement equivalent to habitat lost.

To address wetlands regulators' concerns, the team consulted with state and federal wetland managers to determine what types of regulatory certainty can be provided in states with widely differing quality of wetlands digital data for purposes of avoidance, impact minimization, and mitigation

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results. The status of wetlands information is quite variable across the country, so the team diagramed a workflow with data and tools for inclusion in the Framework that integrates the USFWS's nationally available NWI database with the process for refining and augmenting that information to assure the digital data are complete enough to improve avoidance, minimization, and mitigation outcomes (see Appendix A).

Improving Wetlands Data for Avoidance and Planning

The primary need is to improve the quality of wetlands data by improving its spatial accuracy, currency, and content for avoidance and planning. The team studied how to develop wetlands data in states without high-quality wetlands digital data and developed a practical and efficient process for refining and augmenting USFWS NWI and other national databases to express wetland type, status, ecological integrity, and biodiversity value. Specifically, the team developed methods to accelerate digitizing wetland maps and create wetland mitigation and restoration catalogs. In July 2009, the Federal Geographic Data Committee (FGDC) endorsed a new wetlands mapping standard for the United States, which provided standard mapping protocols for wetlands (U.S. Environmental Protection Agency 2007). Any major data improvements provide the opportunity to assure that the new FGDC national wetlands mapping standard is applied to these data.

Currently, the national information for wetlands is maintained in the USFWS NWI. The NWI represents a major investment of the U.S. government, yet it remains incomplete and underfunded. Figure 2.1 shows the status of national wetlands data in the United States from the NWI annual status report.

According to the NWI, approximately 80% of the United States has digital wetlands data available. In addition to 20% of the country having no digital data, much of the existing digital data are based on wetlands that were mapped from imagery obtained in the 1980s. This means the data may be significantly out of date. Whether or not the data are out of date is largely immaterial because the perception that the data are neither comprehensive nor reliable prevents transportation agencies from obtaining any type of assurances that by using these data early in the planning process they are actually avoiding and minimizing potential impacts.

A major barrier to improving these data is the cost to digitize the remaining paper maps, incorporate scanned maps, update the NWI using current standard methodologies, and develop new digital data in areas such as Utah, southern Montana, and Alaska, where no old paper NWI maps exist.

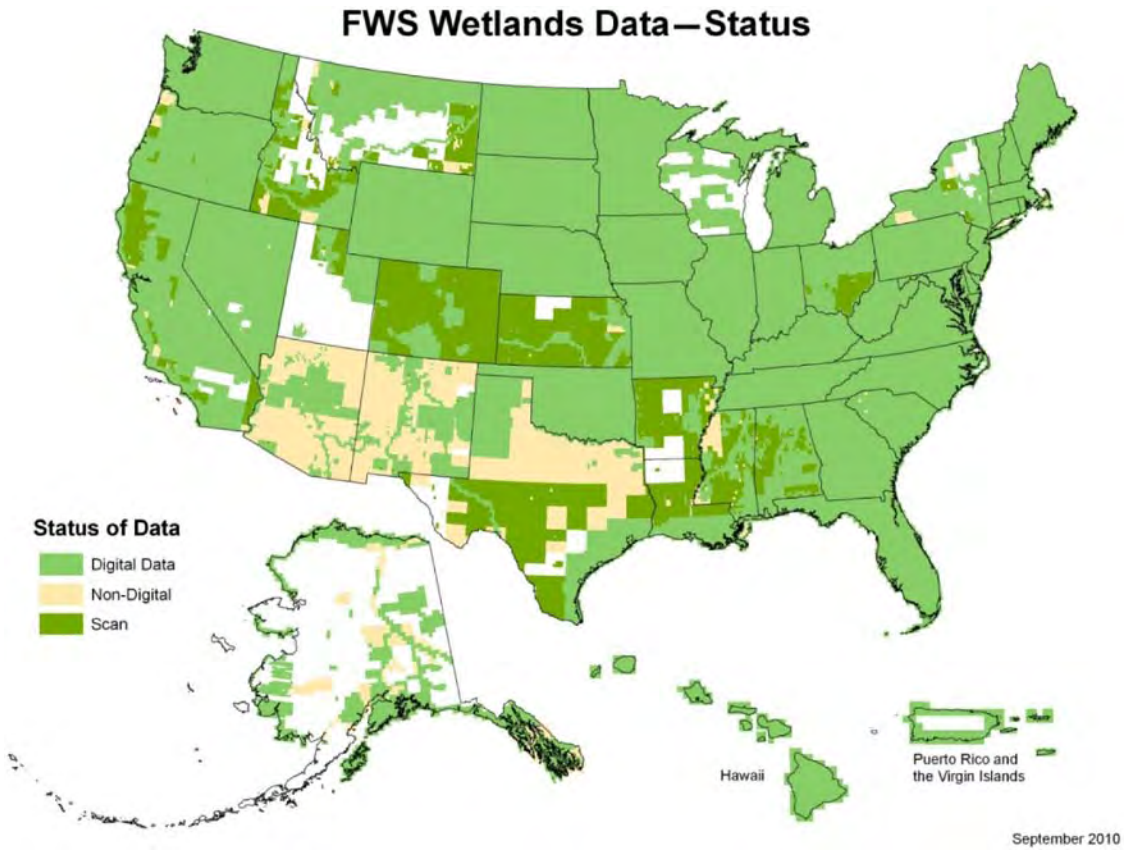

Figure 2.1. Status of digital wetlands data for the United States in 2010 in the NWI.

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The EPA has been working in Montana, Colorado, Oregon, and California, through state wetlands program development grants, to improve this information. However, the current estimates to update and complete these maps by the state wetland regulatory agencies average between $1.5 and 2 million per state. The team developed methods for producing integrated wetlands maps for less money that can be used by transportation agencies working with wetland regulators.

Oregon provides a helpful example of what can be done. Until 2005, only about 20% of the state data were available digitally. Figure 2.2 shows the distribution of digital data in Oregon as of 2006 in red, with the red along the border with California, Washington, Nevada, and Idaho coming from the adjacent states. Although the overall costs to complete digitizing and updating were estimated at $1.5 million, a partnership of agencies, including the Oregon Geospatial Enterprise Office in the Department of Administrative Services, the Oregon Watershed Enhancement Board, and Oregon State University, decided that digital wetlands coverage was essential and took on the task of scanning and updating the available data.

After an investment of approximately $300,000, including $170,000 provided to the GIS Mapping Center at the Oregon Prison Industries, and $130,000 to the Oregon Natural Heritage Information Center through a grant from EPA and the Murdock Charitable Trust, data of the entire state now are available digitally. Figure 2.3 shows the current status of the state.

This case study is included because having the wetlands digital data is such a critical component of the proposed methodology, and it demonstrates that obtaining these data can be developed quickly and somewhat affordably. Providing the data digitally allows transportation agencies to use the data in long-term planning and supports creation of wetland mitigation and restoration catalogs. If transportation planners do not know where the wetlands are, the wetlands cannot be avoided and impacts cannot be mitigated.

Michigan Case Study: Wetland Functions

A consortium of partners led by Ducks Unlimited has been working to update the Michigan NWI data, which were statewide but somewhat out of date and limited to basic NWI data. The consortium's methodology involves using spatial data, modeling, and some imagery analysis to attempt to develop functional attributes for all of the wetlands in the state. The functional data provide valuable information that can assist in identifying the importance of the wetland and the value of the wetlands for mitigation and restoration. The data were used in the Michigan St. Joseph Watershed Pilot to test the overall transportation planning methodology proposed in the team's research (see Appendix C, Michigan Pilot Project Report).

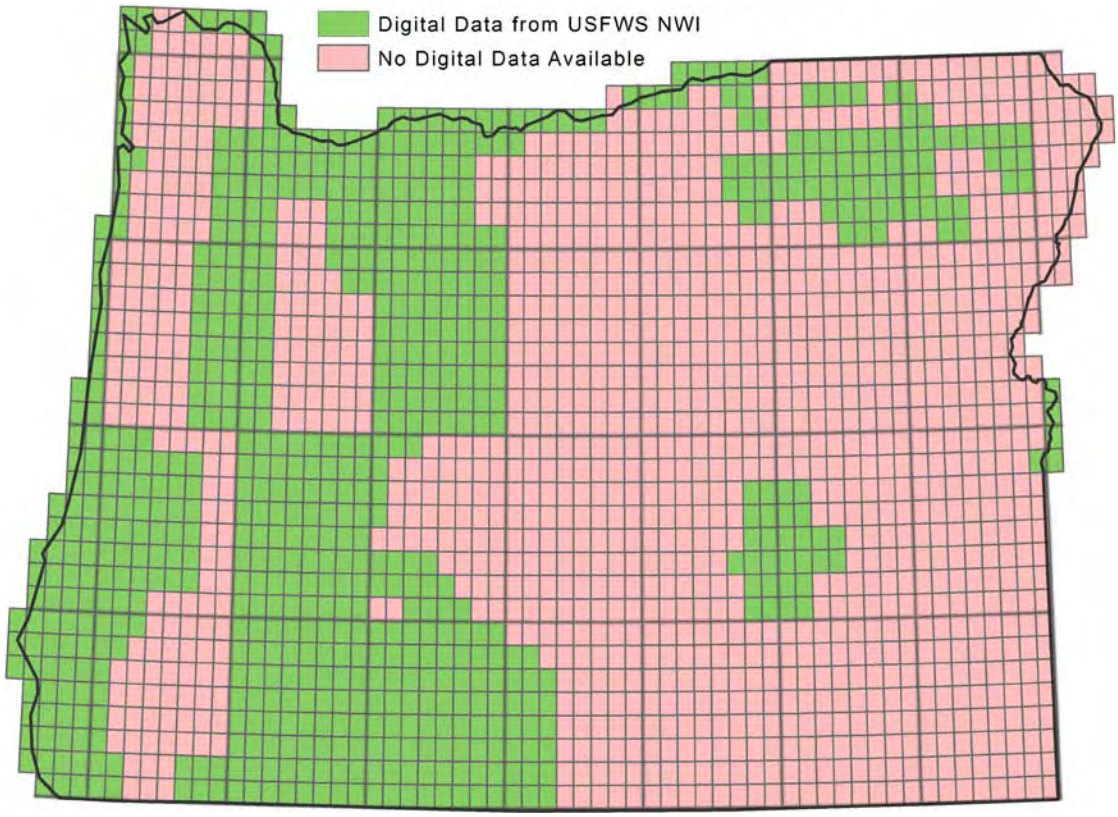

Figure 2.2. Status of digital wetlands data in Oregon in 2006.

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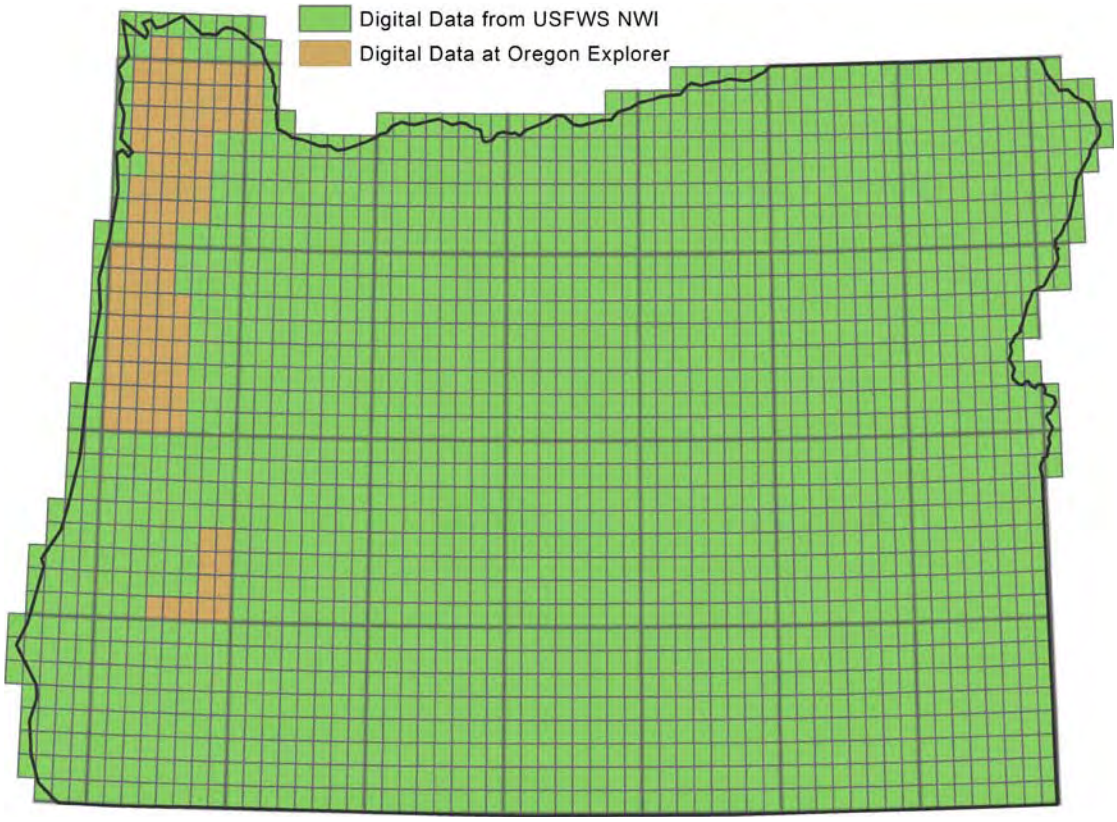

Figure 2.3. Status of digital wetlands data in Oregon in 2010.

This approach helps address the need for statewide and comprehensive functional wetlands data. Wetlands functions are difficult to measure, but if regulators can agree on acceptable information and it can be obtained, it can improve the quality of the wetlands data and the ability to compare changes to wetlands over time, and potentially can improve mitigation implementation by addressing wetland mitigation ratios. Developing this type of data is more expensive (costing approximately $2 million to complete the state) than the simpler methods already described for Oregon or those described in this work for Virginia.

Based on the current national status map in Figure 2.1, most of the wetlands mapping remaining is needed for the western states, primarily Utah, Colorado, Montana, Texas, Idaho, Arizona, and New Mexico. The blank areas in Wisconsin represent an area where the state's maps differ from the USFWS NWI, but high-quality digital data are available. The Natural Heritage Programs in Colorado, New Mexico, and Montana are working to complete the mapping and digitization of wetlands in these states using wetlands program development grants from EPA but are 4–6 years from completion. Idaho Heritage worked at this for a while but has stopped. There are no ongoing efforts to complete the mapping in Utah, Texas, or Arizona, and in these states, a federal agency, NGO, or program from another state may need to complete the mapping. Once digital data are available nationally, the country has the potential to identify mitigation priority sites or create a mitigation and restoration catalog for all states, with sites located in each watershed. This would significantly improve the integration of conservation and transportation planning across the nation.

Improving Mitigation Implementation and Outcomes

The inability to implement mitigation for unavoidable wetland losses is probably the greatest obstacle to transportation project development in the many wetland-rich areas of the country. The team's research indicates the best way to overcome this obstacle is to identify a relatively comprehensive set of mitigation priority sites, a mitigation and restoration catalog. These priority catalogs need to be completed for all areas where transportation development is likely and include at least one and, if possible, a few sites located in each watershed. Some states are working to develop comprehensive catalogs, and these pilot methodologies are described here. If transportation and resource agencies can reach agreement in advance on watershed specific mitigation sites, it should accelerate permitting for projects in that watershed.

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Oregon Pilot Wetlands Mitigation Catalog

A pilot effort to create a wetlands catalog in the Willamette Valley recently was done quickly and cooperatively with limited public funds. Oregon Heritage worked with The Wetlands Conservancy, a local NGO, to develop a set of priority wetlands based on an integrated REF created by an interagency cooperative effort. Partners worked together to integrate the results of five assessments covering the Willamette Basin, and a series of recovery plans and assessments focused on federally listed species (Baker et al. 2004; Bauer 1980; Floberg et al. 2004; Oregon Department of Fish and Wildlife 2006; The Wetlands Conservancy 2005). This effort did not involve setting conservation goals or gathering new information. It was relatively straightforward and inexpensive, although assuring that all the parties were willing to accept the resulting map took more than 6 months.

The wetlands mitigation catalog in Figure 2.4 was created from this synthesis map by Oregon Heritage Program and Wetlands Conservancy staff selecting the areas in the footprint with potential for wetlands: sites with wetland soils in areas

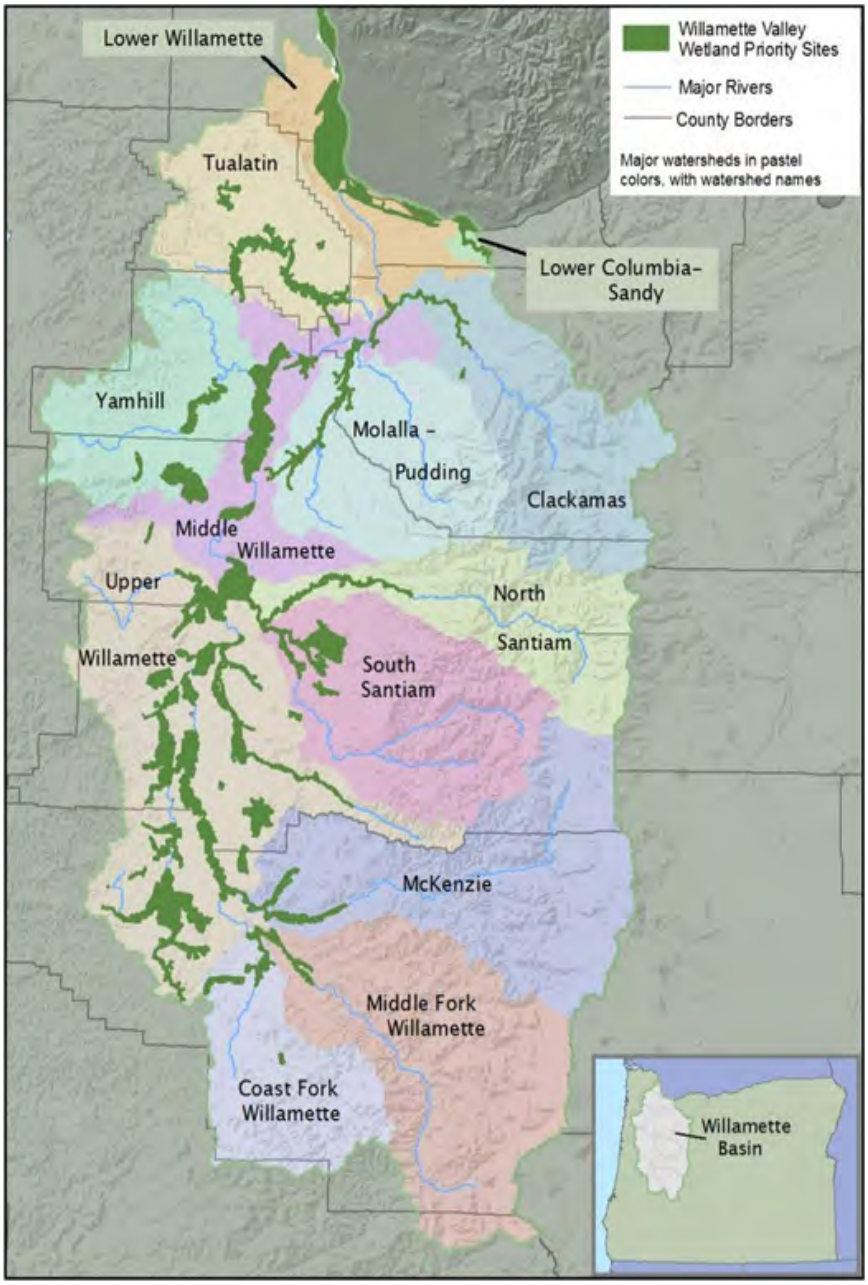

Figure 2.4. Willamette Basin wetlands mitigation and restoration catalog.

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that were farmed, weedy, or otherwise needing restoration; areas with existing wetlands that had become separated by some type of disturbance; or areas with historic wetland losses. Wetlands priority areas were identified in every 8-digit watershed to assure there would be mitigation sites close enough to be considered on-site to any likely development. The resulting map was presented to the state and federal wetland regulators in a meeting as a draft and was modified slightly based on their recommendations. This case represents the quickest and simplest method identified for setting wetland mitigation and conservation priorities and was rapidly accepted by wetland regulators and the conservation community. Because it was accepted so quickly, additional assistance from an EPA Wetlands Program Develop Grant has been obtained to help complete the catalog for the rest of Oregon.

Virginia Pilot Mitigation Catalog

The team was unable to work with the Virginia Department of Transportation on a pilot study site, but was able to test the concept of creating a mitigation catalog to integrate wetland, conservation, and water quality objectives. The Virginia Natural Heritage Program, in the Virginia Department of Conservation and Recreation, had an existing wetland restoration catalog they had developed based on internal conservation priorities. This catalog was limited enough that many watersheds lacked any priority mitigation areas, and the catalog was not used frequently by Virginia DOT or Virginia DEQ. As part of their research, they tested a method to develop wetland priority sites that represented the best places for wetland conservation and the best sites to meet overall water quality restoration needs; they used only spatial data that are most likely available across the country. Their work was tested in an 11-subwatershed pilot area covering the Lower Pamunkey River basin in central Virginia. Data were used to expand existing NWI data to assure that as many existing and historic wetlands as possible were included in the analysis, based on an array of data sets. Details of this methodology are included in Appendix C, Methodology for Developing a Parcel-based Wetland Restoration, Mitigation, and Conservation Catalog: A Virginia Pilot Project. Priority sites were identified with landownership parcels included so that the catalog could be displayed by priority wetland and priority land parcels. The resulting sites were ranked based on their importance for conservation, ability to address water quality needs, adjacency to existing mitigation banks, and restoration potential.

Including Clean Water Act Sections 301, 303, and TMDLs in Catalog Planning

The project team also evaluated other aspects of the CWA compliance, particularly those related to water quality, including nonpoint sources, runoff, and TMDLs. The focus was on the fact that the wetlands restoration or enhancement offers potential (secondary) improvement to water quality in water bodies exceeding water quality standards. Water quality impacts caused by roadway runoff, decreased shading of streams, and increased deposition of nitrogen or phosphorus appear to have data or tools available that could be incorporated into the overall CEAA process.

Initial exploratory work was done with the Natural Capital Project hydrology staff and researchers from the EPA's Western Ecology Division to identify tools and data available to characterize 303(d) attributes spatially. Initially, the project team was unsure if it would be possible to use the Water Quality module of InVEST (the Integrated Valuation of Ecosystem Services and Tradeoffs, a suite of models and software tools under development by the Natural Capital Project, http://www.naturalcapitalproject.org/InVEST.html), but a trial was done as part of this project. EPA is also testing methods that may allow for more rapid assessment and approval of needed mitigation.

The initial focus of the Virginia Wetlands Catalog research had been to directly incorporate water quality data to expand the catalog and evaluate the effectiveness of the various identified sites at addressing identified water quality limitations. Virginia was able to use water quality data to prioritize the catalog but not as a method for selecting priority mitigation sites. In Oregon, the team explored using TMDL and water quality limitations in prioritizing the restoration and mitigation catalog in the Willamette Valley of Oregon. However, in both Oregon and Virginia, the water quality evaluation was completed independently from the wetland catalog development. A potential future area of research is to test methods of developing a catalog of restoration and mitigation opportunities that simultaneously evaluate wetland and water quality attributes.

The Watershed Approach and Other State Efforts

The watershed approach is a method identified in wetlands mitigation rules developed by the U.S. Army Corps of Engineers (USACE) in cooperation with the EPA (ELI 2007; USEPA 2008). Although these rules are relatively general, a number of organizations and localities have undertaken efforts to demonstrate the watershed approach. EPA and USACE staff have tested the approach in central Maryland and believe they can implement it throughout the state. The approach has also been used in watersheds in Delaware, Minnesota, Tennessee, and Montana. The approach is similar to the overall approach developed by the project team, involving collecting spatial data, identifying priorities, and working with partners to determine the most important areas for restoration and conservation.

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The watershed approach has focused on assuring that partnerships are developed with a myriad of local organizations, governments, and the public, which makes this approach relatively easy to implement but more time consuming and expensive to develop. To date, most demonstrations of the watershed approach have been developed locally, with a local government or NGO as the driver of the analysis and implementation.

Assuring comprehensive and readily acceptable mitigation sites are identified and, if possible, preapproved by the regulatory community in any state is a key to gaining early regulatory assurances. Any of the methods tested will meet the goals of the transportation and regulatory community provided they involve an analysis of a relatively comprehensive wetlands data set; some analysis of overall conservation priorities, preferably in an REF; and an identification of mitigation opportunities.

There would be advantages to creating standards for the development of statewide wetland mitigation catalogs, but wetland standards can be difficult, and this would not be critical to obtaining regulatory approval of mitigation banks and priority restoration sites. The fastest and most straightforward method would involve building on existing efforts in the states where these are ongoing and identifying a straightforward method for rapidly creating a statewide catalog in other states based on the Virginia, Oregon, or Maryland work.

Regardless of what method is chosen, moving from existing wetland banks to a system based on priorities is not going to be simple. Grandfathering in existing sites is likely essential. Similarly, methods that rely on wetland functionality to further identify mitigation needs and opportunities will have to be addressed, and permits will still need to be obtained for specific projects based on site-specific impact analysis. The clear obstacle to better transportation and conservation outcomes is the lack of a reasonable and comprehensive set of preapproved mitigation sites that can be used once project-level impacts are agreed upon. As is the case with all issues related to planning and information, the lack of perfect data should not be allowed to stop progress, which is especially important in developing methods and tools used in a regulatory framework.

Improving ESA Data

Most of the uncertainty transportation planners and endangered species regulators face is caused by lack of information on the probable distribution and habitat of these protected species. Although good information exists for known populations, the fear of losing an unknown but potentially important site for a species is a major barrier to many permits. The probable or potential distribution is the most important data to adequately assess impacts and plan for species protection and recovery.

Developing Inductive Species Maps for Federally Listed Species

Most information on listed species locations currently exists in the form of observations, instead of habitat type and predicted distributions. Species occurrence is highly sensitive information and, as a result, is not readily shared with transportation agencies or the public. In addition, observation data are almost always shown and distributed with buffers that reflect the accuracy or certainty of the individual occurrence. As a result, the older, less accurate data show up as large buffers covering large areas, whereas more recent and more accurate data are smaller, with limited buffers. Figure 2.5 shows the federally listed species occurrences from northwestern Oregon and how large the uncertainty buffers are for some older records. The system was designed for project review by regulators but works poorly with electronic decision support tools.

The project team tested the possibility of transforming these highly sensitive maps showing precise known locations of federally listed species into slightly more generalized, public domain maps showing places where these species are likely to occur or where their habitat needs to be protected. This built on the ongoing work in Oregon, New York, Florida, and elsewhere in the Natural Heritage network to develop high-resolution, predictive species maps that do not have the sensitivity of observation data.

The project team met with USFWS Endangered Species staff in Florida, Oregon, and Virginia. Presentations were made on the previously developed models in Florida and Oregon. Models were used to create detailed maps of potentially occupied habitat that would add known occurrences and legally designated critical habitat to create data that could be used in decision support tools and the overall Framework.

These new data are called species distribution maps. The work to date has focused on: (1) working with regulators to determine how to assure the data would achieve the project goals; (2) defining methodology, steps, and costs for developing the data across the country; and (3) addressing issues related to standards, linking the data to the Framework, data security, and data distribution and maintenance. The difference between the traditional incidence and occurrence approach and species distribution maps is illustrated in Figure 2.6.

Using the data from the Natural Heritage network's biotics species observations database and new software for modeling species predictive distributions (DOMAIN, Random Forest, Maximum Entropy), predictive distribution maps of listed threatened and endangered species were developed that better represent where species might be for use in planning new projects. They also can significantly reduce the size of areas requiring potential inventory for endangered species. The models can be used not only to define potentially occupied habitat, but also, most significantly, through probability

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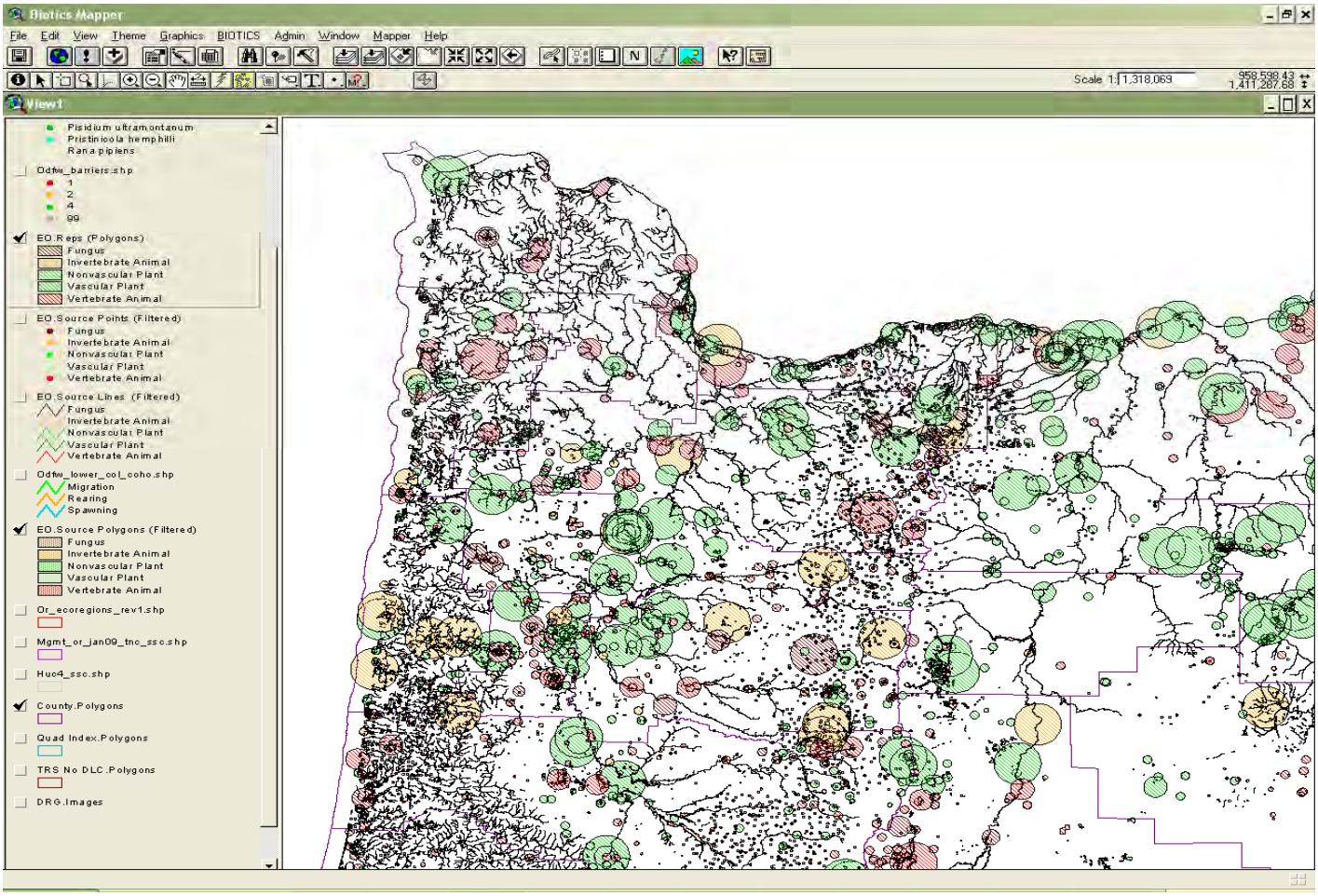
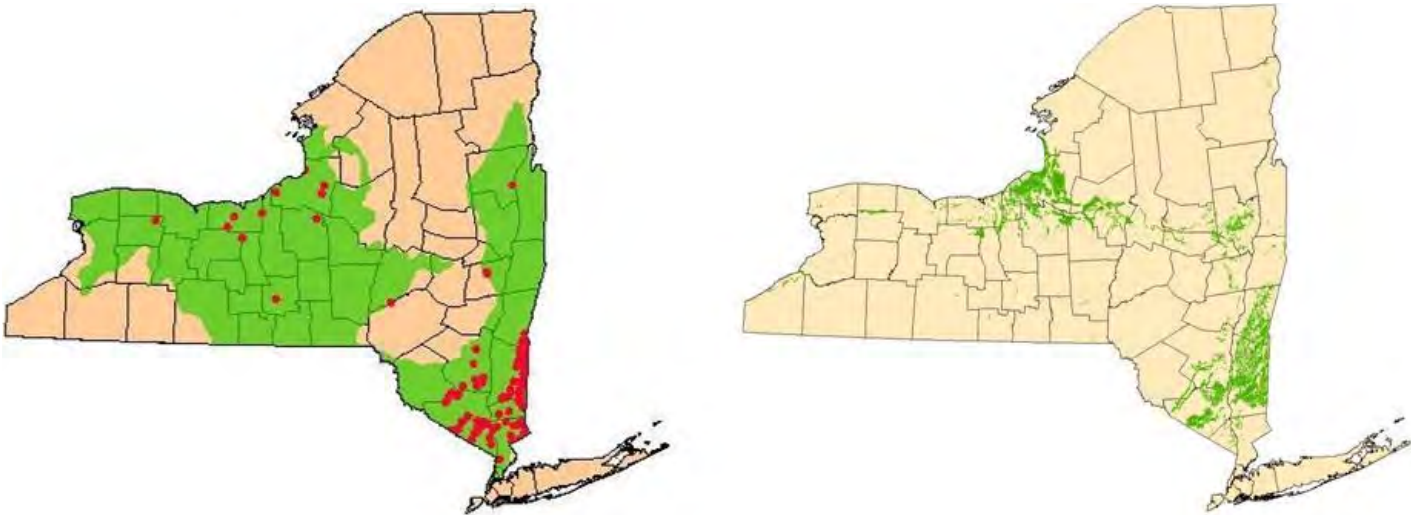


Figure 2.5. Map of federally listed species occurrences in Northwest Oregon.



Note: Maps showing traditional (left) and species (right) distributions of the bog turtle in New York. Red dots indicate occurrences and the green on the left map are the ecological subsections in which they occur. (*Courtesy of NY Natural Heritage Program.*)

Figure 2.6. Comparison of traditional and new distribution maps for the Bog Turtle.

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analyses, areas that are not potential habitat for any listed species. The combination of new data types, such as LiDAR, and increased availability of high-resolution imagery types, such as SPOT and digital color infrared air photographs, along with new image processing types have increased the accuracy and confidence of these models.

Figure 2.7 shows a detail of the bog turtle map, showing how the probability of occurrence can be identified and used to create maps for both Section 7 review and recovery planning. The research team developed a series of detailed methodology questions related to data development and a list of answers from researchers at institutions that have developed these models.

New York made the greatest effort to build at-risk species models using inductive modeling methods, with more than 250 species mapped in the state. Oregon also has done extensive research on inductive models; however, Oregon has completed only 8 species models for listed species and has 15 remaining. Florida is the only state in the United States that has completed models for all listed species, although Florida Natural Areas Inventory (FNAI) would like to update their models to use the new techniques and standards developed by New York and Oregon. Wyoming and Montana have expanded their capacity to create high-resolution maps of species distributions, whereas work is beginning in Colorado, New Mexico, Wisconsin, and elsewhere.

USFWS has been using similar, but simpler, models to derive critical habitat for use in listing species under the ESA or recovery plans. As a result, regulators are familiar with them and understand their potential utility. In addition, USFWS is developing a Section 7 decision support tool that focuses on analyzing impacts based on spatially mapping threats identified in listing and recovery documents and integrating the recommended recovery actions. The current USFWS tool requires distribution information and would be significantly improved by using inductive models. In the transportation planning framework, planners could use inductive models to avoid probable distributions of endangered species and target other (improbable) areas for potential transportation development.

Endangered Species Mitigation

Although ESA mitigation may not be as prevalent as wetland mitigation in transportation implementation, it remains a

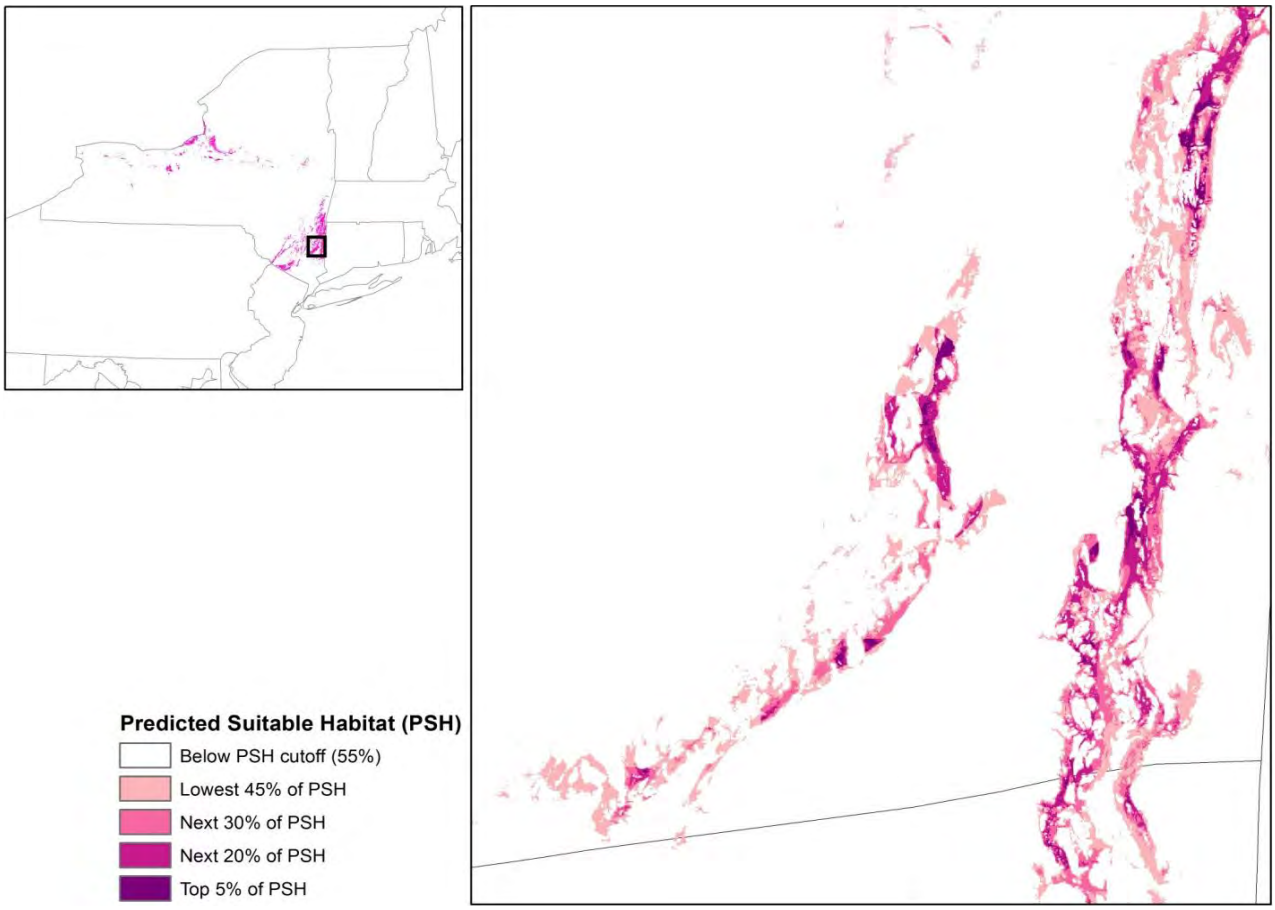

Figure 2.7. Map showing inductive distribution probability for suitable habitat of the threatened bog turtle in New York.

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major focus. A programmatic approach to project planning and implementation is a major goal for ESA implementation by both the USFWS and National Oceanic and Atmospheric Administration (NOAA) Fisheries. Comprehensive species distribution maps based on inductive models will assist in developing and creating priorities for the development of programmatic approaches and avoidance. A completed REF, with information on identified threats and recovery needs for all known or predicted federally listed and proposed species clearly identified, is essential.

Integrated wetlands and ESA mitigation catalogs have been developed for vernal pond species in the central valley of California, in southwestern Oregon, and in south Florida. These examples primarily focused on the needs of listed species that occur in wetland habitats. A number of programmatic efforts focusing on listed fish also have been developed by both NOAA and USFWS. All of these efforts require an analysis of recovery needs and critical habitat. These data currently are not readily available and are another critical information need. Although only NOAA and USFWS can develop these data, integrating available maps and including critical habitat and recovery goals digitally in planning criteria for the REF and transportation plans can be done by state and local agencies. Including this information in the inductive species distribution maps provides the best opportunities for avoidance and agreement on mitigation requirements.

Assuring Planning Data Are Up to Date and Meet Regulatory Requirements

Addressing data distribution infrastructure needs and how the data can best be incorporated into the Framework has yet to be done. The Framework needs to be better developed for this to be done efficiently. The project team will evaluate the Biodiversity Exchange Network, based on EPA's successful Water Quality Exchange Network, as a potential tool for data distribution. To date, the new network is unable to share spatial data. The Utah Natural Heritage Program was funded to develop a functional node with a geo-database. Utah continues to believe they will have a usable methodology.

One of the goals of this research is to assure internal data sharing of newly developed models within the Natural Heritage network and the regulatory agencies and to assure that the models provide regulatory certainty. Another goal remains to assure protocols and software exist to allow programs to provide their data through web services to transportation agencies and other partners. The advantage to providing data through web services is that the primary data manager is electronically and automatically publishing the data for websites to harvest. Data security can be built in, but applications using web services receive constantly updated data. The project team will tailor this ongoing effort to meet the needs of transportation planners and support the CEAA process.

Ecological Accounting

Ecosystem Services and Transportation Planning

The need to better understand society's dependence on natural services and goods has led to the increased study of ecosystem services and the opportunity for ecosystem services to structure new management tools. The ecosystem services literature in the United States dates to Aldo Leopold and conservation biology writers in the early and mid-20th century. Ecosystem services are the goods and services that human communities depend upon for health, safety, and economic prosperity. These goods and services often are grouped into the general categories of provisioning, regulating, cultural, or supporting services (Daily et al. 2009). Provisioning services include more common conceptions of goods from the natural world, such as food, fiber, and fuels. Regulating services include the natural features and functions that protect communities from flood, fires, and storms. Other services that provide us aesthetic, cultural, and recreational values are just as important but often hard to capture. This classification system is opposed by those arguing for a more integrated view of how services interrelate and combine naturally (Fisher et al. 2009).

The use of methods for estimating ecosystem services has been the subject of some debate. One concern is that ecosystem services fail to ensure protection of biodiversity by focusing environmental policy attention on services whose values to humans are more widely understood (Kremen and Ostfeld 2005; Vira and Adams 2009). The concern stems from the way services are defined. Because their value is tied to human use and consumption, it is feared that some natural functions necessary to support biodiversity but lacking a human consumer will be lost or undervalued. Through much of the ecosystem service literature, there is an underlying assumption that if ecosystem services are preserved, biodiversity will be protected. Research on the correlation between services and biodiversity has begun only recently. Some early results suggest that the correlation between ecosystem service provisioning and biodiversity is positive, but it may not be strong in many cases (Benayas et al. 2009; Chan et al. 2006).

A second concern is that many valuations based only on ecosystem services are based on large area analyses that do not directly support local decision making or implementation (Nelson et al. 2009). Some valuation systems rely on large area economic analyses that allow for both a broad scope and set of services to be considered but which are

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difficult to disaggregate to a local level (Costanza et al. 1997). A related argument against ecosystem services providing an economic valuation system is that although they provide an important policy analysis tool, use of these valuations for projects or sites fails to be sensitive enough to measure the difference between small areas of environmental benefit such as one would find in the design of highway infrastructure.

Much of the related literature focuses on valuation methods based on a monetary value. These valuations include replacement value, avoided costs, and contingency or willingness to pay methods (Apogee Research 1996; Kolstad 2000; Wilson and Carpenter 1999). All of these economic methods result in a valuation of services and goods. Framing environmental decision making with this economic-based valuation of ecosystem services allows for decisions to be assessed in the common unit of monetary value. The resulting values also allow for comparison with other nonenvironmental program activities, allowing for a cost comparison between environmental and other expenditures. The challenge for this methodology is that often the economic valuations depend on external economic factors. For example, the value of a natural feature, such as a floodplain, requires a measurement of costs of rebuilding a structure for the floodplain itself to be valued. This scenario leads to a floodplain deep in a wilderness having no value because its ability to protect homes is nonexistent without the presence of human development.

The third challenge to ecosystem service valuation is that species- or service-specific measures lack integration across both the number of services and the areas studied (Nelson et al. 2009). These valuation studies often select a critical service and limit study to a specific area or watershed. Although these studies provide local level data and policy implications, they are limited in how they assess other values in the larger watershed or ecosystem context. The results leave policy makers with no new way to understand trade-offs across the environmental values and across a landscape.

The Problem of Consistent Measures

Conservation planning and regulatory efforts strive to protect communities and the environment from choices that may damage them, intentionally or unintentionally. At the same time, these choices are expected to be limited to as much as is needed—and no more. These goals are classically in conflict in public efforts. Transportation is charged with providing a certain level of infrastructure while safeguarding environmental resources. Outside of the environmental management world, planners and administrators rely on many common measures to gauge progress toward goals and objectives and make new decisions. Job gains and losses are tracked, as are the income of households, the gross domestic product (GDP), unemployment, poverty, and educational attainment. In transportation, the numbers of daily trips and levels of services are assessed.

However, in the environmental realm, it is much more difficult to evaluate how much of a resource or habitat needs to be protected and how well it is being protected. In transportation, we are also challenged to communicate this to the public and elected decision makers. Often we do not know whether our choices have been good until too late. We struggle to measure, communicate, and assess our progress toward conservation and restoration and prove compliance with environmental goals. Even within the regulatory structures, we lack a meaningful way to connect restoration or recovery goals to choices made at a site level. The best the transportation community has been able to do is track a patchwork of resource-specific performance measures but without understanding how they connect to programs, regulations, or budgets.

A new set of measures could accomplish the following goals:

- Provide status and trend information;
- Allow us to link budgets to choices to understand efficiencies and progress;
- Translate high-level planning and regulatory goals to site-level decisions; and
- Communicate effectively with stakeholders, decision makers, and each other.

The federal government has wrestled with concerns about environmental metrics since the 1970s. A 2005 Government Accountability Office report tracks this history and the efforts on a national level to measure and communicate environmental conditions and trends. Starting in the 1970s, the National Academy of Sciences identified that the highest priority for managing the environment is to create a centralized federal monitoring program. Since then, 16 bills or resolutions have passed Congress calling for this or attempting to solve the problem, but none have effectively done so (U.S. Government Accountability Office 2005).

Progress on tracking the environment has focused largely on single-resource questions. This can be pollutant- or species-based or based on acres affected (e.g., areas burned), or it can be resource-based in terms of tons of fish caught or board feet harvested. Today the federal government spends at least $600 million every year on monitoring the conditions and trends in the environment (U.S. Government Accountability Office 2004). State and local governments spend an additional unknown amount to track the environment. The challenge is that none of these measures has remained consistent or been integrated longitudinally to provide a basis for developing new management strategies, theories, or comprehensive assessments. Databases often do not provide information that can

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be shared or used to inform decision making. The inability of ESA recovery plans to provide help in developing Section 7 or 10 consultations is just one example of the resulting dysfunction.

Measurement systems for assessing and quantifying the environment historically have been developed to meet regulatory requirements, with various goals in mind. The metrics that have emerged from the CWA illustrate the multiplicity of measurements and requirements. The CWA includes pollutant measurement systems developed to track individual pollutants, including chemical and physical pollutants. Along with its state analogs, it also generated a measurement system for wetland units based on acres, popularly known as "no net loss." To assess progress in remediating pollution of water bodies, the CWA also fostered the development of indices of biological integrity. Thus, three unique, unrelated, and specialized measurements have been developed, all with the same goal of returning water bodies to a healthy state. In addition, other regulatory drivers working toward improving the health of the environment and ecosystems include the ESA, Clean Air Act, Natural Resource Damage Act, and many state laws that require their own measurements. The multiplicity of regulatory requirements continues to be a challenge for transportation project delivery.

In many contexts, the measurement systems and regulations overlap biologically, but the overlap is not reflected in the policy and regulatory realms. Even if the science suggests that managed resources should coexist, their regulation rarely coexists. For example, a wetland adjacent to a stream with ESA-protected fish may come into a regulatory conflict as mitigation or restoration required by regulations may not be allowed to serve both resources. In all such measurement systems, metrics have been based on single resources or species as a key to capturing the health of the entire system. Population numbers, pollutant loads, or acres of habitat have driven most regulatory systems. The recurrent problem is that the narrow focus on a single resource frequently comes at the expense of other resources.

This challenge has led to calls for a common set of units that can be measured with a bundled or stacked credit system. Stacking efforts have focused on attempts to identify common sets of functions and indicators to allow for relationships between regulated resources to be understood (Oregon Department of Transportation 2007). To date these efforts have been limited to the ecological features included within a regulatory system. However, other biodiversity and natural features are important to consider in assessing human impacts on the natural environment, and include the role the environment plays in protecting and providing for human communities. For example, properly functioning floodplains protect against flooding and improve water quality.

Environmental measures include tools or methodologies for assessing specific impacts or benefits from actions on the landscape. Environmental accounting measures are also needed to evaluate alternatives, assess impacts at project sites, and evaluate benefits from conservation or restoration actions. Accounting includes both the positive credits from beneficial actions and debits from impacts that harm the environment and must be consistent whether used for measuring impacts or benefits. The primary goal for any accounting system is to capture the environmental impacts or benefits in a common unit that bridges different activities, times, and geographies as appropriate.

To address the ecosystem services valuation and measurement issues, the project team developed an ecosystem service accounting methodology for any DOT or MPO to self-diagnose the need for a system, identify existing crediting options, and if needed select a method for developing a custom accounting system. These measurements may be used to provide the basis for credits or debits in a compensatory mitigation context, or to evaluate design alternatives that best avoid or minimize impacts.

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CHAPTER 3

The Integrated Ecological Planning Framework

Introduction

The Integrated Eco-Logical Framework (the Framework) is designed to provide technical support for implementing *Eco-Logical: An Ecosystem Approach to Developing Infrastructure Projects* (*Eco-Logical*), a guide and "permission document" signed by eight federal agencies in 2006 to encourage federal, state, tribal, and local partners involved in infrastructure planning, design, review, and construction to use flexibility in regulatory processes to achieve greater environmental benefits. The Framework provides more detailed technical guidance for practitioners to use in implementing this ecosystem approach to decision making that considers multiple resources. The Framework addresses and integrates the cumulative effects assessment and alternatives (CEAA) process with partnership development, regulatory assurances, and ecosystem services crediting strategies.

- **Cumulative effects assessment and alternatives** (CEAA) process is the starting point for conducting ecological assessment by evaluating the cumulative effects on resources of one or more plan or project scenarios, allowing and supporting conflict identification and creation of alternatives. It also provides the ability to quantify impacts, which is needed for further steps in the regulatory processes and mitigation actions. The CEAA process can also integrate proposed mitigation actions to provide and maintain a dynamic reporting of regional resource goal achievement or gaps.
- **Regulatory assurances strategies** integrate with the CEAA process by adding information on data standards (what data are needed by regulatory agencies) and new predictive modeling methods for species and habitats that are acceptable to regulatory agencies. The purpose of having regulatory assurances strategies is to allow a practitioner to move from regional scale analysis to the level of information and analysis needed by the permitting agencies.
- **Ecological accounting strategies** help direct transportation-related mitigation and other transportation-related decision making to support high-priority conservation goals. Tools are provided to address impacts at the project level, while tying avoidance and mitigation actions to broader conservation plans. These steps can be used within the Framework or as a stand-alone process/strategy.
- **Partnership development strategies** developed in Volume 1 are included throughout the Framework.

These four components of the Framework have been integrated into a nine-step process (see Table 3.1 for an overview and the following sections for details). The steps of the Framework are aimed at guiding DOTs, MPOs, and resource agencies in working together to identify strategic transportation program needs and potential environmental conflicts or conservation opportunities in the state, ecoregion, or watershed. The Framework supports the development of programmatic approaches to increase regulatory predictability during project development while furthering achievement of regional conservation goals.

The Nine Steps of the Framework

A summarized version of each step of the Framework is provided in the text, followed by a narrative that focuses on the application of the technical components contained in each step. Steps of the Framework that focus on the collaborative building components of the Framework are not addressed in the narrative because they are not the focus of the team's research. The complete Framework and supporting database are being integrated into TCAPP.

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Table 3.1. Steps of the Ecological Assessment Framework

Step	Purpose
Step 1: Build and strengthen collaborative partnerships, vision	Build support among a group of stakeholders to achieve a statewide or regional planning process that integrates conservation and transportation planning.
Step 2: Characterize resource status; integrate conservation, natural resource, watershed, and species recovery and state wildlife action plans (SWAPs)	Develop an overall conservation strategy that integrates conservation priorities, data, and plans, with input from and adoption by all conservation and natural resource stakeholders identified in Step 1 that addresses all species, all habitats, and all relevant environmental issues.
Step 3: Create regional ecosystem framework (conservation strategy + transportation plan)	Integrate the conservation and restoration strategy (data and plans) prepared in Step 2 with transportation and land use data and plans (LRTP, STIP, and TIP) to create the Regional Ecosystem Framework (REF).
Step 4: Assess land use and transportation effects on resource conservation objectives identified in the REF	Identify preferred alternatives that meet both transportation and conservation goals by analyzing transportation and/or other land use scenarios in relation to resource conservation objectives and priorities using the REF and models of priority resources.
Step 5: Establish and prioritize ecological actions	Establish mitigation and conservation priorities and rank action opportunities using assessment results from Steps 3 and 4.
Step 6: Develop crediting strategy	Develop a consistent strategy and metrics to measure ecological impacts, restoration benefits, and long-term performance, with the goal of having the analyses be in the same language throughout the life of the project.
Step 7: Develop programmatic consultation, biological opinion or permit	Develop MOUs, agreements, programmatic 404 permits or ESA Section 7 consultations for transportation projects in a way that documents the goals and priorities identified in Step 6 and the parameters for achieving these goals.
Step 8: Implement agreements and adaptive management. Deliver conservation and transportation projects	Design transportation projects in accordance with ecological objectives and goals identified in previous steps (i.e., keeping planning decisions linked to project decisions), incorporating as appropriate programmatic agreements, performance measures and ecological metric tools to improve the project.
Step 9: Update regional integrated plan/ecosystem framework	Update the effects assessment to determine if resource goal achievement is still on track. If goal achievement gaps are found, reassess priorities for mitigation, conservation, and restoration in light of new disturbances that may affect the practicality/utility of proceeding with previous priorities. Identify new priorities if warranted.

Step 1: Build and Strengthen Collaborative Partnerships, Vision

Purpose

Build support among a group of stakeholders to achieve a statewide or regional planning process that integrates conservation and transportation planning.

Outcomes

- Developing a shared vision through mutual understanding, appreciation, and documentation of transportation agencies' and resource agencies' overall goals, priorities, processes and major areas of concern within a specified planning region (i.e., state, watershed, or other ecologically based region).
- Creating mutual understanding of significant land use issues that may affect agency goals and mitigation needs.
- Establishing or reinforcing partnerships through formal agreements on roles, responsibilities, processes, and timelines.
- Identifying opportunities and criteria for using programmatic consultation approaches to better address transportation and conservation planning needs.

Implementation Steps

1a. Identify the preliminary planning region (e.g., watersheds, ecoregions, political boundaries). Drivers may be environmental factors, such as water quality needs, or 303(d) listings, species' needs, watershed restoration needs, or rare wetlands.

1b. Identify counterparts and build relationships among agencies, including local government and conservation NGOs (stakeholders).

1c. Convene a team of stakeholders, share aspirations, and define and develop commonalities. Build an understanding of the benefits of a watershed/ecosystem/recovery planning approach and develop a shared vision of regional goals for transportation, restoration, recovery, and conservation.

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1d. Record ideas and develop MOU on potential new processes for increasing conservation, efficiency, and predictability.
1e. Initially explore funding and long-term management options to support conservation and restoration actions and long-term management.

Technical Considerations

- Integrated Approach: Decide on high-level approach to implement an integrated planning process that most effectively captures transportation effects on species and ecological functions at the landscape scale.
- Types of Resources: What are the types of natural resources to include? Consider federal, state, and local regulated and nonregulated resources (connectivity needs, migratory and declining species).
- Boundaries: Considering ecological as well as political boundaries, select the area for evaluation of direct and cumulative impacts, restoration opportunities, and selection of mitigation sites (i.e., area evaluated for mitigation may be larger than area evaluated for direct impacts).
- Streamlining: What are the repetitive and relatively standardized project activities conducted by the DOT or MPO that could be addressed through programmatic approaches?

Technical Implementation of Step 1

Step 1a

Identify the preliminary planning region.

A boundary is needed to identify the region in which resource and development considerations will be analyzed. There are several considerations in establishing the region boundary. There is no perfect assessment region, but selecting planning boundaries consistent with regional or MPO boundaries can be suitable. For ecosystem assessment the main considerations are: the ability to recognize patterns for ecosystems and biodiversity related to their distribution, regional connectivity, and natural disturbance; opportunities for off-site mitigation; and technical limitations in terms of data precision and choice of tools (addressed in greater detail in this work).

Consulting data that significantly extend beyond the MPO can still allow for these considerations while limiting the extent of spatial analyses to the jurisdictional boundary. For example, NatureServe's Global Rank of Imperilment assigned to most species considers the global extent and threats to species (Faber-Langendoen et al. 2009). This information can be used to select and prioritize species for consideration and establish important criteria and objectives without requiring spatial analyses throughout the species range. Once a planning region boundary is selected, it should be shared with regional partners to assist in identifying appropriate data and expertise. Select the most precise boundary that can be represented with spatial data to reduce inaccuracies and confusion when intersecting it with fine scale data.

Ecosystem Accounting Aspects

Step 6b includes a review of institutional and organizational issues and concerns to include at this stage of the overall process. Reviewing the participant's perspective on new environmental measures and management choices begins at this step. Efforts may involve assessing the history of interactions, impacts, or mitigation and setting a new vision based on better performance goals. Defining the physical, natural, and policy boundaries of the measurement system is critical, and it also occurs in this step.

Step 2: Characterize Resource Status

Purpose

Develop an overall conservation strategy that integrates conservation priorities, data, and plans that address all species, habitats, and relevant environmental issues, with input from and adoption by all conservation and natural resource stakeholders identified in Step 1.

Outcomes

- Compiling existing data and plans into a refined map that identifies areas for conservation and restoration action to use as the basis for an REF and cumulative effects analysis.
- Developing an understanding of historic and long-term trends, priorities, and concerns related to aquatic and terrestrial species and habitats in the region.
- Identifying any gaps in data or plans that may need to be addressed separately and identifying modeling or assumptions to be used to address these gaps.
- Obtaining commitments and schedule for delivery of data and modeling to fill gaps.

Implementation Steps

2a. Identify the spatial data needed to create understanding of current (baseline) conditions that are a by-product of past actions and understand potential effects from future actions.
2b. Prioritize the specific list of ecological resources and issues that should be further addressed in the REF or other assessment and planning.
2c. Develop necessary agreements from agencies and NGOs to provide plans and data that agencies use in their own decision-making processes. Agreements should allow

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data to be used to avoid, minimize, and advance mitigation, especially for CWA Section 404 and ESA Section 7.

2d. Identify data gaps and how they will be addressed in the combined conservation and restoration plan. Reach consensus on an efficient process for filling any remaining gaps.

2e. Produce geospatial overlays of data and plans outlined, as well as supporting priorities, to guide the development of an overall conservation strategy for the planning region that identifies conservation priorities and opportunities and evaluates stressors and opportunities for mitigation and restoration.

2f. Convene a team of stakeholders to review the geospatial overlay and associated goals/priorities and identify actions to support them.

2g. Record methods, concurrence, and rationales of this step based on stakeholder input (e.g., how the identified areas address the conservation, preservation, or restoration needs and goals identified for the area).

2h. Distribute the combined map of conservation and restoration priorities to stakeholders for review and adoption.

Technical Considerations

- What are the quantitative retention goals for each resource to ensure preservation of an agreed upon portion of the priority resources?
- What is the conservation status of identified priority species and habitats (including wetlands)? How accurately does the team know where priority species and habitats (including wetlands) occur or could occur? Are the viability needs of priority species and habitats (i.e., minimum habitat size required for particular species) understood?
- What is the condition of the existing data (e.g., completeness, age, resolution)?
- What expertise and resources are needed to fill any identified data gaps?
- Are conservation priorities and actions represented accurately in the REF, including ones that are not spatially explicit?
- Is there disagreement in the conservation priority areas and goals identified by different conservation plans developed in the planning region? How will this be resolved?
- What regulated resources are most common in the area and are most likely to be affected or are the most sensitive to disturbance?
- What ecosystem services of interest are most likely to be affected by transportation projects?
- Do mitigation banks, habitat conservation banks, or other markets exist for ecosystem services likely to be affected?
- What landscape scale measurements exist, if any, for quantifying ecosystem services and impacts?
- What are the limiting factors associated with TMDLs and 403d limited streams?

Technical Implementation of Step 2

Step 2b

Prioritize the specific list of ecological resources and issues that should be further addressed in the REF or other assessment and planning.

First, one must establish the resource list; this can be done through a variety of methods, but the team suggests a systematic approach:

a. Begin with federal and state legally protected resources.
b. Add resources that are determined to be at risk by the resource collaboration group or scientists.
c. Use ranking systems such as NatureServe's Global Rank of Imperilment (G1-3 status) and the State Natural Heritage Program S-ranks (S1-S3).
d. Apply the coarse/fine filter approach for biodiversity conservation planning (which seeks to conserve the full range of biodiversity).
e. Add trust species (those in addition to legally protected species that agencies are required to manage).
f. Add other resources of interest and value to stakeholders.

Next, it is highly useful to set quantitative retention goals for each resource (e.g., 90% of the distribution of habitat A or 100 occurrences of species B within the planning region) and document the source(s) of information used. Goals typically are set in the systematic conservation planning process using experts in those resources to apply their judgment relative to historic versus current distribution and viability/sustainability requirements such as species population structure and natural disturbance regimes. Although it may be required or desirable to estimate actual historic distribution and loss, this is difficult and expensive for most resources. Some states have created historic vegetation distribution maps, and approaches exist for mapping historic wetland distribution. Individual plant and animal species historic distribution maps are rare and would have high uncertainty. Another approach is to apply NatureServe global ranks of imperilment; the Ecosystem Based Management tool incorporates these global ranks expert judgment on historic loss (NatureServe 2012). For non-legally protected resources, goal setting can be difficult and controversial, but it forms the basis for assessing the significance of impacts in later stages and facilitating mitigation and trade off planning. It is critical to clearly characterize the objectives for legally protected resources, including all goals identified in recovery plans, adopted watershed plans, and programmatic agreements.

The typical alternative to goal setting is weighting the relative importance/priority of resources/features on some categorical

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scale (e.g., 1–5, low to high). Weighting resource importance can be used as an initial step to help inform the magnitude of potential impacts while quantitative goal setting is being conducted (which often is a lengthier process), and weighting often is an easier value to extract from stakeholders than are quantitative goals. However, the use of weights alone limits the usefulness of information generated from the impact assessment conducted later in this process because weights do not result in conclusions about resource viability impacts or the amount of mitigation that may be needed other than for resources for which any impact must be mitigated. Weighting values provided by stakeholders can inform the expert judgment process in terms of gauging the amount of representation of a resource relative to science-based judgment about sustainability (e.g., it may not require much area to continue representing a particular resource in sustainable numbers in a planning area, but stakeholder values may suggest they would like to see it become widespread).

If choosing to use quantitative goals, decide if a single goal or a goal range is desired. For legally protected resources, a single goal likely is needed (often 100%). Goals also can be set as minimum and preferred levels (e.g., 50% and 75%, respectively) or high-medium-low as an expression of risk of future loss (e.g., 10%, 30%, 50%, respectively). Set resource goals and document the source(s) of information used.

A considerable amount of spatial and nonspatial information will be collected and generated through application of this framework. Creating a database for resource information is critical to document the name of the resource (and taxonomy if applicable), reason for selection, champion (meaning which partner[s] hold the resource in trust or otherwise advocate for it and can provide key information about it), and sources of spatial and expert information. This database will also be used to record the retention goals and other key information necessary for effects assessment and retention planning/mitigation described in Step 4a. The process of populating this database can take some time and can proceed in parallel with other tasks, but the sooner it is started, the more likely the information will be in place when needed (in particular for Steps 3 and later).

Populating the database essentially involves having subject matter experts (SMEs) for each resource use extant data, their knowledge and judgment, and that of other colleagues to develop the required attributes. Resource expertise is distributed among many institutions and individuals, and guidance exists for obtaining such information in useful and effective ways, such as the use of workshops (Groves 2003). Experts often are located outside the planning region or otherwise are not available to attend workshops, or funds for such workshops are not available. In those cases, a data collection form can be sent via e-mail. Sample guidelines and forms for assessing and documenting species viability and retention goals through expert input are available from NatureServe as part of their Vista conservation assessment tool (NatureServe 2009).

Step 2d

Identify data gaps and how they will be addressed in the combined conservation/restoration plan. Reach consensus on an efficient process for filling any remaining gaps.

Begin this step by reviewing plan(s) and documents to determine fit of scale, precision, purpose, source, etc., and which resources are included. Determine the value of plans for target resources and gaps in resource coverage by plans. If gaps appear to exist, conduct further investigation of resource coverage and decide how the team will address these. Creators of the plans will be the most knowledgeable about informing whether their plans can suit the REF purpose and with what limitations. It will also be useful to have resource SMEs review the plans to determine if they can adequately represent individual resources.

Next, determine which plans or resource maps to include in the REF and which resources each plan can represent. Each resource should be represented primarily by only one plan, but important conservation areas that include multiple resources may represent an acceptable overlap. For example, a particular conservation priority plan may be deemed acceptable for representing bird conservation generally, but an individual bird species priority map may be added to the REF that better represents that individual resource. Although there is some overlap, both input maps will be useful for the REF.

To understand how well existing plans represent specific resources, the team suggests creating a matrix that cross-references resources to named plan products. If specific resource content is not documented in existing plans (e.g., locations identified only as habitat conservation areas), interview plan developers to determine resource content. If no additional information can be obtained and the plan is to be included in the REF, conduct the following steps:

a. Identify and obtain existing resource distribution maps that the resource SMEs think appropriately represent the resource.
b. Intersect plan priority/management areas with individual resource maps to determine resource content.
c. Identify the resources not covered or not adequately covered by any existing plan and decide how or whether they should be represented in the REF.
d. Document how well existing priority maps include each resource. Consider coding the relationship according to the strength of resource treatment in the plan (e.g., on a 1–3 scale from low to high) and document the strength of the treatment. Strength of treatment may refer to the

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quality of the data used (e.g., recorded observations or range maps vs. accuracy assessed predictive distribution models) and the robustness of analyses (e.g., simple distribution area vs. population dynamics).

e. Determine if enough information exists to include the resources in the process and if so whether they will have separate treatment as individual element layers in the REF or be integrated into an update of an existing plan product by the owner of that plan (e.g., add to SWAP).
f. Document how each resource will be treated and by whom.
g. Fill gaps in conservation plans if feasible and otherwise note deficiencies and how those should be addressed during later phases of long-range planning or project planning.
h. Document priority areas and individual resource distribution maps with the amount of resource area and occurrences. as well as confidence in resource presence in each occurrence. These data will be important for quantifying and evaluating impacts and mitigation needs and opportunities. Confidence information also will be useful for determining reopening clauses (see Step 7).
i. Document priority maps or specific priority areas for any of this information that could not be determined and plans for filling information gaps.
j. Identify any individual resources for which adequate distribution information was not available and plans for filling information gaps.

Step 2e

Produce geospatial overlays of data and the plans outlined, as well as supporting priorities, to guide the development of an overall conservation strategy for the planning region that identifies conservation priorities and opportunities and evaluates stressors and opportunities for mitigation and restoration.

When overlaying the various accepted plans (including individual resource maps), be sure to follow procedures for retaining all relevant attributes as available in those plans. The intent of this step is to create a robust spatial database, not a presentation map because it is not feasible to visually represent all of the inherent information in one map. However, the database will provide the attributes needed to create such visual presentations of particular themes of interest. Suggested attributes include:

a. Source or owner of the input map
b. Type or purpose of individual areas
c. Resource content of individual areas
d. Metadata for methods used to map areas

Areas within these plans need to be distinguished by their conservation status as either secured or unsecured (i.e., areas are or are not under some ownership/agreement to manage them in perpetuity for the resources to be sustained). Alternatively, all secured areas can be moved to a protected area database (PAD), and remaining areas from this step are all unsecured priority areas that should be mitigated or may provide off-site mitigation. Secured areas also inform avoidance in planning and, as priority areas become secured, their availability to offer mitigation is removed. It may be especially useful to attribute areas that contain legally regulated resources.

Prioritizing areas requires a rating system that can highlight areas based on attributes of content (e.g., legally protected or especially rare/imperiled resources or those values integrated in weightings described earlier) and threat from conversion. The REF partnership should come to agreement on the creation of an acceptable rating system. A more rigorous approach uses a key concept from systematic conservation planning called irreplaceability, which informs how many options exist in the assessment/planning region to meet resource retention goals. For example, an area that contains a rare resource with a 100% retention goal (retention of existing distribution) would be 100% irreplaceable. Applying irreplaceability requires the setting of quantitative goals.

Ecosystem Accounting Aspects

The first step in using ecosystem accounting and crediting is to analyze the need and roles of crediting. This may include a scan of regulatory, conservation, and market needs. The regulatory scan starts with a review of the permitting and compliance requirements in the study area. This can include a historic review of agency permitting obligations and costs or reviewing the agency records for permitting. Conservation scans require examining both regulation-based and voluntary-based conservation efforts that may identify species, habitats, or systems that require attention. Market scans include reviewing the regional mitigation need and banking if used.

Ecosystem crediting decision-making begins with agreements on objectives for crediting and the basic rules for their use in transportation planning. The key questions are what existing measurement systems are in use, such as ones associated with ESA recovery efforts, pollutant measures for TMDL management, and wetland measures. Early coordination with other planning efforts identifies both opportunities and challenges that need to be resolved. Steps 6a and 6b coordinate with this step to include context information about the project area.

Step 3: Create Regional Ecosystem Framework

Purpose

Integrate the conservation and restoration strategy (data and plans) prepared in Step 2 with transportation and land use data and plans (LRTP, STIP, and TIP) to create the REF.

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Outcomes

- Producing the REF, an integrated map of resource conservation and restoration priorities, transportation long-range plans and other land use, infrastructure information, and socioeconomic information.
- Reviewing and verifying REF and data sources used with all participating agencies and stakeholders.
- Identifying areas in which planned transportation projects intersect with management/conservation priorities, including existing conservation areas.

Implementation Steps

3a. Overlay the geospatially mapped LRTP (or TIP/STIP) with conservation priorities and other land uses.
3b. Identify and show (1) areas and resources potentially affected by transportation projects and (2) potential opportunities for joint action on conservation or restoration priorities that could count for 404 and Section 7 regulatory requirements.
3c. Identify the high-level conservation goals and priorities and opportunities for achieving them relative to the transportation plan and other land uses/plans.
3d. Review and verify REF with stakeholders.

Technical Considerations

- What areas will be directly affected by transportation development?
- How severe are the likely impacts in combination with other land uses and/or cumulative impacts?
- What and where are the affected natural resources?
- How many of these natural resources are statutorily regulated, and how many are imperiled but not legally protected?
- What areas could be targeted for mitigation? Would these areas contribute to meeting REF objectives?
- What areas should be targeted to avoid impacts caused by the presence of irreplaceable resources (i.e., endemic species or habitats)?

Technical Implementation of Step 3

Step 3a

Overlay the geospatially mapped LRTP with conservation priorities and other land uses.

In this step, the goal is to understand how development plans are likely to affect resource conservation priorities. First, transportation and other development plans must be obtained and integrated. Land use data are an important component of these plans, but existing development and future development must be distinguished. The project team suggests segregating land use data into actual current land use, allowable or planned land use (e.g., from local government comprehensive plans/zoning or public land management plans), predicted/forecast land use (e.g., from urban growth models), and proposed land use that falls outside of existing plans (e.g., a large planned unit development). Include existing conservation lands as a land use to assess the achievement of resource goals under current conditions.

The various development plans undoubtedly will use different names and identifiers for the different development types represented in the plans. It will be highly useful to create a single classification of all of the development types acceptable to the partners. Then land uses can be assigned/cross-walked into a common classification that resource SMEs can efficiently use to assign response of resources to land uses/disturbances (Step 4). It is important that the classification be stratified enough for SMEs to distinguish differences in how resources respond to land uses but not so detailed that it unnecessarily increases the burden on the SMEs to attribute the responses. For example, local governments may have dozens of different named land uses, but most of those will be urban uses that have the same effect on resources. On the other hand, agriculture can mean many different types of practices that have very different resource implications. The use of a hierarchical classification can lump uses together to reduce the classification complexity when warranted. A good example is the classification of direct threats and conservation actions adopted by the Conservation Measures Partnership and International Union for Conservation of Nature (IUCN) (Conservation Measures Partnership 2012). IUCN standards have also been adopted by USFWS for use in their International Personnel Assessment Council (IPAC) online assessment tool.

Once a common classification is established, you can then incorporate the spatial data. The database can depict the distribution of regulated resources to assure the analysis can identify impacts to individual regulated resources along with overall conservation objectives and trade-offs. In particular, these would include species distribution maps for listed species showing areas where listed species are likely to occur and an updated NWI map for the area.

Finally, the REF can be intersected with the LRTP to support Step 3b.

Step 3b

Identify and show (1) areas and resources potentially affected by transportation projects and (2) potential opportunities for joint action on conservation or restoration priorities that could count for 404 and Section 7 regulatory requirements.

In this step, output maps and quantitative reports are generated from the intersection in Step 3a to identify which priority areas and resources would be affected, the amount

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of area/resource distribution affected, and the location of impacts. Note that if Step 4 is not yet accomplished, this simple intersection assumes conflict between all development and all resources/priority conservation areas. This is a reasonable assumption at this stage to understand potential conflicts and needs. Step 4 will add information for more precise results suitable for more detailed planning. However, it is still important at this initial stage to apply a consistent format to these results to facilitate ready comparison between alternative transportation scenarios. Note that to get a truly cumulative effects assessment it is important to combine with the LRTP the existing land uses and other proposed/planned/forecast land use and other infrastructure as described in Step 3a.

The quantitative results from this step are used to evaluate impacts. At this stage, the objective is to identify the resources/areas being affected and the projects/uses causing the impacts. This can lead to identification of opportunities for focused joint action on creation of better alternatives through avoidance or design mitigation and early scoping of compensation opportunities should they be necessary.

Step 3c

Identify the high-level conservation goals and priorities and opportunities for achieving them relative to the transportation plan and other land uses and plans.

The outputs of Step 3b allow us to develop the list and map of affected resources and areas that will be the focus of further assessment and mitigation under the analyzed scenarios. From there, the team can list and map the opportunity areas for mitigation and identify the key players that need to be engaged in the process.

Ecosystem Accounting Aspects

A key consideration for ecosystem accounting at this step is the ability for landscape level measures to connect to site level ones. Landscape level conservation or transportation decisions must translate to a project level through metrics that aggregate appropriately to track progress or support monitoring. The success of Steps 6f and 6g depend on this connection. Landscape goals often can be too general to provide the basis for site level decisions. Detailed landscape measures help to remove ambiguity once the site level is being considered. For example, a conservation level goal may identify the protection of habitat associated with a particular species life stage, but if this is left in general terms, it is impossible to implement at a site level.

Step 4: Assess Land Use and Transportation Effects

Purpose

Identify preferred alternatives that meet both transportation and conservation goals by analyzing transportation and/or other land use scenarios in relation to resource conservation objectives and priorities using the REF and models of priority resources.

Outcomes

- Developing program level cumulative effects scenarios associated with transportation development and other future land uses.
- Identifying preferences regarding avoidance, minimization, potential conservation, and restoration investments to support selection of the best transportation plan alternatives.
- Identifying and quantifying mitigation needs.

Implementation Steps

4a. Work collaboratively with stakeholders to weight the relative importance of resource types (including consideration of resource retention) when needed to help establish the significance of impacts and importance for mitigating action.

4b. Establish individual resource conservation requirements, such as their response to different land uses and types of transportation improvements (and other stressors), minimum viable occurrence sizes, and connectivity requirements.

4c. Develop programmatic cumulative effects assessment scenarios that combine transportation plan scenarios with existing development and disturbances, other features and disturbances causing impacts, and existing secured conservation areas. Include climate change threats to better understand what resources and areas may no longer be viable or what new resources may become conservation priorities in the planning region during the planning horizon.

4d. Intersect the REF with one or more cumulative effects assessment scenarios to identify which priority areas or resources would be affected and the nature of the effect (e.g., negative, neutral, beneficial) and to quantify the effect, noting the level of precision based on the precision of the map inputs.

4e. Compare plan alternatives and select the one that optimizes transportation objectives and minimizes adverse environmental impacts (the least damaging alternative).

4f. Identify mitigation needs for impacts that are unavoidable and that may require minimization through project design/implementation/maintenance, and that may require off-site mitigation. For impacts that do not appear practicable to mitigate in kind, review with appropriate resource agency partners the desirability of mitigating out of kind (e.g., by helping secure a very high

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priority conservation area supporting other resource objectives).

Technical Considerations

- What areas have the highest degree of potential impacts? What impacts should be avoided?
- What areas have opportunities for mitigation or restoration that best benefit target resources (imperiled species, watershed/aquatic resource needs)?

Considerations in assessing mitigation:

- Which impacts should be mitigated on-site or off-site? Including consideration of off-site conservation priority areas?
- What are the specific criteria for determining when off-site conservation actions are appropriate or inappropriate?
- What unprotected conservation priorities can be protected through project mitigation?
- What markets for ecosystem services are available in the area that could be used to meet mitigation requirements?
- Are there opportunities for conservation bank development?
- What rules or methods will be used for weighing resources and transportation objectives when tradeoffs are required?

Considerations in assessing climate change:

- What are the predicted climate change threats to identified resources?
- Which of the priority species and habitats in the planning region are most vulnerable to climate change? How is vulnerability assessed?
- What resources might not continue to be viable and what resources might become priorities in the planning area?
- How does climate change influence the selection of mitigation sites?
- For species in the planning area, what are their needs related to movement and habitat connectivity? What obstacles exist to habitat connectivity? How will species movement needs and possible transportation and land use impacts influence scenario evaluations?
- What are the opportunities for using performance measures to develop standardized conservation outcomes that can be easily incorporated in Section 7 or programmatic Section 7 consultations? For example, for species in the planning area, identify opportunities to conserve or restore their habitats using recovery or habitat conservation plans, and determine if these opportunities can be tied into conservation objectives for other listed species occurring in the area.

Technical Implementation of Step 4

Step 4a

Work collaboratively with stakeholders to weight the relative importance of resource types (including consideration of resource retention) when needed to help establish the significance of impacts and importance for mitigating action.

A first step is to set individual resource/priority area importance weights. Weights in this sense do not replace quantitative goal setting but instead inform a trade off process when not all resource retention goals can be addressed in an iteration of the scenario assessment/mitigation process. The partnership should establish how the weighting system will be used and how the weights will be set (e.g., SMEs, committees, stakeholder involvement). Next, establish the weighting system and criteria (e.g., 1–5 highest to lowest) and set the weights and document source of information/process.

Step 4b

Establish individual resource conservation requirements such as their response to different land uses and types of transportation improvements (and other stressors), minimum viable occurrence sizes, and connectivity requirements.

In this step, information is added to increase the precision of the cumulative effects assessment. In addition to the quantitative retention goal established earlier, expert knowledge is obtained to specify other suggested and optional parameters and input to the resource database, such as:

a. The minimum required area for a patch or occurrence of the area/resource (suggested).
b. Ecological condition thresholds. Ecological condition is a function of the criteria used to assess the quality of the resource compared with viable reference conditions and usually takes into account (besides the minimum required area above) the presence of pollutants, exotic species, age class and vegetation structure, and off-site effects (optional).
c. Responses of REF priority areas and individual resources (if used) to the plan components of the transportation plan (and any other plans or disturbances to cumulatively assess). This component recognizes that not all resources respond equally to different land use and infrastructure types. Responses can be put on a numerical or categorical scale, such as negative, neutral, or beneficial (suggested). The CEAA process does not explicitly call for calculating multiplicative effects of disturbances (i.e., that the sum level of disturbance to a resource from multiple resources is greater than the sum of their individual disturbances) because there is little science to support quantitative assessment of this effect and it

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would likely add considerable complexity. However, if such assessment is desired, it could be conducted as part of this step.

d. Landscape ecological parameters or characteristics such as patch interior area, edge-interior ratios, connectivity, etc. Use parameters that are meaningful for the resource and tractable using available data and tools (optional).
e. Viable species population size and characteristics when these can be reasonably established. Assessment of these characteristics can be difficult and expensive and more likely gathered during field assessment, but recording them during the expert knowledge gathering phase will be most efficient. Because this information is expensive and difficult to determine, it is most often addressed for legally protected species, for which very high certainty of cumulative effects assessment is required (optional).

This information provides assessment that is much more precise by taking into account some important considerations, such as:

a. Not every resource responds negatively to every land use and development activity. Some species will have a neutral response, and some will benefit, although most intensive development will negatively affect most resources.
b. Size and configuration matter: the area of a habitat patch, its shape, context, and connectivity to other habitats are very important in determining its suitability and viability for many species.
c. Condition of habitats is not only very important to suitability for species but also important from a policy perspective for suitability to receive compensatory mitigation.

Step 4c

Develop programmatic cumulative effects assessment scenarios that combine transportation plan scenarios with existing development and disturbances, other affected features and disturbances, and existing secured conservation areas. Include climate change threats to better understand what resources/areas may no longer be viable or what new resources may become conservation priorities in the planning region during the planning horizon.

First, the partnership should decide what scenarios will be defined and evaluated. This step builds on those in Step 3 by conducting a more complete mapping of stressors in the scenarios (existing land use, management, and infrastructure combined with planned future land use and other infrastructure, and climate change effects is possible). Typically, the scenarios to be evaluated include:

a. Current baseline of actual land use and management.
b. A policy baseline of allowable land use/management not yet realized. This is also often know as a build out map for urbanization based on current local government plans and zoning.
c. A trend scenario that predicts likely urbanization, for example based on demand, suitability, and market conditions, but also may include trends such a climate-change effects.
d. Alternative futures scenarios. There are often several of these that represent alternatives to preferred future scenarios that may be based on models, proposals, civic engagement, etc. Examples might include traditional long-range plans assuming automotive travel vs. a transit-oriented development scenario.

Once the desired scenarios are described, conduct an inventory of data sources that can represent the scenario content (uses, infrastructure, management practices, disturbances) for evaluation, such as:

a. Current scenario:
   1. Actual land use mapped with aerial photography or satellite imagery.
   2. Actual land use or management records that specify existing or ongoing activities; this is especially useful for land uses and management that are not easily distinguished through remote sensing, such as working landscape uses/management.
   3. Infrastructure
   4. Protected conservation areas.
   5. Known hazard areas that can threaten both development and resources.
b. Policy and trend scenario:
   1. Land use or management based on existing plans, such as zoning or public land management plans. Note that in cases in which multiple uses are allowed in an area, it may be appropriate to attribute the most intensive allowable use under the precautionary principle.
   2. Urban growth model output for the transportation planning horizon. These are often developed by local and regional governments and other entities. They are not just population projections but often predict types of urban uses for areas expected to be developed. Projections stated as housing unit or human population density can be converted to land use types.
   3. Pest and disease spread. For example, pine bark beetle infestation in the Rocky Mountain region poses a significant cumulative threat to ecosystems and individual resources.
c. Alternative future scenario
   1. Proposed transportation plans and projects and their alternatives.
   2. Proposed land use and management plans and their alternatives.

Resource partners also may collaborate on inclusion of predicted climate change threats to better understand what

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resources may not be viable or what new resources may become conservation priorities in the planning region during the planning horizon. Direct threats modeled from climate change such as sea level rise maps can be incorporated in trend scenarios. In more sophisticated climate change analyses, other indirect resource threats can be modeled, such as species range shifts and regional condition impacts on resources such as temperature and soil moisture.

The data can then be integrated into a single map containing the different scenario components. You may encounter instances in which one map input trumps others that overlap it. For example, many counties will zone public lands in the event that land is swapped that puts that land into private hands (thus it will be appropriately prezoned). However, the project team wants to evaluate public land management, not the theoretical private land zoned use, so use rules for combining the data to recognize when multiple uses actually are or can co-occur and when one should trump others must be considered.

Step 4d

Intersect the REF with one or more cumulative effects assessment scenarios to identify which priority areas or resources would be affected, to identify the nature of the effect (e.g., negative, neutral, beneficial), and to quantify the effect noting the level of precision based on the precision of the map inputs.

Once the scenarios are constructed in the GIS database per Step 4c, the spatial analyses can be conducted. The intersection of the REF and scenarios will first determine the location and amount of each area or resource in each land use type in a scenario by intersecting the spatial data.

Next the process will compare the responses of the areas and resources (e.g., negative, neutral, beneficial) to the land use types. Area and resource distributions with acceptable responses (e.g., neutral or positive) will be compared with other spatial requirements (e.g., minimum viable patch/occurrence size). Areas meeting response and viability requirements will be considered retained under the scenario. Remaining acceptable areas will then be summed and compared with the regional retention goals to determine if a scenario can meet area/resource retention goals.

For assessing impacts on priority areas from the REF (completed in Step 5a), it is most useful to have quantities of individual resources found within those areas to quantify the type and amount of impact. However, without precise resource location information the results have considerable uncertainty if a portion of the priority area is affected versus all of it being affected. When such information is not available, it may be necessary to work with the owner of the plan for these areas to determine the nature of the impacts.

For all areas/resources, a report should be generated that quantifies the current distribution and the expected future distribution to quantify impacts. Maps of locations of expected area/resource loss can identify where impacts would occur and what scenario areas (land use, infrastructure, and management) are responsible for the impacts.

Step 4e

Compare plan alternatives and select the one that optimizes transportation objectives and minimizes adverse environmental impacts (the least environmentally damaging practicable alternative assuring regulated resources are sufficiently addressed).

Having generated spatial and quantitative results in Step 4d, one can readily compare the ecosystem performance of the plan alternatives. Performance is based on meeting area/resource retention goals. The likely rare and easiest case will compare equally acceptable transportation scenarios and readily identify the one with the least impact. In cases that are more common, there will be trade-offs between transportation scenarios and resource impacts. An initial evaluation likely will reveal opportunities to minimize impacts by creating new transportation plan alternatives (e.g., hybrids of plan alternatives or mitigating conflicts in a preferred plan through avoidance on a site-by-site basis where impacts would occur).

If opportunities for plan improvement are identified, then iterations of transportation/land use plan adjustments can be conducted that lead to identification of a preferred scenario in terms of meeting transportation and land use objectives and least impact on resource goals. The map and quantitative outputs of the assessment will prove highly valuable for guiding these adjustments by identifying locations, resources, and development activities that conflict. The database of resource responses to the classification of development activities also will be highly useful for determining compatible uses at priority sites.

Step 4f

Identify mitigation needs for impacts that are unavoidable, those that may require minimization through project design/implementation/maintenance, and those that may require offsite mitigation. For impacts that do not appear practicable to mitigate in kind, review with appropriate resource agency partners the desirability of mitigating out of kind (e.g., by helping secure a very high priority conservation area supporting other resource objectives).

The outputs from Step 4d will provide the quantitative information required to understand what resources are affected and the quantity of the impact (e.g., acres or populations

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affected). Combined with policy information, such as mitigation ratios (number of acres needed to replace each acre lost), the mitigation strategy needed for each resource can be described. This step does not identify the specifics for implementation but describes if the mitigation will be met through minimization or restoration (e.g., through project design stipulations), or through off-site or out-of-kind mitigation when options exist.

For impacts that do not appear practical to mitigate with on-site/in-kind options or when on-site options are not ecologically viable, review with appropriate resource partners the desirability and permissibility for mitigating with off-site/out-of-kind options (e.g., by helping to secure a high-priority conservation area supporting other resource objectives of equal or higher priority). For legally protected resources (wetlands and endangered/threatened species), it may not be permissible to mitigate with out-of-kind options, but for other resources it should be explored whether mitigation can and should be directed to high-priority conservation sites of the REF to support higher conservation values (see Step 6 for more information about value trade-offs). This will support implementation of Step 6 and may require partially completing that step in advance.

Ecosystem Accounting Aspects

Steps 6a, 6e, and 6f connect to this step. Step 6a includes a diagnosis of the environmental, regulatory, and stakeholder issues and creating linkages between these various values to assess trade-offs. The market assessment and implementation decision in Steps 6e and 6f also connect here. These portions of Step 6 define a set of possible options for resolving environmental measurement problems and for finding more effective conservation and mitigation. These two steps connect in Step 4 through the analysis of alternatives and minimization decisions.

Step 5: Establish and Prioritize Ecological Actions

Purpose

Establish mitigation and conservation priorities and rank action opportunities using assessment results from Steps 3 and 4.

Outcomes

Developing and agreeing on:

- A regional mitigation (conservation, recovery, restoration) strategy and conservation and restoration priorities with quantitative and qualitative valuation of mitigation sites. The strategy and priorities should be iterative, and it is important for the stakeholders to identify a process that supports updates to be incorporated.
- The preferred conservation and mitigation actions to achieve the priorities.
- Strategies and actions that consider regulatory requirements and programmatic implementation opportunities, including seeking regulatory buy-in for mitigation solutions or establishing a mechanism by which resource agencies can convey their acceptance/approval of investments in vetted conservation or restoration priority areas.
- Crediting opportunities (see Step 6 for details).
- The lead agency or agencies for each strategy and the method for achieving each strategy.

Implementation Steps

5a. Identify areas in the REF planning region that can provide the quantities and quality of mitigation needed to address the effects assessment and develop protocols for ranking mitigation opportunities. Ranking should be based on the site's ability to meet mitigation targets, along with: anticipated contributions to cumulative effects; the presence in priority conservation/restoration areas of the REF; ability to contribute to long-term ecological goals; the likelihood of viability in the landscape context; cost; and other criteria determined by the stakeholders.

5b. Select potential mitigation areas according to the ranking protocols described.

5c. To increase confidence in the mitigation component of the plan, field validate the presence and condition of target resources for attention at mitigation sites and reassess the ability of sites to provide necessary mitigation. Revise the mitigation assessment as needed to identify a validated set of locations to provide mitigation. Compare feasibility/cost of conservation and restoration opportunities with ranking score and context of conservation actions of other federal, state, local, and NGO programs to determine overall benefit and effectiveness. Predictive species modeling can target areas for the field validation process.

5d. Develop or refine a regional conservation and mitigation strategy to achieve ecoregional conservation and restoration goals and advance infrastructure projects.

5e. Decide on and create a map of areas to conserve, manage, protect, or restore, including documentation of the resources and their quantities to be retained and restored in each area, and the agency and mechanisms for conducting the mitigation.

5f. Obtain agreement on ecological actions from stakeholders.

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Technical Considerations

- What areas within REF priority areas meet the mitigation criteria?
- If required mitigation cannot be found within an REF priority area, what other mitigation opportunities exist that will further the agreed-upon regional restoration plan goals and objectives?
- What other conservation actions are occurring in the area?
- Who owns or manages the identified priority areas?
- What site level measures are needed to verify progress at mitigation sites?
- What are the protocols for ranking mitigation opportunities?
- What is the most effective way to direct and conduct field validation of identified mitigation areas? How can field data be captured and provided to natural resource data maintainers/providers so that it can be used in future assessments?

Technical Implementation of Step 5

Step 5a

Identify areas in the REF planning region that can provide the quantities and quality of mitigation needed to address the effects assessment and develop protocols for ranking mitigation opportunities. Ranking should be based on the site's ability to meet mitigation targets, along with: anticipated contributions to cumulative effects; the presence in priority conservation or restoration areas of the REF; ability to contribute to long-term ecological goals; the likelihood of viability in the landscape context; cost; and other criteria determined by the stakeholders.

For mitigation of impacts to individual resources, it will be necessary to have either high confidence distribution maps of the individual resources or attributes of quantities of resources in potential off-site receiving areas. Quantities will need to be verified prior to putting agreements in place, but the initial information can be used for planning purposes.

However, securing approval and funding for such mitigation may require additional investigation and verification of the resources that would be affected and the value of the proposed mitigation (see Step 5c).

For out-of-kind mitigation, Step 6 must be addressed to determine equivalency of values that can be provided by other areas or resources as compared with those directly affected.

Step 5b

Select potential mitigation areas according to the ranking protocols described.

When searching for mitigation areas, spatial queries can be conducted against REF attributes to identify those areas meeting mitigation criteria and occurring in REF priority areas. When required mitigation cannot be found within an REF priority area, other areas can be identified and investigated. Failure to find any in-kind mitigation opportunities may trigger discussions for out-of-kind mitigation opportunities.

For wetlands, endangered species, and other regulated resources, identify, adopt, or if there is sufficient development likely to occur in the area, develop programmatic approaches to mitigation catalogs or portfolios. Developing these is especially useful if mitigation banking occurs in the area because this can improve both the ease of project implementation and the environmental outcomes for mitigation. Steps for developing a wetlands mitigation catalog are identified in the following section.

Proposed Process for Creating the Priority Wetlands Map for Mitigation and Restoration

A comprehensive digital map of current and historic wetlands needs to be available for successful planning and mitigation. The goal is to ensure that all wetlands larger than 5 acres are represented. If available, comprehensive maps of wetland soils and historical wetlands can greatly improve the quality of the map. The NatureServe national ecological systems map includes the current distribution of wetlands, linked to NWI, NatureServe, and National Vegetation Classification. Biophysical settings maps from the inter-agency LANDFIRE effort depict historical wetland distributions (U.S. Forest Service 2012). Both of these maps are at 30-m pixel resolutions (approximately 1:100 K scale). These may be compared and combined with NWI, wetland soils maps, terrain models, or augmented with additional image interpretation.

There are important benefits to developing wetland maps that are linked to these several standard ecological classification schemes. For example, NatureServe ecological classification units are categorized by conservation status. Using knowledge of relative rarity, trends in extent, and remaining habitat quality, each type is categorized along a scale from critically imperiled to secure. These conservation status measures feed directly into prioritizing sites for wetland conservation. In addition, most wetland types in the NatureServe ecological systems classification (typically, 10–20 types per state) have been reviewed and attributed as habitat for at-risk and focal species, so this information becomes accessible to users for project scoring and selection.

At a minimum, all available wetlands data (national, state, regional, county, and local site information) need to be integrated. In addition, states must assure that all the digital NWI data for significant wetlands are brought up to date using the most recent imagery and air photography that exists for each state. In the case study, Virginia incorporated additional spatial data to assure that farmed and partially developed wetlands were included (see Appendix C, Methodology for Developing

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a Parcel-based Wetland Restoration, Mitigation, and Conservation Catalog: A Virginia Pilot Project).

Develop a synthesis of spatially explicit representations of all conservation and restoration priority sites. This is discussed in steps 2 and 3. The *Eco-Logical* guidance signed by eight federal agencies calls this a "Regional Ecosystem Framework." Having an acceptable REF or accepted overall conservation priorities is an essential step in identifying a potential mitigation catalog.

If a state or a watershed in a state has developed a watershed approach to define wetland restoration and mitigation priorities, such as the EPA–Army Corps of Engineers approach developed in Maryland, this approach and the catalog developed should be used, and the remaining steps can be skipped.

Extract existing and historic wetlands from the synthesis portfolio. To do this correctly, a fairly comprehensive digital map of wetlands needs to be available for the state. Access to a fairly comprehensive map of either wetland soils or historical wetlands (or if possible, both) can greatly improve the quality of the map.

Modify the extracted wetlands coverage into a set of priority wetland polygons. The use of high-resolution digital imagery, such as that provided by the National Agriculture Imagery Program (U.S. Department of Agriculture 2011), to refine the boundaries is an important step for large or poorly mapped areas. By refining the boundaries of these areas and identifying priority sites, the modified coverage will make sense to wetland regulators, as well as to those working on conservation and watershed restoration.

It is important to make sure that wetland mitigation priority areas make sense to project partners. In some of the test areas, the team was forced to eliminate portions of some areas because of criteria associated with wetland conservation (e.g., proximity to transportation infrastructure). For instance, in the Oregon wetlands priority pilot, an airport was included in The Nature Conservancy's synthesis portfolio because of the presence of some rare plants on wetland soils. These showed up on the first draft of the priority map in an area with a number of high-priority sites. Wetlands regulators had us remove this area because they did not want to promote wetland mitigation so close to an airport. If it had been a critically important site, or the only priority wetland in the watershed, the team might have left it in. This is not very time consuming but an important task.

An alternative method, especially useful in areas where there are extensive wetlands, would be the approach used in Virginia, in which all wetlands, historic and existing, were analyzed to determine their conservation significance and ranked accordingly. The highest ranked areas became the wetland priority areas. This is a bit more expensive but could be useful in areas in which an overall synthesis of conservation priorities cannot be developed.

Assure that at least one to five priority wetland conservation sites exist in every watershed. Work with regulators to determine that mitigation occurring in the same eight-digit HUC (fourth field watersheds with an eight-digit hydrologic unit code) could be considered to be in place (assuming the types present are similar enough to be considered in kind). When desired, a 10-digit HUC (fifth field watershed) can be used because these are smaller and provide regulators more assurances of mitigation being in kind and in place. In almost every major basin in the country, one or more watersheds will contain no synthesis, portfolio, catalog, or other priority area. In these watersheds, catalog sites need to be developed using any of the original assessments that had wetland components or by looking for concentrations of natural wetlands.

Across the nation, conditions will vary considerably across eight-digit HUCs. In those in which no potential mitigation sites are already identified, use local plans, known locations of at-risk biodiversity, NatureServe conservation status of wetlands (i.e., imperiled-to-secure), and the documented quality and condition of wetlands to identify priority sites for review by local regulators and practitioners.

Create priorities for the wetlands catalog. Developing priorities can make decision making easier for transportation planners. A simple method is to prioritize or rank the set of priority wetlands within each fourth field watershed. The basic concept is that any restoration, mitigation, or conservation occurring within a priority wetland area should increase wetlands functions and restore important habitats. This may help transportation agencies to demonstrate that all decisions they made were based on regulators' or priority criteria, not theirs, which is why ranking the priority wetlands within each watershed can be useful. Specific criteria for ranking the catalog are not suggested here, although clearly the overall significance to conservation in the REF for each site should be considered.

Vet the priority map with regulators. The priority map must be vetted with regulators. A good first step is to vet the priority map with conservation partners, if they are available in the area. Then leads should meet with regulators, making sure to include the Army Corps of Engineers, EPA, Natural Resources Conservation Service (NRCS), SFWS, any state agencies that regulate wetlands, state fish and wildlife agencies, and state DEQ if they are not the primary wetland regulator.

Promote the wetlands priority products and facilitate their use by federal, state, and local planners. Once the wetland priority maps and resources have been developed, it is imperative to identify further steps that are needed nationally and in respective states, Corps Districts, and EPA or USFWS regions and field offices to facilitate use of the maps and resources in decision making for 404 permitting and as appropriate in ESA Section 7 consultations and other regulatory matters. The best methods for doing this will be different in each state and jurisdiction.

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It is essential that the information be made available to the public as soon as it has been vetted because otherwise wetland bankers who do not have access to the data will have a persuasive argument for protection of nonpriority areas. This information should be made available as soon as possible to local governments and all who develop or approve development applications on the local level because considerable avoidance is anticipated on a voluntary or preregulatory level.

Step 5c

To increase confidence in the mitigation component of the plan, field validate the presence and condition of target resources for attention at mitigation sites and reassess the ability of sites to provide necessary mitigation. Revise the mitigation assessment as needed to identify a validated set of locations to provide mitigation. Compare feasibility and cost of conservation and restoration opportunities with ranking score and context of conservation actions of other federal, state, local, and NGO programs to determine overall benefit and effectiveness. Predictive species modeling can target areas for the field validation process.

It is critical to integrate any field validation information into the REF. This can include adjustments to resource distributions or priority area configurations and resource condition and viability information. By instituting an agreed-upon, standardized approach to input any field work done by or on behalf of the REF partners (and others) into the REF database, the database gradually will improve in its precision and utility. State natural heritage programs (such as NatureServe) conduct surveys for rare and imperiled species and communities and integrate others' survey work (if it meets heritage standards) and thus can serve as a critical partner for both contributing and maintaining such data. Data security and privacy issues may preclude integrating the most spatially precise data directly into the REF database, so data use agreements must be established.

Step 5d

Develop and refine a regional conservation and mitigation strategy to achieve ecoregional conservation/restoration goals and advance infrastructure projects.

The outcome of the previous steps is development of the conservation and mitigation component of the REF that identifies, in a particular analytical cycle, what areas will be conserved and restored to meet partner objectives. This must include documentation of which resources and their quantities are to be retained or restored in each mitigation area and the implementation agency and mechanism for conducting the mitigation. This could be incorporated in or used to update the REF.

Assure the mitigation catalog and mitigation actions are updated based on restoration activities, lost opportunities, and areas conserved.

Ecosystem Accounting Aspects

This step will specify many of the necessary parameters for an ecosystem credit. Step 6b connects to this step to inform decision makers on the various measurement systems available to meet the goals and outcomes of this step. Step 6 provides the tools for implementing these priorities. Similar to earlier goal setting concerns in Step 3, the definition of resources and priorities must provide a level of detail to be used at the implementation steps. Priorities must consider the spatial, functional, habitat, and population issues defined in Step 6b.

Step 6: Develop Crediting Strategy

Purpose

Develop a consistent strategy and metrics to measure ecological impacts, restoration benefits, and long-term performance at the project level, with the goal of having the same analyses language throughout the life of the project.

Outcomes

- Improving and integrating the mitigation sequence at a site level through avoidance and minimization, after which outcome-based performance standards can set the stage for compensation.
- Accelerating implementation and improving mitigation results.
- Supporting implementation tools, such as advance mitigation, banks, programmatic permitting, and ESA Section 7 consultation.
- Supporting use of off-site mitigation and out-of-kind mitigation, where appropriate, because equivalency of value can be determined across locations and resources.
- Informing adaptive management and updates of the cumulative effects analyses.
- Balancing gains and losses of ecological functions, benefits and values associated with categories of transportation improvements, or specific project-related impacts.
- Providing the means of tracking progress toward regional ecosystem goals and objectives (assumes site level ecological metrics are correlated to the landscape level tools used to define the REF).

Implementation Steps

6a. Diagnose the measurement need. Define which ecosystem services need to be measured. Examine the ecological setting (including regulated resources and frameworks,

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nonregulated resources, and ecosystem services); examine the regulatory and social setting and identify additional opportunities.
6b. Evaluate ecosystem and landscape needs and context to identify measurement options.
6c. Select or develop units and rules for crediting (e.g., rules for field measurement of ecological functions, approved mitigation/conservation banking, outcome-based performance standards using credit system).
6d. Test applicability of units and rules in local conditions.
6e. Evaluate local market opportunities for ecosystem services.
6f. Negotiate regulatory assurance for credit (sacking credits and double-dipping).
6g. Program implementation.

Technical Considerations

- How will debits and credits be calculated? Is credit stacking allowed?
- What is the permissible service area for a bank, off-site mitigation?
- Who may participate in the crediting system?
- How will credits be registered and tracked?
- How long will regulatory decisions on a given project be binding?
- How will values be calculated across locations and resources?
- What long-term monitoring is needed?

The ecosystem service accounting methodology follows a seven-step process for a transportation agency to self-diagnose the need for a system, identify existing crediting options, and if needed select a method for developing a custom crediting system. These measurements may be used to provide the basis for credits or debits in a compensatory mitigation context or to evaluate design alternatives that best avoid or minimize impacts.

Step 6a

Diagnosis of the measurement need.

Diagnosing the resource measurement needs with a DOT/MPO requires examining the resources, constraints, and opportunities that affect the choice of a methodology. The first components are the natural environment and resources in the area, either in the entire jurisdiction or within the areas of anticipated transportation improvements. The second component is the evaluation of regulatory requirements and nonregulatory expectations for the agency in managing the environment. The final component is to examine the opportunities for meeting the environmental management needs through existing markets, conservation initiatives, or other innovative solutions. Through this diagnosis, an agency can assess the ecological, social, and economic needs for tracking their environmental impacts in both the regulated and nonregulated arenas.

Examining the Ecological Setting

A key challenge in any environmental planning effort is to understand the scope of what may be affected. Impacts range across types, scales, and time based on a variety of factors, and they occur in a context of other impacts from existing and new actions, as well as other recovery or conservation actions and priorities in a region. Understanding this ecological setting is key to identifying the correct strategy for measuring the environment.

This step overlaps with the process for developing an REF, as described in *Eco-Logical.* The REF and the resources it is based on ultimately become the basis for setting regional ecological goals. Accordingly, to be able to track how projects affect progress toward those goals, the same scan for resources and identification of data needs for the REF will also inform the decision on the type of credit or debit tool used.

Different resource types and habitats each lend themselves to different measurement needs. Highly diverse ecosystems with complex biophysical processes require more detailed measurement systems. Simpler or more homogenous ecosystems can allow for more basic measurement systems. The interaction of ecosystem functions also informs the measurement system selection. In ecosystems with competing processes, the analysis is complicated with a need to either mimic the tension in the natural system or develop a series of tools to weigh trade-offs in implementation that may favor one resource. An example of this can be found when habitat enhancements for an anadromous species may occur at the expense of a native warm water fish species. In this case, a policy decision is made to favor one over the other in a system that may have increasing pressures for both.

Resources to examine can be roughly categorized into three categories based on the resource connection to the DOT/MPO business model. Recognizing that not all DOTs/MPOs have the same levels of authority or support for addressing some resources, these categories can differ from state to state. However, they are based primarily on the existence of drivers to force an issue into consideration in the planning process (Mander et al. 2005).

- Regulated Resources and Frameworks: Working through resource agencies, identify species and habitats covered by the ESA or state or local protections. Data may include species distribution data, such as probabilistic data or recorded occurrence data. Water quality regulations will identify aquatic resources to consider in measurement,

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along with other data sets, such as local or national wetland inventories.

- Nonregulated Resources: In addition to species or resources with specific protections, resources or habitats may exist that require consideration for community or regional interests. These resources may include species of local or state concern that are not afforded protections but are recognized by the public or NGOs as important. Examples are recreational, fishing and hunting, or subsistence resources. Native foods or resources may also need to be included.
- Ecosystem Services: Ecosystem services should be selected for inclusion in analysis or in a measurement system. Depending on the classification system used, ecosystem services can be divided into many categories, often too numerous for implementation in a transportation context. The Millennium Ecosystem Assessment provides a broad set of definitions for ecosystem services that can help identify ecosystem services to include in analysis (Millennium Ecosystem Assessment 2003).

Examining the Regulatory and Social Setting

Regulatory and social conditions can be evaluated through a historical review of DOT/MPO experiences and a forward-looking one that evaluates potential new regulations or social expectations from projects. A review of the historical experiences should include compiling permitting documents from previous projects over the past 5 years. This creates a baseline level of impacts that provide important planning information. First, this baseline helps understand the trends in resource impacts. Ideally, it includes cost assessments for compliance to understand the organizational costs. This baseline must be understood in the context of the statewide or metropolitan transportation improvement program (STIP/MTIP) priorities over the past planning period and compared with current priorities. Planning and project delivery often come in cycles of periods of greater and lesser construction intensity. Looking at the decisions made by policy makers about what is included in the LRTP or the STIP/MTIP can forecast the regulatory needs for existing regulations. Additional forecasting is needed to assess future potential regulation. In interviews with transportation planners, the project team uncovered a concern about the expansion of listings under the ESA, the growing applicability of the Safe Drinking Water Act, and the role of climate change regulation in transportation planning. These are examples of a need to analyze the potential challenges for transportation permitting and delivery assumptions in the early stages of planning.

The social setting captures the concerns, usually outside the formal regulatory system, that the public expects the DOT/MPO to address. These concerns often are identified via scoping or the development of environmental documents. These concerns can also be captured in a review of ongoing press and stakeholder communications in a more passive approach to assessing public concern (Costanza and Folke 1997). Often the public has not had the opportunity to fully study environmental issues, so clear and consistent preferences are not established. The team experiences these first hand in environmental processes in which stakeholder positions shift greatly over the life of a project as they learn more about the issues. This calls for a more active approach to developing public input, in which the public becomes not just an input during the process, but also is allowed to develop public judgment (Yankelovich 1991).

In this process, stakeholders are engaged to become experts of their own in the issues. Integration of transportation planning with conservation planning furthers this effort as conservation, transportation, and other stakeholders can build better understanding of issues through the crafting of the REF. This process is critical because preferences and values for natural resources often are difficult to capture at a personal or site level. To assure fairness and equity in environmental planning, transportation and conservation planning need to share information with the public about the functions and role of natural systems and allow preferences to be expressed or formed (Costanza and Folke 1997).

Identifying Additional Opportunities

Additional components to assess are ongoing compliance efforts or conservation programs that can provide opportunities for off-site mitigation actions that may provide improved environmental performance (Bean et al. 2008). These same programs have provided better transportation cost efficiencies and have ensured that costs are controlled and specific in project delivery (Oregon Department of Transportation 2008).

Traditionally, these opportunities have focused on examining existing banking or mitigation programs the DOT/MPO can take part in (ELI 2007). As mitigation banking has evolved, more innovative solutions are emerging from other biodiversity-based drivers derived from state or local laws (Carroll et al. 2008). However, new policy research has called for opening up innovative DOT/MPO-sponsored environmental mitigation and conservation programs to private entities to increase private environmental compliance and support DOT/MPO environmental programs (BenDor and Doyle 2010). BenDor and Doyle examined the North Carolina Ecosystem Enhancement Program (NCEEP) and identified the difference in compliance efforts by public versus private permittees. They suggest that the public-based system can be a smart extension to support local land use compliance requirements in private developments.

Nonmitigation-based opportunities can include examining the greenspace, open space, or other public land needs of neighboring jurisdictions, including state or county parks or local

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parks districts. These approaches can align with regional open space or green infrastructure programs, including "greenprint" or green infrastructure programs (Benedict and McMahon 2006). Although these programs may not be available legally for compensatory mitigation under federal law, they may provide an opportunity to meet with state, local, or nonregulatory expectations for projects, especially urban capacity projects.

Step 6b

Evaluate ecosystem and landscape needs and context to identify measurement options.

The initial step of diagnosing the needs for a measurement system identified the important boundaries for managing the resources. The subsequent step is to evaluate the necessary scale and units for management and identify linkages to landscape tools such as the REF or other selected tools.

The starting point for evaluating the need for an environmental measure is to define the service area boundary that the measure will be used within and the relevant resources and actors present. A service area is defined by the spatial limits that include resources with ecological connections and provide a definition for where off-site actions might be undertaken. For aquatic resources, service areas often are hydrologic. For faunal species, the service area may be a particular range or habitat. Air resources, especially carbon, can have large service areas. If an REF is being developed for the area, this is the proper starting point for identifying the appropriate boundary. However, additional refinement may be needed to assess the measurement options available if multiple resources are being combined. In addition to the ecological boundaries, it is important to be aware of traditional regulatory or political boundaries, such as ones created by federal or state law and local conservation regulations or land use requirements. It may be necessary to identify multiple boundaries initially, and once crediting is decided upon, the boundaries can be reevaluated for integrity.

Crediting Definitions and Considerations

Environmental measures can be divided into three classes of systems. First are condition-based measurements. Measurements in this category focus on quantifying changes in the status of the regulated resource. For instance, species of concern would be measured through population surveys. These systems also include pollutant load measurements, which are normally defined by quantifying specific amounts of criteria pollutants added or removed from the system (e.g., pounds of nitrogen or percent increase in turbidity). Condition-based examples include fish return counts, water quality measurements, and indices of biological integrity.

The second form of environmental measures is model-based measures that rely on data to estimate species or ecosystem response. Often these measures rely on concepts similar to condition-based ones or try to replicate a condition-based measure with models.

The third form of environmental measures is function-based ones. These measures focus on habitats, structures, and processes as the basis for measuring the environment. Function-based systems are not species specific and are used when rare or unique resources need measures that are not easily measured with one species. Model-based measurements can start to combine elements of a function-based measure and a condition-based system, in which the model relies on habitat or field data to estimate habitat use and densities.

To truly get at a measurement for use in transportation projects, the results need to tie the natural impacts back to specific actions at a site. This is needed for the full suite of mitigation decisions: avoidance, minimization, and compensation. These concerns need to guide the selection or development of a measure. In the following sections, the various existing measures used in environmental management settings are presented. This is followed by a guide for the development of custom measurements.

Condition-based measures are structured to collect data on the physical, chemical, and biological attributes of a system. These measures can be as simple as a plant and animal survey to measure the occurrence of a set of species. More complex measures provide the basis for long-term monitoring and management of a region.

Condition-based measures can be applicable in certain cases for transportation projects, although they present important challenges that must be considered before their use is agreed to in permitting or restoration. For transportation projects in remote and undeveloped areas with no other anthropocentric inputs to affect environmental quality, condition measures may be able to evaluate an action's level of impact. Condition-based measures also may be important in regulatory settings, where they are a common tool for management, such as under the CWA or Safe Drinking Water Act. An example of such a use is a river crossing with potential impact on surface drinking water sources. Disturbances to surrounding upland areas potentially may create erosion and sediment inputs that place the water body over limits for turbidity in a municipal water system.

Two primary forms of condition-based measures are indices of environmental quality or integrity and observation-based systems: indices and observation.

Indices-based measures for environmental measures are based on identifying a set of field-based measures that can provide a comprehensive index for health. Early implementation of the CWA was supported with the development of indices of biotic integrity (Karr 1981). These methods reflect an understanding that biological organisms better capture the health of a system than do strictly chemical or physical

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measures. This places a focus on a selection of species that are understood to represent the health of a system, such as macroinvertebrates or fish species. These measures provide a relative measure of health based on the comparison of reference sites and other randomly selected sites that are considered comparable for analysis. This process develops measures of deviation and allows for long-term monitoring. Data collected in this process are based on sampling surveys. Data can include species abundance, diversity, size classes, species composition, observations of health, and other biological measures. Data can be in absolute terms, such as abundance, or in qualitative terms, such as health (Hughes et al. 1982).

Observation-based measures are rarely used in accounting applications because of challenges in attributing causation to the observed data. A reasonable use is for relatively closed systems in which the DOT/MPO actions are clearly the only source of undesired impacts. Observation-based systems also apply in situations with species or resources that are relatively static, such as with floristic species. Observed measures also may be a component of monitoring sites after restoration or disturbance. Permit conditions also can be based on observed data. Examples of this include water quality monitoring in systems in which the contributors to turbidity are easily understood and any observed increase of the expected levels can be assigned to the construction activities in the watershed. This method has been used in limited cases and depends heavily on well-understood watershed processes that the permittee and regulator both agree on and trust.

Probability-based distribution mapping tools may replace traditional inventories of observed points, as described in Chapter 2. These probability-based tools are best suited for project planning to incorporate avoidance and minimization measure, and support the identification of sites for compensation. In general, observed data are not recommended for use in developing environmental measures unless a trusted and continuous base of data is available to provide reference conditions for comparison.

Model-based systems rely on an agreed-upon set of rules and conditions that are expected to result in an environmental outcome. Model-based systems are similar to condition-based measurement systems but usually are used for planning purposes. Unlike condition-based systems that focus on sample-based data, models focus on the elements of the ecosystem that can be affected by human action.

Examples of this are found in biological and chemical applications. Salmonid modeling, such as with the Ecosystem Diagnosis Tool, identifies the restoration actions or ecosystem components that contribute to species health (Lestelle et al. 1996; Mobrand et al. 1995). In a similar manner, the emerging carbon protocols for climate change accounting are agreed-upon models that represent the carbon benefits or detriments of specific actions (Voluntary Carbon Standard 2008). Models are best applied in complex environments where complete baseline data are not easily available and individual actions or impacts need to be understood in a context of many human actions that are difficult to attribute.

Function-based systems combine elements of condition-based systems and model-based systems. A function-based measurement identifies attributes that capture the habitat structures, elements, and other biophysical features. A function can be both abiotic and biotic. Abiotic measures tend to be more common because they are relatively static and easily observed. Biotic measures are also used but are more complex, relying often on multiple subfunctions to assemble to a properly functioning measure.

Functional measures often are performed with field-based observation and investigation. Attributes are empirical, observed data that include such measures as percent cover of vegetation, substrate types, slopes, species mixes, and so forth. The attributes are then evaluated based on scoring protocols built on existing literature, models, or peer review processes. These attributes then combine to provide a measure of performance for that function. The final unit of measure is a combined multifunction level of performance by area. This provides a functional areal measure that can be compared with other sites. Although reference sites are not necessary for functional measures, they can be used to test outcomes and calibrate scoring of credits. In this manner, they are based on site level evaluations with values based on best available science.

This approach provides a common unit of measurement for biological, chemical, and physical processes that can be linked readily to economic decision making (Groot 1987). Functions also provide a robust common unit for analyzing multiple resources or ecosystem services because functions provide a bridge between the biophysical and the final outcomes for which resources are managed (Boyd and Banzhaf 2007; Brown et al. 2007). Environmental economists have recommended making a shift toward function-based measures because they also allow for analysis of the services before clear pricing or valuation is developed. The structures and functions of a natural system must be understood before any value system can be placed on top of it (Limburg et al. 2002).

Several implementation benefits are available with the use of function-based systems. First, because the natural environment and ecosystem services are measured through constituent functions, multiple resources can be captured in a single measure. Second, the empirical basis of observed attributes of functions allows for easier inclusion of functional measures in contracts or permit terms and conditions. They are objective and enforceable elements that can be requested of an agency or contractor. Alternative analysis and scenario-based planning also can be implemented with function-based measures. The future scenarios specify the assumed attributes to

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be found on a site and can then be scored and credits or debits estimated. Scenarios in this context can include alternative vegetation management programs, stream restoration, forest management, as well as impact scenarios based on highway development. The alternatives can then each be evaluated based on the number and type of credits generated or diminished by the proposed actions.

Another benefit for functional measurement systems is that they provide a basis for ecosystem service measurements (Farber et al. 2002; Limburg et al. 2002). Adding the opportunity to also provide a field-based measurement provides the best approach to an empirical measurement for ecosystem services. Currently, function-based approaches are developed regionally with methods used based on the local scientists. Developing standards may be difficult but could improve the adoption of these methods.

Summary of Challenges

These three forms of measure can be understood based on the type and nature of data required and the temporal frame within which these measures work. Data included in these systems can be primary or secondary. In general, condition- and function-based systems focus on primary data collected specifically for the measure, although secondary data can be used. Modeled data processes existing data and does not rely on field-based data sets necessarily. The temporal frame is the usability of the measurement system to track changes versus the ability to forecast change. Functional and model systems are able to forecast change based on proposed actions or change in the environment. Condition-based systems rely on historic data and are challenged when they attempt to forecast future changes in condition. This temporal frame is critical in a regulatory or crediting scenario because proposed impacts and proposed restoration actions need some certainty in measurement before they are implemented. A common application of credits is in the terms and conditions of permits: these credits must be easily defined based on proposed restoration actions that may be written into a construction contract or similar agreement.

Condition- and model-based systems center on species and their responses to impacts on the environment. These measurements are most commonly used in monitoring species health and for responding to impaired landscapes, such as in restoring water quality. These measurement systems are suited for comprehensive management for a given resource. The challenge they present for impact and conservation actions is they do not provide a methodology to attribute the benefits or impacts of a given action. For example, a protocol for condition-based measures may include random sampling for macroinvertebrates. Ideally, longitudinal data collection has occurred to provide the baseline and level of variation. After construction of a project, the monitoring can continue and document a change. In practice, this is problematic. The baseline and variation analysis present the main barriers to implementation, which does not rule out the use of condition-based systems: they can provide information in design about resources that are considered vulnerable and thus required to avoid. However, the need to compare actual affected conditions to a reference site makes these measures best applied after construction of a project. This makes estimating credits in the planning stages challenging. The measures do not lend themselves to reliable forecasting of change because of the level of assumptions required. Condition-based systems can also provide a support for long-term monitoring after construction of a highway project or a restoration project.

Recognizing that each region, agency, and regulatory setting requires a unique response, these general classes of measurement are presented to help decide on the best system to use. In areas with lower levels of biodiversity, or with only one or two resources of concern, condition-based measures can assist transportation project delivery. In this context, the condition-based measure is tiered off of the REF, conservation plan, or recovery documents to provide priorities. For more complex environmental settings or when forecasting impacts are more critical because of the sensitivity of resources, models and functional measures excel. Finally, if multiple resources need to be tracked, forecasted, and credited, functional measures excel.

Selecting the Right Measure

This project has identified a number of tools at the landscape and planning level that address the need for integrated resource management with transportation development. These integrated programs provide guidance in planning to the project level. The crediting system documented here addresses the connection needed between planning level analysis and site level analysis. To fully implement the planning tools, a functional measurement system is needed to reconcile multiple resources at a site level.

One of the key challenges in site measures for multiple resources is the stacking of various credit types. Because many of the crediting programs will need to connect back to both regulatory and nonregulatory processes, it is necessary to document that no single credit is satisfying multiple regulations. In other words, credits must be shown not to "double dip" or count twice for a liability. One strength of functional measures is that credits are created with constituent functions that can be assigned to specific regulations or goals and mathematically isolated to prevent double dipping. It is important to note that this challenge is not an environmental one. Stacking in the environment is common because multiple resources can benefit from a single feature. For example, a riparian forest provides shading to cool adjacent waters,

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carbon sequestration through growth, and song bird habitat. These resources evolved to maximize the use of these benefits. However, the regulatory system requires that mitigation benefits be counted only for the debit to which they are assigned. This is technically accomplished with functions, but this distinction is important to remember that although the environmental benefits of stacking are clearly beneficial, they are seen as undesirable in the regulatory system. The technical details of stacking are discussed in the next step.

Step 6c

Select or develop units and rules for crediting.

This step provides the basis for developing a custom measurement system based on functions for multiresource crediting. If an appropriate existing measurement system was identified in the previous step, this step may not be necessary. The following sections detail the considerations and issues that must be addressed for a robust measurement that is also balanced with the level of effort needed to implement it. An excellent introduction into regional scale measurement requirements for ecosystem services can be found in *The Law and Policy of Ecosystem Services* (Ruhl et al. 2007).

Development of a measurement system must first consider the resources of concern and the size of the areas to be included. Much of this will have been identified in Step 6a, with the assessment of the various ecological, regulatory, and social contexts. However, in this step the details of the resources are further developed.

Identify Resource and Ecosystem Services

The first question to ask is what services or resources are of concern. An important starting point is to review the highway or agency-specific concerns and then identify services from there. For example, stormwater treatment may be identified as a concern. From an ecosystem services perspective, the site level need is for more naturally occurring water quality regulation. Water quality regulation as a service is provided by functions performed based on the existing vegetation, soil types, site topography, and other such factors.

Similarly, a regulatory agency or other stakeholder may identify a resource concern, such as a listed species or species of concern. These are biodiversity services. Functions are then identified that support these specific biotic concerns. For example, concern over aquatic species will require functions that support various life stages of the species, such as foraging and rearing, spawning, and connectivity for migration. These functions can then be defined through specific attributes, such as pool or riffle types, substrate, and adjacent bank characteristics.

As the services or resources are compiled and the necessary functions are identified to support them, overlap of functions will occur. Using the example of the water quality and aquatic species above, both will rely on functions performed by streamside vegetation that shades water bodies or reduces sediment and pollutant transport into water bodies. This overlap is a critical feature of the multiresource functional measurement system. It allows for the multiple resources to have a relationship that can inform site and design choices.

Develop Functions and Attributes to Measure Services

The basic spatial unit of a functional system is the map unit, a relatively homogenous and contiguous landcover type. Within these map units, attributes are collected that indicate the level of functional performance. Functions must be developed understanding this structure. Functions can be divided into the abiotic and biotic ones or functions that address biophysical processes versus species-specific processes. The measurements are based on attributes that can be easily collected by a field crew without extensive field instrumentation or long-term monitoring.

An overall functional performance score for the map unit is derived equally from the contributions of the abiotic and biotic functions. The respective biotic and abiotic functional performance scores are combined to provide a total biotic and total abiotic functional performance score for the map unit. The abiotic functional performance score and the biotic functional performance score are then combined and multiplied by area and habitat type to obtain the overall measure of functional performance for the particular map unit. These scores are summed to provide the functional performance score for the entire site.

A conceptual diagram is the first step in the development of a biotic or abiotic function. This aids in all aspects of the development of the function but most importantly in terms of the application of the measurement system. The conceptual diagram considers pre-existing conditions or current conditions to describe what the function requires at a site level. In general terms, this creates the logic of how and when to score a map unit for a particular function. The system itself turns functions on and off within the equations based on the triggering conditions identified in the conceptual diagram.

With the functional diagram completed, the attributes and scoring must be generated. Through a survey of literature, available science, outreach to experts, and other tools, the list of field-based data needed is developed for the function. In addition to identifying these attributes, their role in contributing to the performance of the function is evaluated. For all functions, there is a 100% level at which the natural system is performing the function at its highest possible level. It is helpful to consider this in evaluating the type and amount of attributes needed. Similarly, at 0% function, it is useful to think of what attributes, if missing, would limit the function fully. It is important to remember that at this level, other functions may

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be affected. For example, a function that is highly dependent on canopy cover will not co-exist with a function that is dependent on exposed ground or grasslands.

As attributes are identified, their relative contribution to the function will start to emerge, but the next step is to score all attributes for the function. For example, in a function that is evaluating a map unit's ability to infiltrate stormwater, the amount of pervious surface needs to be scored. In this case, it may be a logarithmic curve that indicates slight loss of functional performance as the initial increments of impervious surface are added to the map unit. However, each additional increment of change to impervious surface will have an increasingly rapid impact to the functional score. The scoring curves are drawn for all attributes that contribute to the functional performance.

As the functions are developed, the attributes must be checked across all the functions to assure that the data collection protocols remain constant. This is frequently a challenge in which different measurement standards are combined across disciplines. The compilation of the attributes will provide the basis for the creation of a functional measurement data sheet that combines all the data requirements for the system into a single instrument for field use. Another benefit of this functional approach is that as new functions are identified, they can be built from existing attributes or with just a few additional attributes needing to be programmed into the system.

The final consideration for functional measure development is temporal factors. To ease implementation, the goal should be for measures to work at any point in time. Water cycles, seasonal fluctuations, and other natural system dynamics can complicate this. For example, substrate observations for stream systems may be influenced by turbidity that limits visual assessment. These considerations need to be addressed because attribute data collection is defined in the field protocols. Other measurement methods may need to be developed or other assumptions may need to be in place to address the limitations.

As functions are developed, they are combined based on agreed-upon rules. Depending on the selection of functions to combine, there are often policy considerations that inform the relative importance of functions. For example, stormwater management functions may be prioritized over other functions in a transportation context. In these situations, formal weighting factors must be applied to capture these priorities. Although other services may still be important, they must be combined at a lower level with the higher priority stormwater management functions.

Step 6d

Test applicability of units and rules in local conditions.

The application of a functional measure is a three-step process. Initially, the current pre-implementation (baseline) condition of the site is determined using data collected onsite. The system generates a baseline functional performance score for the site. The second step of the process is to generate one or more design alternative scenarios. For each of these design alternatives, a set of map units and data for each is generated based on the information in the design plan. This should reflect conditions on the site at some pre-determined future date. In general, a 20-year postimplementation time period is used. Using this set of map units and data, a future conditions functional performance score is generated for each alternative considered. To determine the uplift or impact of a given design, the baseline conditions site score is subtracted from the future conditions site score. If the resultant number is negative, a debit has been generated; if positive, the project results in uplift. The degree of impact or uplift is the number generated.

Step 6e

Evaluate local market opportunities for ecosystem services.

Market opportunities can include existing wetland or conservation banking systems or more advanced payment for ecosystem service (PES) systems. PES programs are negotiated contracts with landowners to maintain a certain level of environmental performance to maintain or enhance ecosystem services (Forest Trends and Ecosystem Marketplace 2008). Criticisms of these systems come from a concern that there is no clear way to track the performance. However, this is a technical measurement problem and does not undermine the potential power of PES systems (Redford and Adams 2009).

Developing ecosystem metrics and tracking project impacts using those measures can make it easier to access any operating regional ecosystem markets. Step 6a includes consideration of the existence of ecosystem markets as part of the regulatory compliance considerations associated with selecting or developing an ecosystem metric. If these criteria have been properly considered, the DOT's/MPO's ecosystem measurement system should be well suited to ecosystem market use.

There are a number of reasons why ecosystem markets provide a better solution for DOTs/MPOs, including the following:

- **Certainty.** Purchasing credits from a mitigation bank removes the schedule risk and uncertainty associated with getting approval of mitigation site and design. In addition, there is greater budget certainty because the cost per credit generally is a known quantity, whereas the costs of mitigation design and construction are not (particularly for sites that have difficulty with plant establishment). The costs of mitigation and the liability associated with those costs can extend 5 to 10 years or more.

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- **Transfer of Liability.** Many ecosystem markets include a transfer of liability for mitigation success. Wetland mitigation banks pursuant to Section 404 of the CWA and conservation banks pursuant to the ESA place the liability for restoration/conservation success on the banker. Note that this is not universally the case. Liability under the CWA's National Pollutant Discharge Elimination System (NPDES) program remains with the permittee, even when the permittee is meeting permit conditions through a market transaction.
- **Better Alignment of Missions.** Although many DOTs and MPOs employ highly qualified and experienced biologists and ecologists, the mission of the DOT/MPO is focused on providing and maintaining transportation systems. This means the DOT/MPO project delivery focus is on the road, bridge, or other aspect of transportation infrastructure, not the wetland or native habitat being restored as part of the project's impact compensation. In this circumstance, it is not uncommon to have the mitigation lumped into the same contract as the road or bridge construction. This can lead to situations in which the grading and earth work for the mitigation site are done by contractors with experience and expertise in road construction. Restoring a wetland and building a road require different skill sets. It is best when restoration professionals build mitigation sites and road construction contractors build highway infrastructure.
- **Improved Ecosystem Outcomes.** Ecosystem markets provide the opportunity to focus larger and more meaningful restoration projects toward addressing regional ecosystem priorities. In making this shift, the postage stamp mitigation that is the frequent outcome of DOT/MPO projects is eliminated. These small mitigation sites are inefficient and too often not ecologically viable or useful.

On the other hand, mitigation bankers have an incentive to focus on ecologically desirable outcomes (because regulators are less likely to approve use of the bank if it is not providing good ecological benefits). In addition, they have an incentive to focus on the site and make it successful because in most banking contexts, credit release is incumbent upon reaching preestablished success criteria. This means that not only is society more likely to realize the ecological benefits, those benefits are in place before the impact occurs. In traditional mitigation, at best the restoration activities are concurrent to the impact activities, but there is inevitably some temporal lag before the mitigation starts to provide ecological benefits.

To add to all these benefits, mitigation banks provide in perpetuity protection for the site. Often this means turning the site over to a third party (e.g., land trust or conservation organization) with an endowment to pay for long-term site management. In contrast, until new regulations were adopted in 2008, a typical mitigation site received only 5 to 10 years of monitoring and then was on its own.

Step 6f

Negotiate regulatory assurance for credits (sacking credits and double-dipping).

Ecosystem functions and services have interconnected relationships that can be complementary, conflicting, or magnifying based on their interactions. The ability to measure multiple resources and services at once is a critical feature in functional measures, particularly when used to generate credits that will be bought or sold in a mitigation or ecosystem marketplace context. By working at the most basic level of environmental measurements, functional measures provide a system that can stack or combine multiple credit types or resources and, at the same time, assures that credits are used only as approved and allowed. This stacking function allows for the interactions of the natural elements to be more fully measured.

Incentives for investing in conservation and restoration actions that generate a wide variety of ecosystem benefits are currently missing in regulation-driven, acreage-based credit systems. Generally, once a site meets the minimum regulatory requirements for mitigation of a given resource, all potential additional benefits provided by the site are ignored or forgotten. But with a stacking credit system, the proper incentives for conservation can be introduced as the benefits of an action to all resources become clear. Similarly, in an impact context, stacking allows the effects on resources to be better understood.

Stacking requires strict accounting to prevent the use of credits to offset impacts of multiple projects. In a regulatory context, this is critically important. Through the function-based nature of credits, individual functions are assigned to the credit type that must be audited. This ties the constituent components of the credit together, ensuring that credits are not used repeatedly in different transactions (double-dipping).

Step 6g

Program implementation.

There are a number of ways in which good metrics can inform transportation planning processes and be incorporated into project compliance documentation and regulatory processes. For instance, good metrics can provide a much better means of conducting NEPA alternative analysis. A good metric also can provide the basis for terms and conditions, conservation measures, and performance standards. In addition, when combined with an appropriate landscape measurement system, it can be the basis for justifying off-site or out-of-kind mitigation. It is important that project delivery staff be aware of these opportunities.

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There are a few basic thing DOTs can do to encourage these improvements. For instance, it is important to provide ongoing training and support for staff to help them understand the potential opportunities for process improvements. An easy way to affect this type of support is to use a community of practice approach so that relevant staff have a mechanism to share concepts and ideas and impart lessons learned about what worked and what did not work. Another useful step for program implementation is to develop a data sheet that standardizes the metric application. Ideally, the data sheet will become an integrated part of project data collection and will be used to make that process more efficient and effective.

Step 7: Develop Programmatic Consultation, Biological Opinion, or Permit

Purpose

Develop MOUs, agreements, programmatic 404 permits, or ESA Section 7 consultations for transportation projects in a way that documents the goals and priorities identified in Step 6 and the parameters for achieving these goals.

Outcomes

- Agreeing on resource management roles and methods.
- Incorporation of outcome-based performance standards into programmatic agreements to improve project avoidance and minimization, as well as aiding effective monitoring and adaptive management actions.
- Establishing Programmatic ESA Section 7 consultation, SAMP, RGP, or agreements enabling agencies to proceed with conservation action in line with CWA Section 404 and ESA program objectives/requirements and with maximum assurance that investments count and will be sufficient.

Implementation Steps

7a. Ensure agreements are documented relating to CWA Section 404 permitting, avoidance and minimization, ESA Section 7 consultation, roles and responsibilities, landownership and management, and conservation measures.

7b. Plan for long-term management and make arrangements with land management agencies and organizations (e.g., land trusts or bankers) for permanent protection of conservation and restoration parcels. Notify and coordinate with local governments for supportive action.

7c. Design performance measures for transportation projects that will be practical for long-term adaptive management and include these in the 404 permit and/or Section 7 BA/BO.

7d. Choose a monitoring strategy for mitigation sites, based on practical measures, ideally using the same metrics as those used for impact assessment, site selection, and credit development.

7e. Develop programmatic ESA Section 7 consultation, Special Area Management Plan (SAMP), Section 404 Regional General Permits (RGPs), or other programmatic agreements to advance conservation action in line with CWA Section 404 and ESA program objectives/requirements and with maximum assurance that conservation/restoration investments by DOTs count or will count.

7f. Set up periodic meetings to identify what is working well and what could be improved.

Technical Considerations

- Who will lead in development of needed agreements?
- Under what conditions would the agreement be revisited?
- Set up periodic (at least annual) meetings to identify what is working well and what could be improved.

The use of the integrated planning method described in this report provides the ideal basis for programmatic agreement implementation. Programmatic agreements (programmatics) can include agreements for compliance under a number of regulations or statutes. Common programmatic agreements include biological opinions (BOs), Section 404 permits, and local permits. In general, programmatic agreements require more time and effort initially as the details and terms are developed. Because of this, the usual application of programmatic agreements is in settings in which a project or series of projects will require numerous permits or consultations and each will be similar to the others. In this case, a traditional review process would drain staff and agency resources through repetitive reviews that do not add value.

The level of resource and transportation information developed in the REF and transportation plan documents provide a strong foundation for identifying programmatic implementation opportunities. Through an analysis of the common impact types developed in Step 6, a set of programmatic permits can be developed to help speed project delivery. Programmatic agreements within the REF must describe the resources covered, the types of impacts or activities covered, and clear instructions on avoidance, minimization, and mitigation in program delivery. The programmatic also must include tools to assist in monitoring and management of the programmatic to assure the sum of the actions included is meeting the expectations of the signatories and participants.

Advantages for using programmatic agreements or permits rest primarily on the streamlining allowed once the agreement is in place. Once the agreement is in place, use of a programmatic agreement or permit can be as simple as

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a one- or two-page letter that outlines the action and the affected resource information and certifies that the impacts of the project are documented and within the agreed-upon thresholds. Programmatic agreements allow resource agency time to be more efficiently used and the agreements to focus on monitoring or tracking of projects. These agreements can also cover multiple regulations or resources, and in the REF setting should in fact do this. This multiresource programmatic approach can integrate permitting decisions to avoid conflicts between regulated resources, such as listed species and Section 404 requirements. This multiresource approach also may rely on on-the-ground ecosystem credits, as identified in Step 6. These multiresource credits encourage comprehensive mitigation with conservation priorities included.

Challenges for a programmatic tend to rest on the complexity of the resources and the diversity of impacts included. Another important component of programmatic agreements is the level of trust and history of collaboration among all involved agencies. These agreements may require high-level support and an ongoing collaborative staff relationship. If these two components are not in place, programmatic agreements are difficult to create and maintain. This may also include stakeholder buy-in. Conservation groups or other advocacy groups can play a key role in challenging these agreements or supporting their implementation. Thus, the relationships identified in Step 1 and maintained throughout the planning process will be instrumental to successful implementation.

Volume 1 documents the benefits and challenges in implementing programmatic agreements, includes guides for developing these agreements, and provides sample documents based on agency and resource.

Even in cases in which the diversity of resources, impacts, or stakeholders makes programmatic agreements difficult or impossible, the data and values from the REF can provide a key path to individual permit decisions. The REF and ecological priorities allow for analysis of alternatives, permit performance standards, and other important decisions to be reached without having to perform the analysis for each permit. This savings alone can speed project delivery greatly and reduce costs from delays.

Step 8: Implement Agreements and Adaptive Management

Purpose

Design transportation projects in accordance with ecological objectives and goals identified in previous steps (i.e., keeping planning decisions linked to project decisions), incorporating as appropriate the programmatic agreements, performance measures, and ecological metric tools to improve the project.

Outcomes

- Maintaining continuity from early planning processes into the project implementation phase, including:
  - Use of regional ecological goals and objectives in project planning and decision making
  - Use of REF map to guide project avoidance and mitigation decisions
  - Incorporation of performance standards and programmatic agreements as appropriate into permitting and consultation documents
  - Integration of programmatic cumulative effects analysis into project NEPA, Section 404 and Section 7 analysis
- Incorporating tools and approaches into a monitoring and adaptive management strategy to ensure positive project outcomes.
- Accurate record keeping and tracking of all commitments by transportation agency in project delivery.
- Updating information from construction and operation into REF.
- Measuring performance success in project delivery.

Implementation Steps

8a. Design and implement methods to complete transportation project(s) consistent with REF, conservation and restoration strategy, and agreements.

8b. Identify how advance mitigation and conservation will be funded, if this has not been done already.

8c. As needed, develop additional project-specific, outcome-based performance standards related to impact avoidance and minimization.

8d. Design transportation projects and integrate performance measures to minimize impacts to resources.

8e. Use adaptive management to ensure compliance with requirements and intent of performance measures.
  - Develop and track ecoregional biodiversity, indicators of viability, and integrity.
  - Develop and track conservation status, protected and managed area status, and management effectiveness.
  - Identify remedial actions and needed plan adjustments.
  - Adjust the planning process and management processes and/or management of individual conservation areas.
  - Incorporate outputs into future cumulative effects analyses for the region.

Technical Considerations

- What tools are available that could help document goals and priorities identified in the REF that need to be considered in project delivery?
- What tools and methods can be used to track how projects contributed to and/or improved the REF priorities and goals?

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Ecosystem Accounting Aspects: An important aspect of any crediting system is to include an adaptive management or policy feedback loop that allows for new discoveries to inform better crediting. Credits should be monitored and measured against other measurement systems. This is an important step, and one that may change standards from one version of the crediting to the next. This is an acceptable change if justified by new science or policy priorities. However, it is important to set these changes in the context of previous decisions so as to not create new barriers for crediting in future projects. Adaptive management relies less on the idea of precedents and more on the notion of new discoveries and decisions: the process cannot become overly tied to past decisions if new information is available.

Step 9: Update Regional Integrated Plan and Ecosystem Framework

Purpose

Update the effects assessment to determine if resource goal achievement is still on track. If goal achievement gaps are found, reassess priorities for mitigation, conservation, and restoration in light of new disturbances that may affect the practicality/utility of proceeding with previous priorities. Identify new priorities if warranted.

Outcomes

- Updating REF and cumulative effects analysis.
- Updating conservation and restoration priorities.

Implementation Steps

9a. Integrate any revised conservation plans into the regional integrated plan and ecosystem framework and, where appropriate, update individual resource spatial information.

9b. Update the area and resource conservation requirements, responses, and indicators in collaboration with stakeholders (e.g., assess regional goals, update to minimum required area for species and/or habitat, review confidence threshold for achieving goals, review weighting values of resources in REF, evaluate responses to land use and infrastructure).

9c. Update the implementation status of mitigation areas in the REF to review areas that are contributing to REF goals and priorities and determine if additional conservation/protection action is required.

9d. Update the cumulative effects analysis with new developments, new disturbances, proposals, and trends (e.g., ecosystem-altering wildfire, new policies, plans, proposals, and trends such as new sea level rise inundation models).

9e. Conduct regular review of progress, including effectiveness at meeting goals and objectives, current take totals, and likelihood of exceeding programmatic take allowance.

Technical Considerations

- Has the status of species or habitats changed? How does this affect REF goals?
- Do areas on the landscape critical to meeting goals identified in REF need additional protection or restoration action?
- How often should the REF be revised to incorporate new conservation data or plans?
- How often should the cumulative effects analysis be updated?
- Are indicators used to track conservation progress capturing the correct trends?
- Are transportation project delivery indicators improving (e.g., streamlined decision making and/or better conservation outcomes)?
- How can modifications be moved forward to alter mitigation and restoration priorities previously identified but not yet implemented?

Technical Implementation of Step 9

Step 9d

Update the cumulative effects analysis with new developments, new disturbances, proposals and trends (e.g., ecosystem-altering wildfire, new policies, plans, proposals, and trends such as new sea level rise inundation models).

The Framework implementation as described is explicitly designed to support adaptive planning and management. A key aspect of this process then is to re-analyze the cumulative effects when there is a significant change in potential stressors to the ecosystem. Each assessment iteration should entail the following:

a. Update the effects assessment to determine if resource goal achievement is still on track.
b. If goal achievement gaps are indicated, reassess priorities for mitigation in light of new disturbances that may affect the practicality or utility of proceeding with previous priorities.
c. Identify new priorities if warranted.

Ecosystem Accounting Aspects: As changes occur in the REF or new information is included in the decision-making, the crediting system also will need to adapt. This may be due to new resource concerns, emerging regulations, or public concern that is critical but not yet regulatory. Periodically re-evaluating Step 6 will assure that the crediting system is current and in alignment with environmental, social, and regulatory concerns.

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CHAPTER 4

Pilot Projects

Background of Pilot Tests

This chapter summarizes the results of testing the CEAA process, including the wetlands and ESA regulatory assurance approaches, in three states. Appendix C includes a detailed report of each pilot test addressing how and why the project was selected; the original project and project area; detailed results of the testing comparing original outcomes to outcomes using the CEAA process; and conclusions and lessons learned.

Summary of Pilot Test Results

In the pilot tests, the project team compared the approach and outcomes of the original project and planning efforts in each state with the approach and outcomes using the CEAA process. The comparison focused on decisions and outcomes related to direct impacts, cumulative impacts, and mitigation effectiveness.

Overall, in the three pilot areas, the team found that transportation agency staff accurately understood and accounted for direct impacts to natural resources. The transportation agencies used existing data in combination with environmental studies to support the evaluation and selection of the transportation alternatives that typically looked at direct impacts. Using the CEAA process, the pilot assessments achieved results similar to the original project assessment. Thus, in the realm of direct impacts, the team's approach produced results similar to traditional methods used by transportation agencies. It is important to note that the CEAA testing process did not include any field studies, yet very similar potential impacts were found at a much lower cost and likely in much less time. Because of the limitations of data accuracy and resolution, the need for on-the-ground evaluation of a project site may remain, but the CEAA process could target field studies and thereby reduce overall assessment costs.

For cumulative impacts, the traditional approach is to look at the impacts to a species or resource based on the existing condition of the landscape or habitats. The team's pilots included information that indicated how the habitats looked historically to show how the habitats had been affected over time, and thus provided a truer picture of the cumulative effect that additional impacts would cause. Data that show how the landscape looked historically often are not used because they are not readily available, but in most cases there are other sources of data often available through state or federal agencies that can be used as a proxy for historical data (such as hydric soil data).

When the team assessed cumulative impacts and the selection of mitigation options, the pilot test teams observed more significant differences using the CEAA process, especially when compared with long-range and corridor planning efforts. These differences were attributable mostly to these factors:

- The team's process suggests that for species within a project area or corridor, cumulative effects and mitigation options should be evaluated within a larger, more ecologically based area than is typically used.
- Some of the original planning efforts in the pilot states included less comprehensive or no ecological information.
- Different or more comprehensive data (e.g., historical landscape, wetland priorities, and predictive species distribution maps) were utilized in the team's assessment of the project area.

Through this comparison, the team came to a better understanding of issues related to the use of data to assess impacts to natural resources, evaluate mitigation options, and recommend the development of key data sets to improve the assessment of ecological resources. For example, the pilot tests illustrated how the accuracy and resolution of data influence what types of data are most useful for planning level decision

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making versus project level decision-making. Therefore, one key component of the CEAA guidance is a suggested list of data sources that support each step of the guidance. The CEAA also provides suggestions on other high-priority data sets, such as high-quality data on wetlands and endangered species that generally are not available across the country but, if they were available, would streamline the assessment of landscapes for planning and project development. The team then documents how these data sets could be created for areas where they are not yet available.

The project team also looked at the time and cost of planning and project development for the pilot test areas and documented ideas on how the use of the CEAA could have streamlined transportation planning and project development decision making, likely saving time and money. The Michigan pilot illustrated that the evaluation of corridors using the CEAA process would result in a more accurate assessment of potential impacts and support the selection of corridors with the lowest mitigation-related costs.

The most significant differences found from each pilot test state when comparing the outcomes of the original assessment versus the outcomes of the CEAA were as follows:

1. *South I-25 Corridor (Colorado):* CEAA assessment promoted a more accurate assessment of cumulative impacts (therefore effecting the ratio of mitigation requirements) by including spatially explicit analyses using data not included in the original assessment, and by defining a larger, ecologically based assessment area.
2. *US-131 Corridor (Michigan):* CEAA assessment resulted in the selection of a different alternative that had the least number of impacts and therefore would have reduced mitigation requirements. The results differed because the C06 pilot team used more detailed ecological data than was used in the original corridor assessment, including historical wetland data and data from a 2005 wetland functional assessment, and used a decision support tool allowing a very precise and quantitative impact assessment for each resource.
3. *Pioneer Mountain to Eddyville Project (Oregon):* CEAA assessment recommended mitigation in larger priority wetland areas in the watershed that would have provided opportunities for creation or enhancement of salmon (coho, chinook, and steelhead) habitat.

It is worth noting that the project team used two different decision support tools to conduct the CEAA pilot tests. NatureServe Vista (NatureServe 2009) was used in Colorado and Michigan, and Envision (Guzy et al. 2008) was used in Oregon. Although the focus of these pilots was not to demonstrate the efficacy of decision support tools, the detailed pilot test report for Michigan (found in Appendix C) includes information on the advantages of using NatureServe Vista versus a GIS without the Vista ArcGIS extension. The efficacy of decision support tools has been demonstrated in many publications. These tools allow the practitioners to automate the process of running new transportation alternative scenarios as information or priorities change, something that cannot be done as efficiently using only GIS (Hamilton and Baker 2003).

An unexpected and unfortunate finding of the pilot tests was that in all three states, the data that were used for original assessment of the project area were not readily available and were not available in a GIS layer suitable for use with a decision support tool. Thus, even data collected from costly field studies were not captured in a way that could be used for future assessments. Encouraging collection and maintenance of GIS data and developing data management standards that can be adopted by both transportation agencies and natural resources agencies will lead to increased data accessibility, allowing data from single projects or agencies to be applied to future projects or regional studies. For example, if field studies for a listed species were completed and that information provided to a database on the status of imperiled species in that state (such as those maintained by state Natural Heritage offices), that information could contribute to rangewide assessments of those species by USFWS and other natural resource practitioners for conservation planning purposes. Not only can sharing data across projects and agencies increase the transparency and completeness of future projects, it can reduce costs by cutting down on the staff time needed to gather all necessary data for the project planning process.

Conclusions

Overall, the pilot tests were essential in demonstrating the practical value of using the CEAA process to streamline and improve decision making in transportation planning and project development. Clearly, the CEAA could be effective in creating more accurate "sign posts" early in any transportation decision-making process that could alert practitioners to potential impacts and mitigation opportunities.

Some key findings and conclusions from the testing of the CEAA process included:

- ***Better Outcomes.*** The most significant changes were in the areas of mitigation site selection, evaluation of multiple corridors, and development of transportation plans. The pilot test results led to the selection of mitigation sites with more ecological benefits and provided more accurate and comprehensive scenario assessments that identified corridors with the least number of direct and cumulative impacts.
- ***Benefits of Modest Investments in Data.*** The usefulness of the CEAA for planning and project development are dependent on the accuracy and resolution of available data. A

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relatively modest investment in process changes and data development upfront would create more accurate sign posts early in the decision-making processes of potential impacts and mitigation opportunities, vastly improving planning, corridor evaluation, and consideration of mitigation opportunities.

- ***Increased Scientific Credibility.*** Decisions have more credibility because the CEAA process ensures the use of a standardized, scientifically based, peer reviewed process that uses the best available suite of methods, data, and tools.
- ***Savings in Time and Resources.*** The CEAA approach likely would save time and resources by reducing impacts and therefore mitigation requirements, as well as supporting more targeted field studies for assessment of alternatives.
- ***Standard Data Management Practices.*** Better data management and data sharing practices would contribute to better application and accessibility of data collected during transportation alternative assessments for future decision making not only by transportation agencies but also by natural resource agencies.

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CHAPTER 5

The Web Tool

An interactive database was developed to provide ready access to the CEAA technical guidance and supporting strategies for regulatory assurances and environmental crediting. The database is designed to integrate with and support the website developed by Project C01, Transportation for Communities: Advancing Projects through Partnerships, (ICF International 2012). The site's full practical application will have links to key decision points. A permanent repository for the website will be developed in collaboration with TRB and FHWA.

The website is intended to serve as a hub, promoting interdisciplinary collaboration by filtering the vast quantities of information and resources supporting local and regional transportation planning and ecosystem-based management according to four themes: tools and methods; cases; references; and data. Thematic content will be linked across these four areas and will follow the nine steps of the Framework, providing multiple access points for practitioners to locate relevant information. The interactive database and website represent a valuable platform to make research and resources readily available to communities and for this information to be in the form of a living document that is constantly updated and refined.

Users will be able to access information in the following ways:

- **Search by Concept.** The user wants to better understand how off-site mitigation might be done and why it is useful. The user wonders about predictive species modeling and why it is relevant to transportation planning.
- **Search by Case Study.** The user is wondering what neighboring states are doing. The user can search by location or type of work being done (such as cumulative effects assessment, and spatially explicit long-range planning).
- **Search by *Eco-Logical* Step.** The user is familiar with the *Eco-Logical* framework steps but want to understand one of them in more depth or how others have implemented this step in the framework.
- **Search by Data.** At a recent conference, the user heard about a source of data or a new type of data that might be useful in his/her state, and he/she is trying to understand more about it and where in the state he/she might be able to acquire it.
- **Search by Tool.** The user heard about a tool and want to understand how it can be useful in integrating conservation and transportation planning.

The primary audience for the technical guidance is transportation agency staff, state and federal fish and wildlife agencies, and other environmental regulatory agencies. To fully realize the vision, a secondary audience is also addressed. This audience includes nonregulatory agencies and organizations that typically create data and other products such as conservation priorities of use in the assessment process.

The database and resulting website are written in an accessible, hierarchical way so that users can begin with the overall Framework and hyperlink to increasing levels of detail based on their role and interests. For example, a manager may want to understand the overall Framework, whereas a resource specialist will want to link to details about specific tools, data, and analytical procedures. The site has interactive search capabilities and the ability to tap into a rich database of sister sites. The site will provide forums for practitioners to communicate informally and highlight innovative programs and activities. The website is designed to be flexible, easily refined, and expanded as the process evolves and is implemented. The project team thinks the guidance set forth by the CEAA process ultimately will best be updated through the volunteer efforts of the transportation community, much like open-source software.

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CHAPTER 6

Symposium

At a symposium held in September 2010, the SHRP 2 Capacity Project 6 research was presented to transportation and resource agency participants. The project team's work was presented after each step of the Framework for integrated conservation, restoration, and transportation planning. The results of the pilot projects were summarized. This chapter summarizes the feedback received from participants, with a focus on the technical and scientific work done by the project.

Feedback and discussion started by asking participants to write down what they see as the greatest opportunities for implementing the integrated planning approach and what they think is needed to make it practical for users. One comment summarized much of the discussion, "There is an emerging paradigm where transportation can be an ally, and not an enemy, in the conservation process that is starting to take hold." The written answers to the introductory questions were combined with discussions captured from facilitated breakout groups to summarize the principle themes raised at the symposium.

Approaches and Frameworks

Transportation agencies now are considering what the right project is and factoring in ecosystem approaches and watershed frameworks, rather than doing business as usual where these factors may have been ignored. The new approach encourages better information sharing and allows information to be used and improved on an ongoing basis. New approaches such as ecosystem services markets are aligning interests of development entities, conservation groups, landowners, and investors. Development of these markets not only could provide on-the-ground conservation, but also could drive data collection and information generation to minimize investment risk.

Working Together

Resource agencies are collaborating and providing a basis for broader regional collaboration. Trust is growing, and interagency relationships are starting to build, which leads to more consensus on areas of ecological importance, improves conservation outcomes, and promotes leveraging funds for enhanced ecological success. As one participant said, "Agencies and organizations are coming together more and sharing initiatives, ideas, and priorities, realizing we are all going in the similar direction and making changes to work together (and not staying in our bubbles)."

Transportation and resource agencies are talking, learning, and sharing more at all levels. The conversations are moving beyond technical matters and legal requirements to recognition of the need for trust to make progress. Collaboration such as this is needed at all levels, including with interest groups and stakeholders.

It is critical to develop a better understanding of terms being used (e.g., mitigation, avoidance, assurances, restoration, conservation) and systems being developed (e.g., *Eco-Logical,* REF) to avoid confusion and ensure clear communication. This is vital in terms of building on all the work currently under way. The discussion suggested that transportation and resource agencies may use terms such as avoidance, mitigation, and restoration differently. There was not time to sort out the differences at the symposium.

Awareness and Recognition

There is increasing recognition that all agencies can integrate conservation within their missions and work together toward shared goals. Recognition of the need to protect natural areas, functions, and services across jurisdictional and ownership boundaries is also growing. There is widespread recognition that the current process is failing us and

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failing ecosystems. This has led to an emerging push to balance mobility needs with the need to preserve and restore ecosystem health.

Institutional Change

The participants identified several forces driving the need to shift to an integrated conservation and transportation planning system and several needs that must be met if these opportunities are to be realized. The upcoming transportation reauthorization bill and climate change both create a sense of urgency. It will be vital to build partnerships with other development and land use agencies beyond transportation agencies, particularly land use decision makers, for the value of the approach to be fully realized.

High-level officials now recognize that the comprehensive ecological approach is good for the environment and the economy, and new state legislation is being enacted to develop integrated ecosystem market places. The Obama Administration initiatives, such as Sustainable Communities (see U.S. Environmental Protection Agency 2012a), complement the *Eco-Logical* approach and should be built on. In contrast, the Administration's National Infrastructure Initiative does not include natural resources or green infrastructure, and it should. Many organizations now seek to work with EPA and USACE to apply the watershed approach. There are now more mitigation banking systems, landscape level approaches to project mitigation, statewide connectivity plans, and other examples of integrated transportation and conservation planning for regulated and nonregulated resources.

These developments represent a major cultural shift for transportation and resource agencies from a single project (project by project) to a landscape approach focused on ecosystem results at a larger scale. The landscape approach allows more flexibility and requires more stakeholders. Ultimately, it is critical that all agencies look at ecosystems in their entirety, not just regulated resources.

Regular face-to-face meetings at the regional level are needed to develop trust and maintain continuity for integrated planning. This approach also requires staff with specific responsibilities to support this integrated planning process in local government, state transportation, and resource agencies.

For the Framework to be implemented, champions need to be recruited at all levels of transportation and resource agencies. The symposium participants said that resource agency staff do not know what *Eco-Logical* is, even if their agencies signed the agreement. Even in states or regions where the integrated approach has been embraced, staff changes and continuity pose major problems.

Funding

Transportation agencies have perhaps the largest source of dedicated public funding for restoration and conservation, and they have been willing to fund projects that do not necessarily benefit the transportation systems directly. Local agencies have also been willing to fund advanced mitigation. Flexible funding is needed for holistic solutions that address pre-existing deficiencies and enhancements.

Regional Ecosystem Frameworks

The biggest issue raised regarding REF preparation was the need for some entity to own it and assure that it is implemented. Answering this question is critical to selling the approach. The second issue raised was who pays for it? One participant said that the Framework underplays the amount of time, money, and effort needed to do it. It needs to be able to explain how much these processes cost and what a DOT needs to do to make this approach happen. The third issue was the audience. The audience needs to be targeted in the write-up of the Framework.

An opportunity exists to use REFs for projects other than transportation projects. For example, the REF could be useful in helping to figure out the best way to replace aging infrastructure overall. Energy companies and other utilities should become partners in integrated planning efforts. The REF could support improved stormwater management, asset management, and climate change responses. The approach could be sold on the basis of these benefits.

Inevitably, in states where there are more listed species and wetlands, such as California and Florida, there is a demand and urgency for innovative solutions that does not exist in states without those species and wetlands. One participant also noted that transportation agencies are doing fewer new capacity projects. Most of the transportation projects in this state are categorically excluded from NEPA, so there is little reason for a transportation agency to participate in the REF work because the projects are so small they have little cumulative effect.

Data, Tools, Scientific Information, and Decision Support

Advances in remote sensing and species and habitat inventories improve information on population distributions, whereas new decision support tools support the *Eco-Logical* approach and improve conservation outcomes. Landscape scale and project-specific scale data are different, but this hierarchy can be flattened now given greater computing power and modeling methods. The new information and tools are more accessible and usable by nonspecialists, allowing agencies to share data,

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tools, and analysis. A wish was expressed for a database of potential mitigation and restoration projects that could meet multiple federal and state requirements and the goals of non-government entities.

Data needs and opportunities were discussed in some detail. The participants repeatedly noted the need for improved geospatially explicit data sets in digital form that capture historic, as well as current, information. Data set development needs should be prioritized for investment. The data need to be collected and maintained to provide ready access for multiple users and applications and to incorporate data from all levels and projects. This will require data for multiple functions, not just transportation.

The data need to be live to allow users to create their own data mashups. These data are needed to populate decision support systems such as the USFWS's online Information, Planning and Conservation System (2012b). Tools need to be developed to use the data in implementing the Framework, and the tools should have a common interface. There needs to be a primary funding source for gathering and managing these regional, state, and nationwide data sets.

Participants confirmed what the project team found in their research. Most DOTs and MPOs do not have protocols for data collection and management, and they do not require consultants to integrate data they collect into an accessible central system. For an integrated planning system to work, consistent protocols are needed describing what type of data is to be collected, how data will be evaluated, and what data should be retained and managed. The overall system must be designed to assure that data are updated regularly because natural events (fire, disease, flood, climate change) and development can alter resources of concern. A long-term commitment to gathering, managing, and sharing data also is required.

Crediting and Advance Mitigation

There are challenges with crediting that the Framework cannot address, such as market development, double-dipping, and the sophisticated operations and management and accounting systems needed to assure a market delivers results. Resource agency staff often are leery of crediting and concerned that mitigation done for one project not count for another. There is a tendency for regulatory agencies and transportation agencies to focus only on the project site.

In terms of both crediting and advance mitigation, metrics from the planning process need to carry through to project delivery and monitoring. At the planning level, transportation and resource agencies need to think about whether the right project for the context is being proposed. Participants also noted that for all planning and projects, there is a "sweet spot" at which money for the transportation project is available at the same time the mitigation or conservation opportunity exists. Mitigation is likely to be more effective for long-term conservation, and advance mitigation is more likely to occur when funds line up with opportunity in this way.

Participants emphasized that buying land and doing a mitigation or conservation project is not enough. Long-term land management is essential to assure that the environmental outcomes are both achieved and maintained.

Implementation Activities

Specific suggestions were made to the TRB on how to implement the results of the C06 research projects.

- Share the research results with key public officials. Engage AASHTO regarding streamlining project delivery and groups such as Environmental Council of the States (ECOS), Association of Fish and Wildlife (AFWA), Western Governor's Association (WGA), and National Governor's Association (NGA).
- Document the benefits of the approach—sell it. The documentation should include the business case (return on investment of time and money) and address time savings (especially if they made it possible to reallocate agency resources), cost savings, triple bottom line (people, planet, profit) co-benefits and quality of life benefits, and improved conservation outcomes. Examples of success should be included. Opportunities for streamlining processes or programs should be demonstrated.
- Require implementation. One participant suggested requiring it in legislation.
- Fund more pilot projects. More pilot projects are needed to illustrate how to implement the approach, including regional forums for engaging local, state, and federal agencies.
- Interagency training. Regional seminars and interagency training are needed to implement the approach beyond the *Ecological* grants and customary technology transfer. Interagency training is especially useful if it is related to specific projects or permits so that it can be used as a demonstration.
- Guidebook and website. Prepare a guide with chapters for each step and examples and provide an accessible and searchable website.

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CHAPTER 7

Conclusions

The Framework developed by the C06 project will help transportation agencies and resource agencies work together during long-range planning to identify transportation program needs and their potential environmental impacts and conservation opportunities. The CEAA process provides technical guidance to help transportation and natural resource practitioners bring the right expertise, data, methods, and tools to the right stage of the transportation planning and project delivery decision-making process. The results of using the Framework are better environmental outcomes through reduced impacts, identification of high-quality mitigation and enhancement opportunities, and accelerated permitting through proactive inclusion of resource considerations early in the transportation planning process.

Within the overall Framework and the CEAA process, two strategies are critical. First, transportation planners and project managers must address regulatory requirements, ideally as early in the transportation planning and development process as possible. Based on the project team's research, the team thinks that, particularly for wetlands and endangered species, regulatory conflicts and delays result primarily from transportation planners and regulators having insufficient, incomplete, or poor quality data. The team also showed how inductive species models can be used to improve avoidance, minimization, and mitigation results. The team's research developed new methods of mapping wetlands and prioritizing restoration sites through wetland catalogs.

Environmental accounting strategies can be used to reach agreement with regulatory agencies on project impacts and mitigation requirements. In the Framework and CEAA process, the team focused on linking and correlating environmental measurements at a landscape scale with measurement of similar resource issues at a site level. This allows transportation planners to broadly understand and plan around a resource at a regional scale, identifying goals and desired outcomes for that resource. It also allows specific outcomes for that resource to be measured at a site level that allow assessment of a project's effect on the resource. Linking measurement scales maintains continuity between early transportation planning and project-specific planning, improves regional goal setting and tracking of the effect of specific projects on the progress toward those goals, provides a framework for understanding and presenting cumulative effects analyses, and improves understanding of the opportunity/need for using programmatic approaches and an improved ability to develop them.

There are challenges to implementing the Framework. As with most innovations requiring broad partnerships, the key challenges tend to be institutional, political, and financial rather than technical. One of the biggest of these institutional challenges is getting transportation and resource agencies to agree on who will convene and lead the REF process and ongoing maintenance and updating of data. Many of the technical challenges and limitations of the past have been overcome with improved computing power and creation of decision support tools to automate a considerable amount of the CEAA process. The remaining technical challenges are: (1) creating robust analyses understandable to decision makers and stakeholders; (2) integrating and maintaining information from distributed sources; (3) integrating dynamic processes and information; and (4) developing methods for low-capacity agencies to use the process.

Addressing data distribution infrastructure needs and how the data can best be incorporated into the Framework has yet to be done. One of the team's goals is to assure internal data sharing of newly developed models within transportation and regulatory agencies, and more broadly with NGOs and other partners. Another is to assure that the models provide as much regulatory certainty as possible.

The pilot tests demonstrated the practical value of using the CEAA process to streamline and improve decision making in transportation planning and project development, particularly in the areas of mitigation site selection, evaluation of multiple corridors, and development of transportation plans. The pilot test results led to the selection of mitigation sites

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with more ecological benefits and more accurate and comprehensive scenario assessments that identified corridors with the least number of direct and cumulative impacts.

The usefulness of the CEAA for planning and project development depends on the accuracy and resolution of available data. A relatively modest investment in process changes and data development upfront would create more accurate "sign posts" early on in the decision-making processes of potential impacts and mitigation opportunities, vastly improving planning, corridor evaluation, and consideration of mitigation opportunities. Encouraging collection and maintenance of GIS data and developing data management standards that can be adopted by both transportation agencies and natural resources agencies will lead to increased data accessibility, allowing data from single projects or agencies to be applied to future projects or regional studies.

The CEAA approach likely would save time and resources by reducing impacts and thus mitigation requirements, as well as supporting more targeted field studies for assessment of alternatives, although evaluating the extent of these savings was beyond the scope of the team's research.

The project team identified the need for additional research on several issues. Specifically, the team was not able to develop methods for early assessment of water quality impacts, particularly in the context of TMDL implementation and stormwater impacts. The team discovered a need for transportation agencies to develop data retention standards so that data acquired by consultants in the course of environmental impact assessments is retained for the long term and shared with resource agencies. The symposium revealed a real need to develop a standard vocabulary and common understanding regarding avoidance, minimization, and mitigation and the use of programmatic agreements.

Implementing the results of the team's research will require additional effort. Integration into the TCAPP website is under way, which should make the CEAA process accessible to transportation and resource agency staffs. However, to be successful the research results should be shared with key agency leadership, along with supporting documentation of the business case for adopting the Framework. Additional pilot projects, such as those that will be undertaken under Project C21 currently under way to test this framework, are needed to illustrate how the approach can be used in different settings, with different data availability. Regional seminars and interagency training are also needed.

Despite these challenges, the project team thinks the Framework and the new tools and methods discovered during the team's research will lead to better planning, implementation, and mitigation of transportation projects. Using the best data available or using these new tools to update or create quality data sets will allow projects to better avoid regulated species and habitats and minimize impacts or choose meaningful mitigation sites when impacts cannot be avoided. Not only will this save time and money by avoiding conflict, the results of the project will be more ecologically meaningful because of the expanded scope of the Framework. Taking this wider view will lead to both transportation and natural resource goals being met.

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APPENDIX A

Wetland Workflow and Data Development

Workflow for Oregon Wetland Database Development, September 2009

Specification Development

Develop a specification, keeping in mind how you anticipate the wetland geodata will be used. Will it be used mostly in an ecological, outreach, or jurisdictional context? Will a Cowardin classification suffice, or will other information, such as hydrological alteration, hydrogeomorphic classification, wetland management, historic conditions, or vegetation communities, be needed for detailed analysis or decision making? Having a clear picture of the database usage will help determine what types of attributes are essential and what attributes may be useful but can be populated at a later time. Creating a more extensive database that is not fully attributed can save time later.

If the geodata will be used in a jurisdictional or quasi-jurisdictional context, consult with the state wetland permitting agency. Have attributes clearly separating field-delineated wetlands from wetlands determined from imagery or non-detailed field observation.

Determine if tracking historical loss or changes is an important potential use for the database. For Oregon, the project team established a nonoverlapping wetland polygon paradigm, choosing to have the polygons represent current reality. This involves modifying or deleting obsolete polygons or attributing them as "developed." Such a paradigm does not easily support change analysis.

Embed metadata with each polygon to permit an assessment of their relative quality. Such information can include: who developed the polygon set; whether it was aerial-photo or field-based; whether it was field-delineated or field-observed; what year it was done; if it was aerial, what are the month and year of the imagery, and at what scale was it done?

Data Set Development

National Wetlands Inventory (NWI) data should form the basis for a wetland geodatabase. Obtain a geodatabase directly from U.S. Fish and Wildlife Service (USFWS) that includes polylines. The NWI online distribution center does not distribute linear features (polylines). Older digitized quads often represented linear features with polylines, and although the USFWS intention is to convert these features to polygons, many areas currently have polylines. If polylines are present, buffer them to 5.0 meters total width, and burn the layer on top of the polygon layer.

There are several known problems with the NWI database, including incomplete coverage and varying consistency with coverage, especially with stream networks. If there are major gaps in your statewide coverage, consider hydrography data sources as potential stopgap data: National Hydrography Dataset (U.S. Geological Survey 2012) and NHDPlus cover most of the lower 48 states and include open waterbodies and wetland-oriented features, albeit at 1:100 MBscales. Some states or regions may have hydrography data sets with attributes that can be cross-walked into a Cowardin classification. If large sections of NWI data are missing from your state, consider digitizating NWI paper maps, or if necessary, for their initial digitization. If digitizing, coordinate with USFWS for training and NWI development methodology.

Hydrography data sets can be spatially queried to check for potential wetlands that may not have been identified in the NWI data set. For example, a marsh may have been missed in the initial NWI development because of the limitation of the source imagery (not ideal time of year or perhaps a drought year). Based on the experience of the project team, each polygon needs to be evaluated individually; automation may introduce too many false cases.

In areas with limited wetland information (for example, the NWI data are sparse or nonexistent), hydric soil data from Natural Resources Conservation Service (NRCS) soil

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surveys can be helpful. With the use of the NRCS Soil Data Mart, map units with a significant component of hydric soils can be extracted. NRCS surveys typically are done at scales much broader than wetland delineations. Depending on the analysis needs, such data may be sufficient as a wetland surrogate, or for mapping needs, the soil data can direct one's attention to areas for closer examination of unidentified extant wetlands. USDA Forest Service Soil Resource Inventory or Terrestrial Ecological Unit Inventory studies may be consulted for hydric soil areas in regions with no published NRCS soil surveys.

Similar to hydric soils information, flood zone data developed by Federal Emergency Management Agency (FEMA) or U.S. Army Corps of Engineers (USACE) may be useful in identifying areas of potential wetlands, where no other wetland data exist. Flood zone data may be useful in helping determine historical wetland extent or areas for potential wetland re-creation, as many river bottoms have been altered significantly from historic conditions.

Some states have mandates for natural resource inventories conducted by local jurisdictions. Such inventories likely have detailed wetland information that can replace NWI data. If used, develop an inventory boundary file to clearly designate where field-based inventories took place.

Develop contacts with wetland ecologists and geographic information system (GIS) analysts in federal and state land management agencies. Agencies may have their own field-based wetland mapping reports and data. Anticipate that many older reports will not be digitized. Agencies may identify areas with special ecological significance, such as the Bureau of Land Management's area of critical environmental concern, with wetlands comprising a significant portion or with wetlands being the primary purpose of designating the area.

Given the physical constraints of road and highway placement, state and local transportation departments are well aware of wetlands in and adjacent to rights-of-way. State fish and game (or equivalent) departments may have field-mapped wetland information, especially for waterfowl management.

If possible, it is extremely useful to establish reference wetland sites within all ecoregions of your state. Such reference sites typically are minimally altered from presettlement conditions and offer a functioning condition reference for wetland restoration projects. Likewise, identifying wetlands that have unique species assemblages or host wetland-obligate threatened and endangered species assists in developing mitigation and conservation priorities. Most state Natural Heritage offices have spatial databases with information on wetland obligate or facultative state sensitive species.

Obtain land management spatial information for your state. Data from Gap Analysis Program analyses can form a baseline (see National Biological Information Infrastructure 2012), but there may be wetland-specific management goals not encompassed by such data sets. The Wetland Reserve Program, managed by NRCS, is an example of a land management designation specifically targeting wetland re-creation or restoration. Wetland mitigation banks are another example. Water rights permitting agencies can be consulted for permits to private parties for purposes of wetland re-creation or restoration. Land trusts or private conservation-oriented organizations in your state may have large wetlands under their ownership or management via conservation easements. Jurisdictions may have zoning plans that identify areas protected from additional development or may have identified special natural features or areas to eventually acquire.

Field-derived vegetation coverages also may be used to enhance the wetland geodata as a vegetation attribute or perhaps identify new wetlands. For example, a riparian vegetation study may outline areas containing ecoregion-specific wetland facultative or obligate species.

Data Set Maintenance

Anticipate spending time on ongoing maintenance of the geodata. Examples of changes include development of wetlands, wetland re-creation and restoration, and changes in estuary composition caused by sea level changes or natural disturbances. NWI geodata derived from 1980s imagery may be obsolete over large areas. Wetland management changes can occur as jurisdictions decide to change protection designations or nongovernmental organizations (NGO)/land trusts obtain property for permanent protection.

Using the Data

In Oregon's Willamette Valley, the project team identified priority sites within each fourth-level HUC unit to encourage a focused agency and NGO effort for wetland restoration projects. The team took advantage of a synthesis project by The Nature Conservancy (TNC) in Oregon, wherein TNC reviewed numerous conservation-oriented action plans and identified the best areas in the Willamette Valley to target for additional conservation. Included in the TNC synthesis project was an initial version of wetland priority sites that was done without the benefit of a wetland geodatabase. The team's objective was to determine if the near-final TNC version was adequate or needed significant modification.

The team's wetland geodata consisted of several dozen locally based wetland inventories that replaced the NWI polygon coverage, along with more current information on species of concern and special wetland areas. For areas that had only NWI data, the Cowardin codes provided some informa-

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tion on wetland condition. Open waterbodies and riparian areas were filtered out. The team took advantage of historical reconstruction data, based on General Land Office records that suggested the presettlement extent of wetlands in the Willamette Valley. The team's analysis combined FEMA flood zone data, current wetland density, wetlands of special concern (those with unique communities or that host obligate threatened and endangered species), and recent and ongoing wetland restoration projects. The analysis identified several areas not initially identified in the original data set and minor border adjustments to the original wetland priority site layer.

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APPENDIX B

Lists and Sources for Plans and Data for Regional Ecological Frameworks

This list is not exhaustive but includes environmental-related data and plans typically found in most regions and data and plans most commonly used in conservation or land use planning. Identification of sources does not ensure plan availability in any particular area. Acquisition of some plans or data may require license agreements.

Federal Lands and Federally Managed Lands

- Department of Defense Integrated Natural Resource Management Plans;
- Department of Interior Bureau of Land Management;
- Department of Interior National Park Service;
- Department of Interior U.S. Fish and Wildlife Service (USFWS);
- USDA Forest Service;
- U.S. Army Corps of Engineers (USACE) and NOAA have Special Area Management Plans (SAMPs); and
- National Oceanic and Atmospheric Association (NOAA) and USFWS recovery plans.

State and Regional Agency Plans

- Statewide long-range transportation plans (LRTPs), any other state or regional transportation plan that includes proposed transportation projects (such as corridor analyses, regional transportation profiles, transportation improvement plans).
- State wildlife action plans (SWAPs) (Association of Fish & Wildlife Agencies 2012), or other conservation/land use plans that are mapped and have actionable priorities. Some plans may have buy-in across the state and thus offer a preendorsed plan.
- Wetland Conservation Plans.
- State lands and reserve plans.
- State game and trust species management plans, including wildlife crossings.
- State Natural Heritage or state natural area plans (see NatureServe 2012a).
- State comprehensive outdoor recreation plans.
- State open space plans.

Local Agency Plans

- Local land use plans or comprehensive plans, green infrastructure plans (The Conservation Fund 2012); greenprint (The Trust for Public Land 2012) plans;
- Land use and landcover; and
- Local watershed restoration plans completed by state water quality agencies or local watershed organizations. These can include municipal water supply watershed plans.

Nongovernmental Organization Plans

- The Nature Conservancy's (TNC's) Eco-Regional Conservation Plans, covering all states in the United States. These may be especially useful when SWAPs lack mapped, actionable priorities (The Nature Conservancy 2012).
- Other potential conservation areas that are widely adopted.
- The Audubon Society's Important Bird Areas plans, joint venture waterfowl or waterbird plans, or other various single-resource, focused, scientifically derived priority plans developed (Ducks Unlimited and Trout Unlimited).
- Local and regional land trust plans developed with systematic methods.

Data

- Protected area data (see Conservation Biology Institute 2012; GreenInfo Network 2012);
- National Conservation Easement Database (The Conservation Registry 2012);

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- Natural Heritage Program Species Locations (NatureServe 2012b);
- Predictive species modeling data;
- Ecological systems or natural communities (NatureServe 2012b);
- National Hydrography Dataset (U.S. Geological Survey [USGS]);
- Soils (USGS), hydric soils data (Natural Resources Conservation Service);
- Wetland and Watershed—NWI, local watershed plans by state or local organizations or municipal water supply watershed plans (e.g., wetlands of special state concern);
- Impaired (303 d listed) streams (U.S. Environmental Protection Agency, state agencies);
- Impervious surfaces (state or local government);
- Floodplain (100-year; Federal Emergency Management Agency); and
- Point sources (state government).

Other Useful National Data Portals

Examples of tools aimed at watershed protection are PlaceMatters (2012) and the Midwest Spatial Decision Support System Partnership (2012).

- **Ecosystem Based Management** (EBM) tools are software or other highly documented methods that can help implement EBM by: (1) providing models of ecosystems or key ecosystem processes, (2) generating scenarios illustrating the consequences of different management decisions on natural resources and the economy, and (3) facilitating stakeholder involvement in a planning processes. The EBM Tools Network is an alliance of EBM tool developers, practitioners, and training providers (NatureServe 2012a).
- **Geospatial One-Stop.** National/international geospatial data clearinghouse and computer network of data servers/portals. Available geographic data and metadata posted, shared, and coordinated with the National Spatial Data Infrastructure (NSDI) and Federal Geographic Data Committee, which provide individual web links for each national, state, regional, and local data portal/server that is part of the overall national/international data clearinghouse (Federal Geographic Data Committee 2012). The U.S. government also provides a search engine for various types of data and information across all data servers within the overall data clearinghouse (Data.gov 2012).
- **Open Geospatial Consortium** (OGC, OpenGIS). An international industry consortium of more than 300 companies, government agencies, and universities participating in a consensus process to develop publicly available interface specifications. OpenGIS specifications support interoperable solutions (Open GeoSpatial Consortium 2012). The specifications empower technology developers to make complex spatial information and services accessible and useful with all kinds of applications.
- **National States Geographic Information Council** (NSGIC) is an organization committed to efficient and effective government through prudent adoption of geospatial information technologies (National States Geographic Information Council 2012).
- **The National Biological Information Infrastructure** (NBII) is a broad, collaborative program to provide increased access to data and information on the nation's biological resources (National Biological Information Infrastructure 2012). It is also linked to the national/international Geospatial One-Stop program described above.

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APPENDIX C

Pilot Project Reports

Approach to Testing C06B Technical Guidance

Overview

The Integrated Ecological Framework (hereafter Framework) will be tested with associated templates in three states: Colorado, Michigan, and Oregon.

The research team's general approach is to conduct the pilot tests as described here, but the analyses in each state will vary slightly based on the nature of the project, the data available in each state, and the tools used by the states for conservation and transportation planning. For example, in Colorado the team is doing the analyses on an entire metropolitan planning organization (MPO) region that involves multiple projects, which allows testing of the cumulative effects methodology in a large landscape context taking into account multiple potential impacts in an area. In Oregon, an ecological project has funded the development of predictive species range maps for listed species, and an U.S. Environmental Protection Agency (EPA) project has resulted in the development of priority mitigation sites, so the team will analyze how these data affect the decision outcomes. In Michigan, the team will test how using the Framework will affect the outcomes in an area where conservation priorities were not identified previously.

In all three states, the team will be comparing data and outcomes from the original projects with outcomes using new and updated data and the methods outlined in the Framework. In this comparison, the team primarily will be looking at:

- **Direct impacts** identified based on original data and methods versus the data and methods identified in the Framework.
- **Mitigation effectiveness** based on the sites selected in the original project versus mitigation sites identified using data and methods identified in the Framework, and predicted ecological outcomes at the different sites.
- **Cumulative impacts** estimated from the original data and method versus the data and methods identified in the Framework for at least the resources targeted in the selected pilot site.

The C06B Technical Guidance is broken up into nine distinct steps with many substeps. Each pilot project tested the steps and substeps that were relevant to the project. The nine steps are

- **Step 1:** Build and strengthen collaborative partnerships, vision;
- **Step 2:** Characterize resource status; integrate conservation, natural resource, watershed, and species recovery and state wildlife action plans;
- **Step 3:** Create regional ecosystem framework (conservation strategy + transportation plan);
- **Step 4:** Assess land use and transportation effects on resource conservation objectives identified in the REF;
- **Step 5:** Establish and prioritize ecological actions;
- **Step 6:** Develop crediting strategy;
- **Step 7:** Develop programmatic consultation, biological opinion or permit;
- **Step 8:** Implement agreements and adaptive management; deliver conservation and transportation projects; and
- **Step 9:** Update regional integrated plan/ecosystem framework.

General Approach to Testing the Framework

Introduce Project to Natural Resource and Transportation Agencies

Meet with state transportation agencies (DOTs), MPOs, and key state and federal agencies in the selected pilot states (Colorado, Michigan, and Oregon) to introduce the project and get initial input on areas in the state that meet the pilot project selection criteria (see Pilot Project Criteria and Requirements).

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Select Site for Pilot Test

Follow up with each pilot state to get more information about data available for the areas proposed in which to conduct pilot tests. Then an area can be selected in each state based on how well the area meets the pilot project selection criteria (see below), whether or not a sufficient amount of the spatial data from the original project are available digitally (in geographic information system [GIS], CAD, or similar format).

Data Collection

Collect all data used in the original evaluation of the project selected, including the original infrastructure footprint, final project footprint, biological data or other conservation data sets, environmental impact statement (EIS) or environmental assessment (EA), record of decision (ROD), and other public concerns (noise, air quality, water quality, historic/cultural sites). The data available will vary among the pilot areas according to the concerns and capacity of each project.

Run Pilot Test

Choose an Ecologically Based Geographic Boundary for the Analyses

An ecologically based area considers the full extent that a species or habitat could be affected or considered for mitigation. The following are the steps to considering the full extent:

1. Identify the resources that intersect the project area.
2. For aquatic resources, include the watershed that is expected to be inclusive of stream reaches, wetlands, and other water bodies that could contain the connected populations of species involved.
3. Nest the watershed within an ecoregionally defined unit. The unit may be an aggregation of subdivisions of the EcoMAP or similar accepted ecoregion-based geographic map. In a manner similar to that used for the aquatic unit, the subdivisions to be included would incorporate the resources intersecting the project area and including the priority conservation areas from the regional ecological framework (REF) that contain those same resources and likely could serve as mitigation-receiving areas for affected resources.

Adopt or Develop an REF

Follow the cumulative effects assessment and alternatives (CEAA) template methods for developing an REF or accepting a previously developed plan of conservation priority areas. This includes:

1. Identifying ecological resources to be considered in analyses and goals related to protection of those resources. Using ecological data layers and conservation plans.
2. Collecting, incorporating, or developing current ecological data for the area being evaluated, while if possible, including or developing predictive species distribution data and priority wetland data. When new data are used, evaluate their acceptance (via interviews or meetings) by the relevant regulatory agencies.
3. Reviewing previous analysis or analyzing data to determine the terrestrial and aquatic elements and areas that will be included in the analyses.
4. Identifying and integrating land use and transportation planning information available spatially.
5. Considering the information in Appendix B, the Lists and Sources for Plans and Data for Regional Ecological Frameworks, when building REF.

Analyze the REF

The REF will proceed through workflow templates beginning with the REF source inputs detailed above. A GIS decision support system (DSS) will provide the analytical functions to produce the outputs used for the following step (c). The templates used for the pilot projects provide a relatively simple but highly robust and flexible approach to conducting regional cumulative impact assessment and the consequent development of alternatives and mitigations. The workflow is modeled on some of the core concepts of systematic conservation planning (Margules & Pressey 2000) and the use of GIS tools that automate a great deal of the technical GIS work necessary to carry it out (Sarkar et al. 2006). An important component of the GIS DSS approach to be used in the pilot projects is the application of suggested goal levels and indicators based on expert or stakeholder input.

The templates developed by the C06B team depict the flow of information from source inputs to outputs used in decision making. It is important to emphasize that the workflow and supporting toolkit are decision *support* systems, not decision *making* systems, so the results require review and judgment in terms of how they should affect decision making. The Colorado and Michigan pilot projects will use the NatureServe Vista DSS, a free extension of ArcGIS 9.3. The Oregon pilot project will use ArcGIS 9.3 without NatureServe Vista.

A cumulative scenario analysis focuses on land uses but can include management practices, natural disturbances, and so forth. Land use change is then analyzed using multiple scenarios:

1. **A current or baseline scenario** will describe current actual land use based on the best available data. The pilot projects will attempt to identify land use conditions at the time the original project was started.
2. **The original project scenario** will include the long-range transportation plan or corridor plans associated with the original project.

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3. **An alternative scenario** will incorporate REF data and be processed according to the proposed C06B framework templates.

Evaluate Results of Test With Original Project Outcomes

Compare the results of the analyses in Step 4b with the data and outcomes from the original project with a focus on direct and cumulative impacts and selection of mitigation sites.

1. **Direct impact comparison:** The C06B project team will evaluate whether using the Framework in evaluating the project area identified differences in the number, aerial extent, or types of natural resources, or more accurately identified the severity of the impact within the project area(s) than did the original project review under National Environmental Policy Act (NEPA).
2. **Cumulative impact comparison:** This aspect of the analyses includes looking at the project within a regional landscape context or looking at the current and historic extent of habitats for potentially affected species and seeing how that compares with the results of the original project or planning in the area, such as more severe impacts or impacts to resources located in areas surrounding the project.
3. **Mitigation evaluation:** This aspect of the analyses will illustrate whether the Framework approach uncovered:
   a) more viable sites for mitigation (based on landscape context),
   b) sites with multiple conservation resource values, or
   c) sites that would provide greater contributions to other resources (i.e., water quality, priority nonregulated species)
4. **Savings in time or resources:** The C06B team will try to show how using the Framework would result in a more streamlined decision-making process. This analysis likely will require direct input from the natural resource and transportation agency staff of each pilot state.

Analyze Permitting, Mitigation, and Other Crediting Opportunities

Step 4c will use compiled information from interviewees in DOT and with data collected in Steps 4a and 4b to evaluate the available crediting methodologies that may have supported the project better.

1. **Analysis of regulated resource crediting:** The project team will review the measurement challenges in the permitting stages to understand other mitigation actions in the region that generate mitigation demand both within the agency and among other permittees. A key component is to understand where measures are a barrier for consultation or permitting.
2. **Analysis of credit markets:** The team will review DOT and non-DOT based markets for credits when such information is available; this will include §404 or Endangered Species Act (ESA) banking.
3. **Recommendation based on future needs:** The interviews with DOT staff will indicate upcoming regulated and nonregulated needs that crediting potentially could address. Tools and methods will be recommended to address these needs.

Follow-up Meeting with Natural Resource and Transportation Agencies in Pilot States

Set up webinar with the team's transportation and natural resource partners from each state to review and discuss results of analyses and comparison with original project outcomes.

Finalize Templates

Make adjustments to template based on input from federal and state agencies in pilot states.

Pilot Project Criteria and Requirements

Scope and Scale

- Capacity project with unavoidable ecological impacts—a measurable footprint change (required criteria);
- Project includes preproject decision-making process (i.e., corridor or other planning level process took place before project was selected) (required criteria); and
- Project has been completed within the past 5 years (highly desirable).

Challenging Ecological Issues

- Multiple types of habitats, ideally including wetlands and/or streams in addition to other upland habitat types; habitats can be regulated or nonregulated;
- Multiple types of species potentially affected by project;
- Other key ecological or other water quality concerns; and
- In-kind, on-site mitigation was not ecologically preferable but was required by regulatory agencies.

Background Data

- Ecological data and ecological goals for region (e.g., recovery documents);
- Project design footprint information and mapping (required information);
- Baseline environmental documents (NEPA documents, biological assessments, mitigation plans and permits, best management practices (BMPs) (required information);

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- Site photographs before construction (highly desirable information);
- Orthorectified air photos of project area, ideally before and after the project (highly desirable information); and
- Details of mitigation performed for the project (highly desirable information).

Specific Challenges Experienced During Design and Permitting

- Concerns related to project delivery, certainty (highly desirable information);
- Agency and public concerns regarding assurances (highly desirable information); and
- Budget and rough schedule for amount spent (time and money) on environmental analysis and compliance efforts (highly desirable information).

Colorado Pilot Project Report

Pilot Test Area Introduction

A workshop was held on December 15, 2009, in Golden, Colorado, with attendees from the Colorado Department of Transportation (CDOT), Colorado Department of Natural Resources, EPA, U.S. Army Corps of Engineers (USACE), Bureau of Land Management, Pikes Peak Council of Governments (PPACG), and Pueblo Area Council of Governments (PACOG). Potential pilot project areas were discussed, and five different project areas were proposed by participants. These were quickly narrowed to three based on CDOT's preferences and the availability of data on the project area:

- Combined transportation projects in El Paso County (PPACG);
- State Highway 9 Frisco to Breckenridge; and
- South I-25 Corridor (combined improvements to I-25 and US-85).

Application of the pilot project criteria and discussion with CDOT lead the team to choose the South I-25 Corridor, which is located between Colorado's two major metropolitan areas, Denver and Colorado Springs. The project is situated in western Douglas County, part of the Denver MPO region. Denver Regional Council of Governments (DRCOG) facilitates coordination and planning among the region's governments and creates comprehensive land use/landcover data for the MPO region, an important component for a cumulative effects assessment. The project encompasses multiple transportation improvements: lane widening on both I-25 and US-85, construction of a frontage road, reconstruction or improvements to eight interchanges and overpasses, and the replacement of a railroad overpass on I-25. There were no significant realignments or alternative routes considered; the corridor largely expanded existing infrastructure. The project's EIS took 3 years to complete, and the final EIS was released in 2001. Two years later, the ROD was revised and signed (U.S. Department of Transportation et al. 2001). The project had affected designated critical habitat for the threatened Preble's meadow jumping mouse (PMJM, Figure C.1) (*Zapus hudsonius preblei*), state priority habitats, and wildlife linkages (U.S. Department of Transportation et al. 2001). The PMJM is a small mammal, approximately 9 inches in length, with large hind feet adapted for jumping, a long bicolored tail (which accounts for 60% of its length), and a distinct dark stripe down the back. CDOT, FHWA, and the U.S. Fish and Wildlife Service (USFWS) negotiated an agreement in 2003 to restore and preserve approximately 25 acres of PMJM habitat affected by the highway project. This acreage established the first conservation bank for the species, and habitat was restored to improve conditions for PMJM (Colorado Department of Transportation et al. 2003).

Photo courtesy of U.S. Fish and Wildlife Service.

***Figure C.1. Preble's meadow jumping mouse* (Zapus hudsonius preblei).**

Testing the Ecological Assessment Framework

The Colorado pilot project tested only steps 1–5 and certain associated substeps of the C06B Technical Guidance.

Step 1: Build and Strengthen Collaborative Partnerships, Vision

1a. Identify planning region

The pilot project is located at the western edge of the Central Shortgrass Prairie Ecoregion (Neely et al. 2006). Before settlement by Anglo-Americans, the pilot project area was characterized largely by rolling plains and tablelands of shortgrass prairie. Most of the region is now largely urbanized by the Denver metropolitan region. Conversion of the prairie to urban development and cultivated cropland has completely

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changed the landscape of the pilot region. Most sensitive wildlife species have vanished from the landscape (e.g., sharp-tailed grouse), whereas others maintain a tenuous presence (e.g., elk, PMJM, and pocket gopher). The PMJM was formally listed as threatened under the ESA in 1998. Its decline has been largely attributed to loss and degradation of its habitat: well-established riparian areas and nearby prairie uplands (U.S. Fish and Wildlife Service 2003). Urban development, water development, flood-control activities, and agriculture are the major sources of habitat loss. The pilot project boundary encompasses a highly transformed and fragmented landscape.

Much of the area in the South I-25 Corridor project is a foothills transition zone between the Shortgrass Prairie and the Southern Rocky Mountains. Dominant upland ecological community types are the Western Great Plains shortgrass prairie, Rocky Mountain Gambel oak-mixed montane shrubland, Southern Rocky Mountains ponderosa pine woodland, and Western Great Plains foothill and piedmont grassland. Dominant grass species include blue grama (*Bouteloua gracilis*), western wheatgrass (*Pascopyrum smithii*), and buffalo grass (*Buchloe dactyloides*), whereas Gambel oak (*Quercus gambelii*), juniper (*Juniperus monosperma*), and Ponderosa pine (*Pinus ponderosa*) are the most common tree species (Neely et al. 2006). Along streams, plains cottonwood (*Populus deltoides*), thinleaf alder (*Alnus incana*), and willows (*Salix* spp.) are the common components of the Western Great Plains riparian community.

The entire pilot area (Figure C.2) drains into the South Platte River, part of the Missouri River watershed. The river and its tributaries compose the bulk of the riparian and wet-

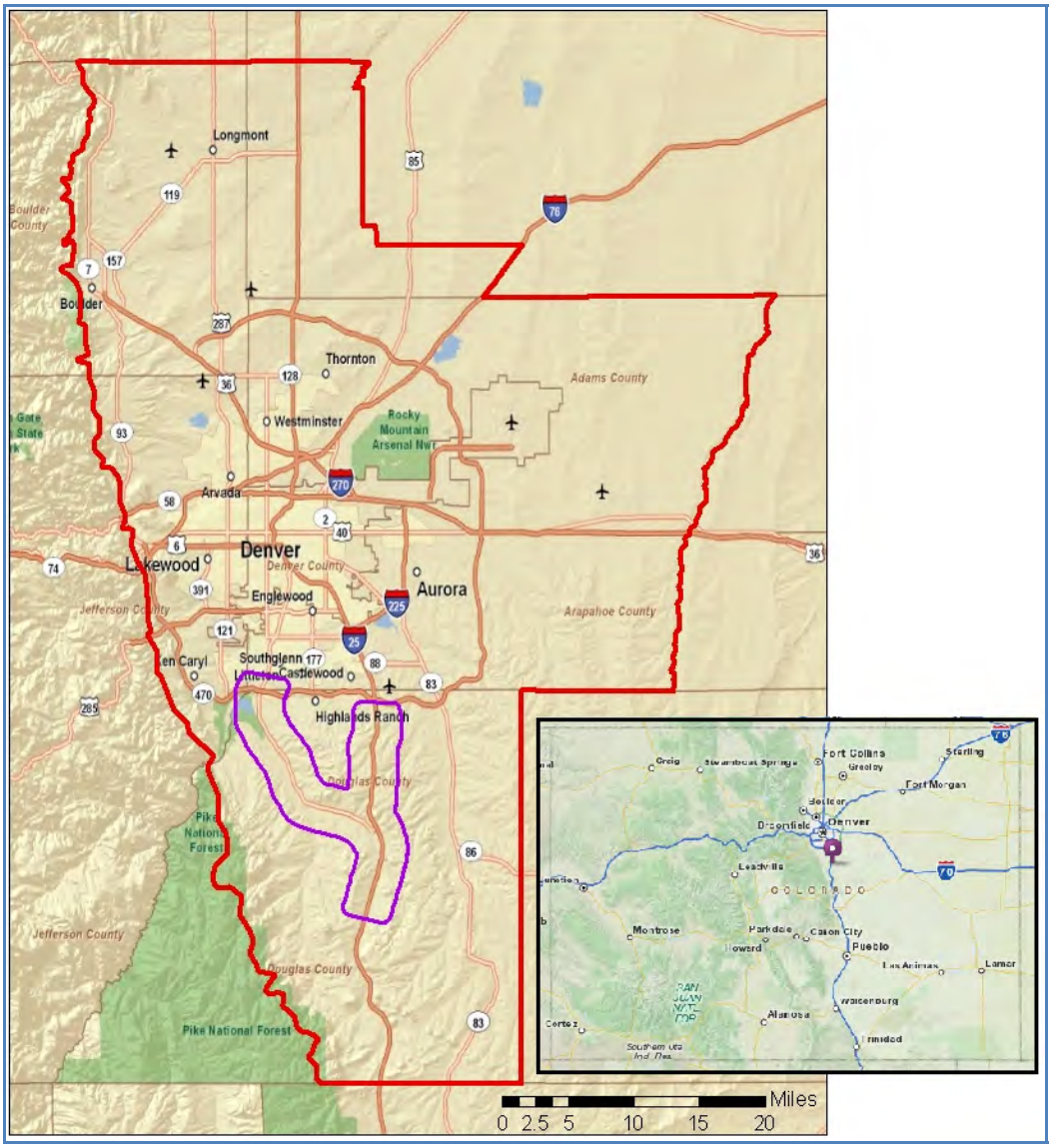

Figure C.2. Location of the pilot project area boundary (red) and I-25 Corridor (purple).

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lands areas in the ecoregion. Although riparian areas and wetlands represent just a fraction of the total area, they host a disproportionate number of flora and fauna. The I-25 Corridor area straddles the watersheds of Plum and Cherry Creeks. Both are particularly important as refuge for native species. Water from both streams is used for irrigation and drinking water for the communities of the pilot region.

In contrast to many areas in the West, federal lands are a small component of the protected areas in the pilot region. This is the typical landownership pattern of Colorado's Front Range, an area stretching from Colorado Springs north to the Wyoming state line. Areas under conservation easement, especially ranchland, provide habitat for many Shortgrass Prairie species when sound management practices are applied. The Cherokee Ranch, a historic ranch in the South I-25 Corridor, is one of the largest conservation easement properties in the region. The makeup of the protected area network reflects local citizens' commitment to invest in protected areas and open space.

The Colorado pilot project region encompasses the eastern half of the DRCOG service area. DRCOG is the regional government entity charged with fostering cooperation among county and municipal governments in the Denver metropolitan area.

The transportation projects included in CDOT's South I-25 Corridor are almost entirely within western Douglas County, a rapidly urbanizing region. Located between Colorado's two largest metropolitan areas, Denver and Colorado Springs, Douglas County has experienced tremendous urban growth. During the 1990s it was the fastest growing county in Colorado and one of the fastest growing counties in the nation, its population almost tripling from 60,000 to 176,000 people. Such extensive population growth in and around Douglas County prompted the state and county to expand its infrastructure to accommodate the influx of residents, many of whom will need to commute into the metro regions of Denver and Colorado Springs for work. This growth significantly drives the land use and landcover of the project area, shown in Figure C.3.

The I-25 Corridor plan does not include new or expanded roads planned by county or municipal authorities, and it does not examine the cumulative impacts of urban growth or other infrastructure improvements such as an expanded rail network.

The research team used NatureServe Vista on an ESRI ArcGIS 9.3.1 platform. NatureServe Vista is a decision-support tool for incorporating resource information, especially biodiversity, to define systematic conservation goals and alternate scenarios (NatureServe 2012).

Step 2: Characterize Resource Status; Integrate Conservation, Natural Resource, Watershed, and Species Recovery and State Wildlife Action Plans

2a. Identify the spatial data needed to create understanding of current conditions.

2b. Prioritize the specific list of ecological resources and issues that should be further addressed in the regional ecosystem framework.

2e. Produce geospatial overlays of natural resource data and supporting priorities.

Key Data Sets and Sources

Although the South I-25 Corridor project affected only an area of western Douglas County, the projected wanted to put the project into a regional context that included the Denver

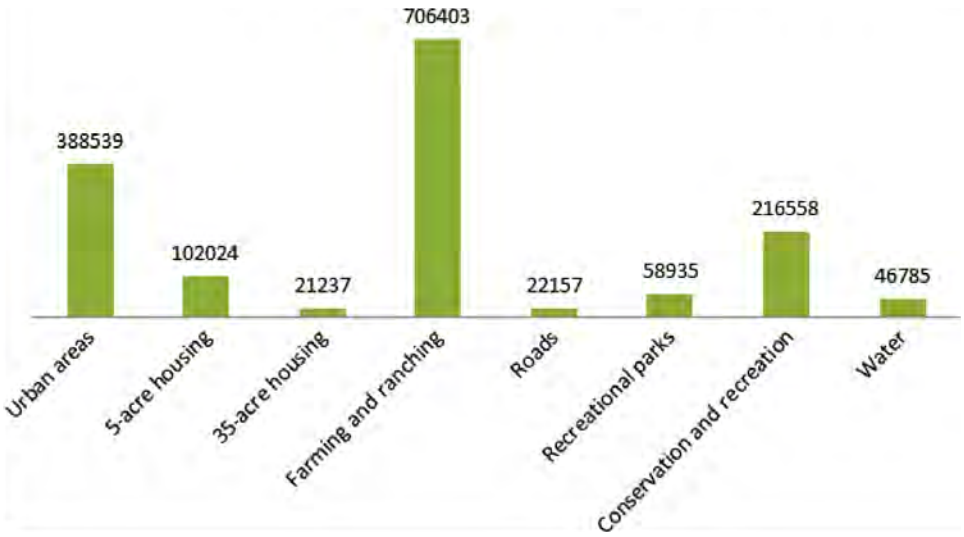

Figure C.3. Simplified landcover and land use classification for pilot region (in acres).

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metropolitan region. The DRCOG MPO boundary spans two very different ecoregions: to the west are the forested, mountainous areas of the Southern Rockies, whereas to the east are the major urban areas and remaining fragments of the Shortgrass Prairie. These ecological differences plus the opportunity to examine the South I-25 Corridor within the context of the MPO region shaped the decision to clip the project boundary to the Shortgrass Prairie portion of the MPO project area. This gave the team the distinct advantage of accessing the data produced by DRCOG, which allowed not only the capture of changes in transportation impact on species and ecological functions at a landscape scale but also those regarding urban growth and other planned infrastructure.

1. How was this step addressed (which sections of this step were addressed, did the team follow the guidance as written or make adjustments because of data gaps or other factors)?
2. What were the results (address direct and cumulative impacts, selection of mitigation sites, and other results)?

The spatial data needed to create understanding of current or baseline conditions were obtained from existing sources. The research team relied on previous studies and research from local, state, and federal authorities to inform its understanding of the landscape. The data needed would reflect the current land use, future land use, and biological or ecological priority areas. Land use data were obtained from DRCOG and CDOT. Natural resource data (See Table C.1) were obtained from a variety of sources described in the next substep.

CDOT requires the 20-year transportation plan include expected environmental, social, and economic impacts of the recommended transportation network, including an objective evaluation of a full range of alternatives to balance transportation needs and environmental needs in a safe and

Table C.1. Natural Resource Spatial Data Incorporated into the South I-25 Corridor Project

Name	Alternate Name
Element Occurrences (19 elements)	
American yellow lady's slipper	*Cypripedium calceolus* ssp *parviflorum*
Ottoe skipper	*Hesperia ottoe*
Ovenbird	*Seiurus aurocapillus*
Plains sharp-tailed grouse	*Tympanuchus phasianellus jarnesi*
Prairie goldenrod	*Unamia alba*
Prairie violet	*Viola pedatifida*
Preble's meadow jumping mouse	*Zapus hudsonius preblei*
Richardson alum root	*Heuchera richardsonii*
Rocky Mountain sedge	*Carex saximontana*
Bells twinpod	*Physaria bellii*
Black-tailed prairie dog	*Cynomys ludovicianus*
Colorado butterfly plant	*Oenothera coloradensis* ssp. *coloradensis*
New Mexico cliff fern	*Woodsia neomexicana*
Northern pocket gopher	*Thomomys talpoides cacrotis*
Northern redbelly dace	*Phoxinus eos*
Moss elfin	*Callophrys mossii schryveri*
Mottled dusky wing	*Erynnis martialis*
Hops feeding azure	*Celastrina humulus*
Fork-tip three-awn	*Aristida basiramea*
Natural Community (24 elements)	
Foothills Ponderosa pine savanna	*Pinus ponderosa, Muhlenberghia* montana woodland
Foothills ponderosa pine scrub 2	*Pinus ponderosa, Quercus gambelii* woodland
Foothills ponderosa pine scrub woodlands	*Pinus ponderosa, Cercocarpus montanum*

(continued on next page)

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Table C.1. Natural Resource Spatial Data Incorporated into the South I-25 Corridor Project (continued)

Name	Alternate Name
Coyote willow mesic graminoid	*Salix exigua,* mesic graminoids shrubland
Freshwater emergent wetland	Freshwater emergent wetland
Freshwater forested shrub wetland	Freshwater forested shrub wetland
Freshwater pond	Freshwater pond
Great Plains mixed grass prairie	*Hesperostipa comata,* Colorado front range herb vegetation
Lake wetland	Lake and pond wetlands
Mixed foothill shrublands	*Danthonia parryi* herbaceous grasslands
Mixed mountain shrubland	*Quercus gambelli-Cercocarpus montanum/Carex geyeri*
Montane grassland	*Danthonia parryi* herbaceous vegetation
Montane riparian willow carr	*Salix monticola* mesic forb shrubland
Montane wet meadow	*Carex pellita* herbaceous vegetation
Mountain Muhly herbaceous vegetation	*Muhlenbergia montana* herbaceous vegetation
Narrowleaf cottonwood riparian forests	*Populus angustifolia,*-Salix exigua woodland
Other wetland type	Other
Peachleaf willow alliance	*Salix amygdaloides* woodland
Plains cottonwood riparian woodland	*Populus angustifolia/Symphoricarpos occidentalis*
Riverine wetland	Riverine wetlands
Strapleaf willow, coyote willow	*Salix exigua, Salix ligulifolia* shrubland
Thinleaf alder forb riparian shrub	*Alnus incana* mesic forb shrubland
Xeric tallgrass prairie	*Andropogon gerardii, Spirobolus heterolepis*
Xeric tallgrass prairie 2	*Andropogon gerardii, Schizachyrium scoparium*
Priority Areas (16 elements)	
Priority Conservation Area (PCA)[a] all other PCAs	Other Colorado Natural Heritage Program (CNHP) priority conservation area
PCA Newlin Gulch	Newlin Gulch priority conservation area
PCA Plum Creek at Louviers	Plum Creek at Louviers priority conservation area
PCA South Platte River	South Platte River priority conservation area
PCA Wolhurst North	Wolhurst North priority conservation area
DoCo Chatfield proposed corridor	Douglas County Chatfield Reservoir Proposed Wildlife Corridor
DoCo Overland connection area	Douglas County wildlife movement corridor
DoCo riparian conservation area (RCZ)	Douglas County designated priority riparian areas, prime PMJM habitat
DoCo wildlife conservation areas	Douglas County designated wildlife conservation areas
DoCo wildlife corridors	Douglas County designated wildlife corridors
DoCo wildlife crossings	Douglas County designated wildlife crossing areas
DoCo wildlife high-value habitat	Douglas County designated areas of high value for wildlife
DOW ponderosa pine key habitat area	Division of Wildlife Ponderosa pine key habitat area
DOW sand dune shrubland key habitat area	Division of Wildlife sand dune shrubland key habitat area
DOW shortgrass prairie key habitat area	Division of Wildlife shortgrass prairie key habitat area
DOW shrub-dominated wetlands key habitat area	Division of Wildlife ponderosa shrub-dominated wetland key habitat area

[a]Potential Conservation Areas (PCAs) are developed by the Colorado Natural Heritage Program using data and expertise to delineate areas around occurrence(s) of rare species and/or plant community(ies) that include the minimum geographic area needed to support the habitat and ecological processes upon which the species and community(ies) depend for their continued existence. PCA's have no legal status; they are intended for conservation planning purposes only.

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efficient manner (as stated in Colorado Revised Code section 43-1-1103[1][d]).

Key sources for the natural resources included in the pilot project included:

- Colorado Division of Wildlife Key Wildlife Areas;
- Colorado Natural Heritage Program Element Occurrences (EOs), Natural Communities and Priority Conservation Areas;
- Douglas County environmental and conservation layers: Riparian Conservation Area (RCA), wildlife habitat areas, wildlife corridors and highway crossing areas; and
- U.S Geological Survey (USGS) National Wetlands Inventory.

The research team was unable to obtain digital data of the South I-25 Corridor improvements from CDOT directly. Although the data existed in a digital CAD format, the data were in the possession of the original planning consultant. According to the planning consultant, the data were stored in various places and formats, requiring multiple days of staff time to assemble and copy. However, the project EIS and ROD were available online. The necessary supporting technical documents were loaned to us by CDOT.

To spatially represent the source, type, and magnitude of current and anticipated future transportation impacts associated with the South I-25 Corridor, the team assembled two scenarios, shown in Table C.2.

The preconstruction scenario depicts the I-25 Corridor before CDOT began construction and the land use from DRCOG's 2008 regional land use map (Denver Regional Council of Governments 2008). The EIS provided descriptions of all planned changes under the preferred alternative. The planned changes, primarily the addition of new lanes, were estimated using the suggested minimum right-of-way (ROW) width from the geometric design standards outlined in the CDOT Roadway Design Guide (Colorado Department of Transportation 2005). Improvements to the South I-25 Corridor are ongoing, thus Google Earth's most current imagery (2008) was sufficient to digitize constructed interchanges. The research team thought that this adequately represented the postproject scenario, given the lack of available data and the level of detail used in long-term transportation plans or in the early planning stages at the transportation corridor level.

Current land use was taken from the DRCOG 2008 land use map and transportation network maps (Denver Regional Council of Governments 2008). Trends, including historic, current, and anticipated future changes, in land use practices were represented by two layers obtained from DRCOG: 2035 transportation network and the 2035 urban growth boundary (Denver Regional Council of Governments 2005). See Figures C.4 and C.5 for examples of the preconstruction and postconstruction scenarios.

Data Sources Consulted

In the South I-25 Corridor pilot project, the team decided that a missing resource that needed to be addressed was a finer scale map of natural area cores and their connecting corridors. The idea of protecting cores and corridors to protect wildlife habitat has been established, but the idea that it represents an important part of a community or region's infrastructure has been best described as green infrastructure (Benedict & McMahon 2006). In 2006, Chatfield Basin Conservation Network, a local conservation group in partnership with Douglas County, published a green infrastructure study aimed at continuing to implement the Network's vision of "Conserving Connections for Nature and People" through protecting and interconnected system of green infrastructure (Chatfield Basin Conservation Network 2006). Although this was not incorporated because of the lack of digital data, this would be a useful component of the REF.

Three other sources were reviewed but were excluded from the pilot project because they lacked spatially available data or were too coarse to incorporate in the pilot project. The Nature Conservancy's Central Shortgrass Ecoregional Assessment includes portfolio areas of highest conservation value. Of 43 terrestrial portfolio sites, there are 6 terrestrial portfolio sites in the pilot area. Three of these intersect the South I-25 Corridor: Cherokee, Cherry Creek and Plum Creek. Five aquatic portfolio areas occur in the pilot project site,

Table C.2. Scenarios Created to Support Pilot Analysis

	Preconstruction Scenario	Postconstruction Scenario
South I-25 Corridor	Digitized the South I-25 Corridor area of impact, the road plus the rights-of-way on either side, using Google Earth's imagery from 2003	Used EIS descriptions with CDOT Roadway Design Guide to estimate width of new lanes and right-of-way. Used 2008 imagery to digitize completed interchanges.
Regional Land Use	DRCOG's 2008 regional land use map	DRCOG's 2035 metro vision road network and build-out to urban growth boundary

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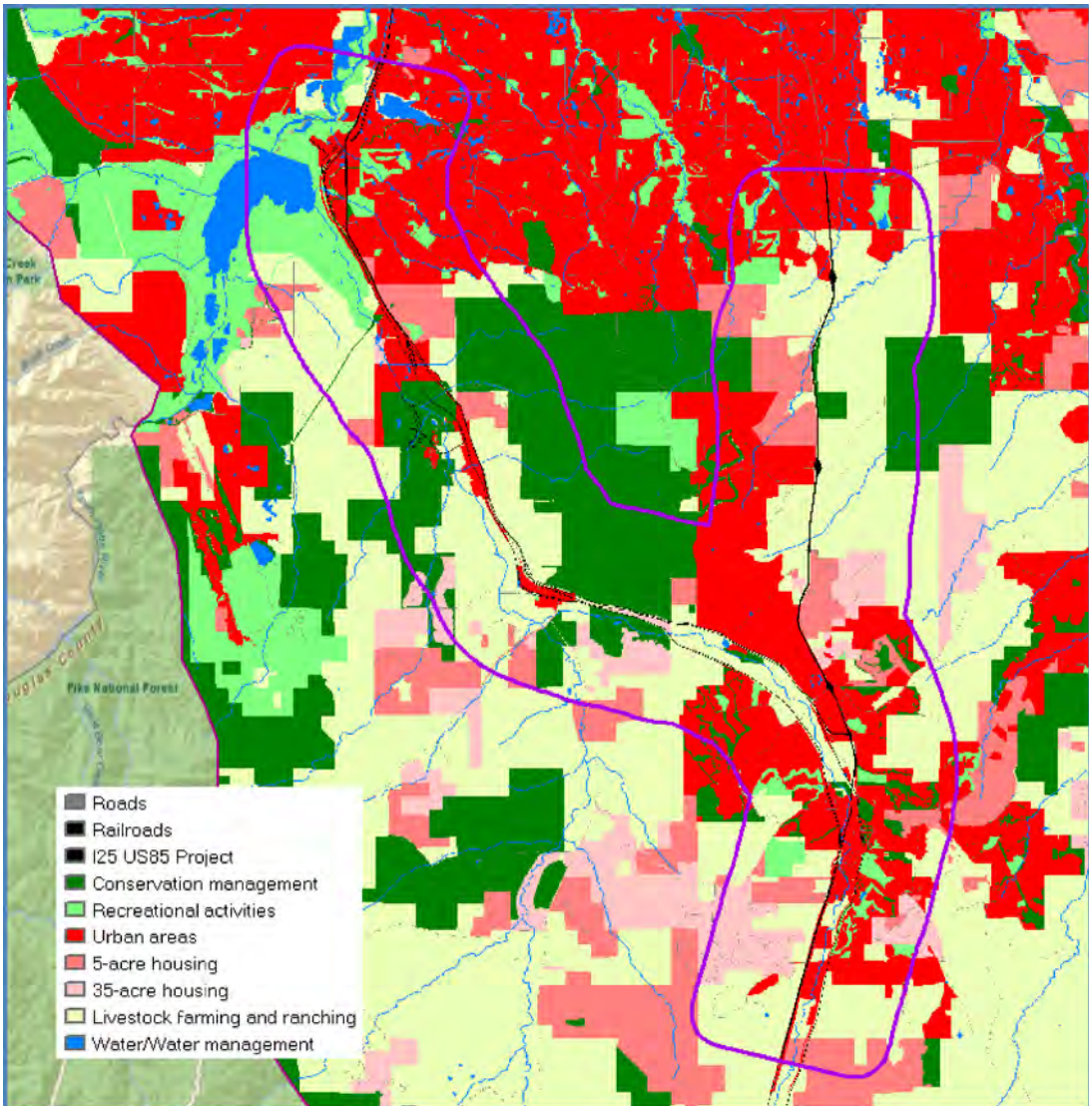

Figure C.4. The preconstruction land use scenario zoomed in on the South I-25 Corridor.

two of which intersect the South I-25 Corridor: the Upper South Platte River and Plum Creek.

The largest of the Audubon Society's Important Bird Areas in the pilot area is the Chatfield Basin Conservation Network, which encompasses much of the Plum Creek watershed. The Audubon Society has documented more than 320 bird species in the area (Audubon Colorado 2012).

In *Linking Colorado's Landscapes* (Kintsch 2005), the Southern Rockies Ecosystem Project (now part of the Center for Native Ecosystems) conducted research that identified several priority wildlife linkages in the pilot area: the Denver West Foothills and Douglas County Front (Southern Rockies Ecosystem Project 2005). The latter intersects the South I-25 Corridor and identifies black bear, mountain lion, and elk as species that likely would use region to disperse or migrate seasonally.

Prioritizing and Creating Spatial Overlays

The preproject scenario was created using the best available land use data to represent the pilot area before the South I-25 Corridor project (see Figure C.6). The research team used NatureServe Vista to combine all layers representing land use and reclassify these in simplified categories that better depict the level of impact the land use has on the ecosystem. For example, DRCOG tracks a range of land use types that are important to city planners: schools and city/county facilities.

The next step in the analysis required reorganizing the data into three broad categories:

- **Species (element) occurrences:** These are the spatial representation of a species or ecological community at a specific location. An element occurrence generally delineates a

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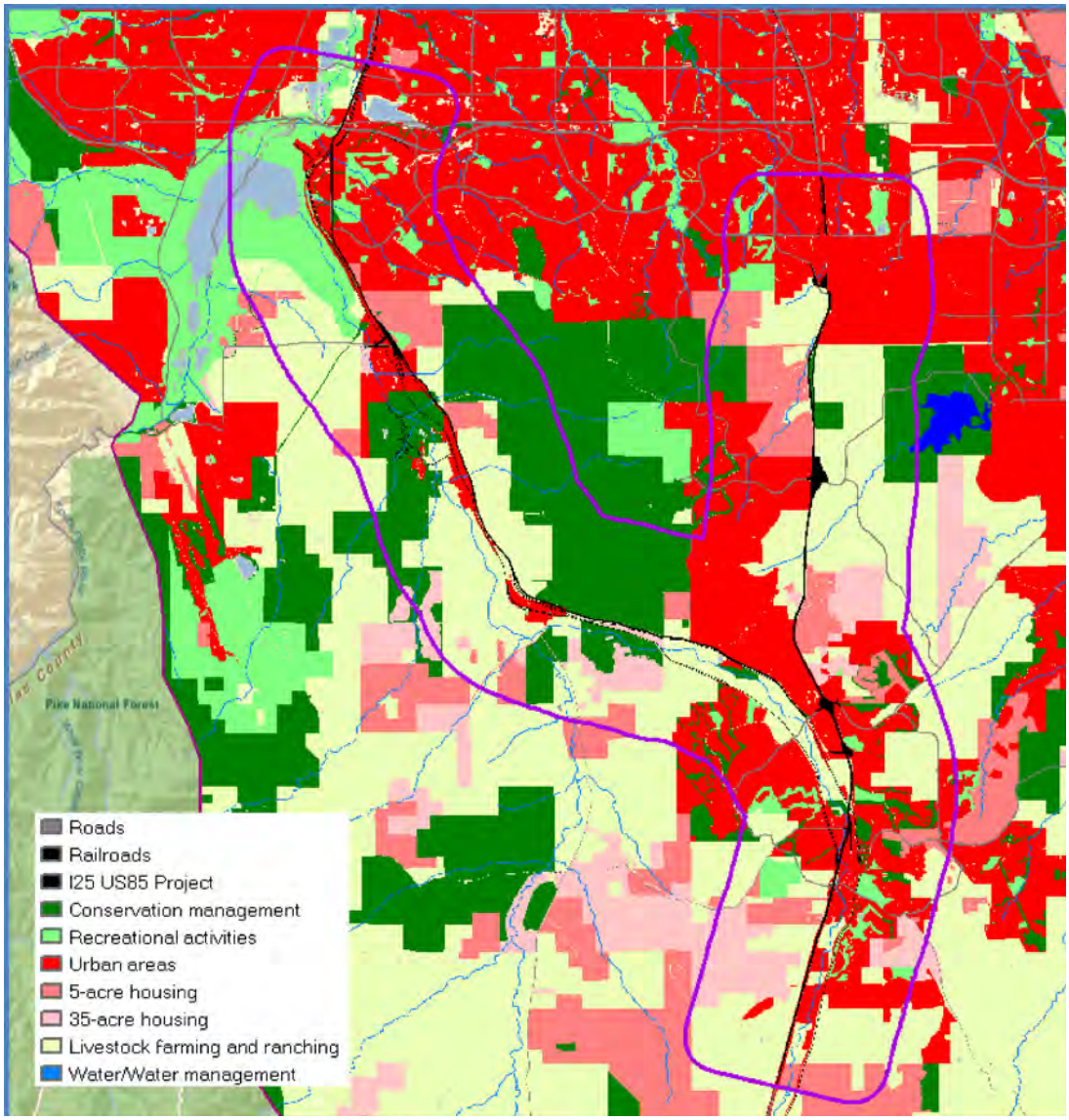

Figure C.5. The postconstruction land use scenario zoomed in on the South I-25 Corridor.

species population or ecological community stand and represents the geo-referenced biological feature that is of conservation or management interest. Examples include black-tailed prairie dog, northern pocket gopher, and Bell's twinpod.

- **Natural Communities:** These are defined as a distinct and recurring assemblage of populations of plants naturally associated with each other and their physical environment. Examples include Great Plains mixed grass prairie, freshwater forested/shrub wetland, and foothills ponderosa pine savanna.
- **Priority conservation areas:** These are areas that have been established as a priority for protection through a scientific- or stakeholder-based process. The research team included priority conservation areas from local and state organizations.

Step 3: Create Regional Ecosystem Framework

3a. Overlay the geospatially mapped long-range transportation plan

3b. Identify and show: areas and resources potentially affected by transportation improvements and potential opportunities for joint action.

3c. Identify the high-level conservation goals and priorities and opportunities for achieving them.

Figure C.7 shows a close-up of the geospatially mapped South I-25 Corridor overlaid with conservation priorities. This highlights the importance of an area along Plum Creek as a location with multiple element occurrences, natural communities, and priority areas. US-85 intersects more areas of importance than does I-25, especially federally protected

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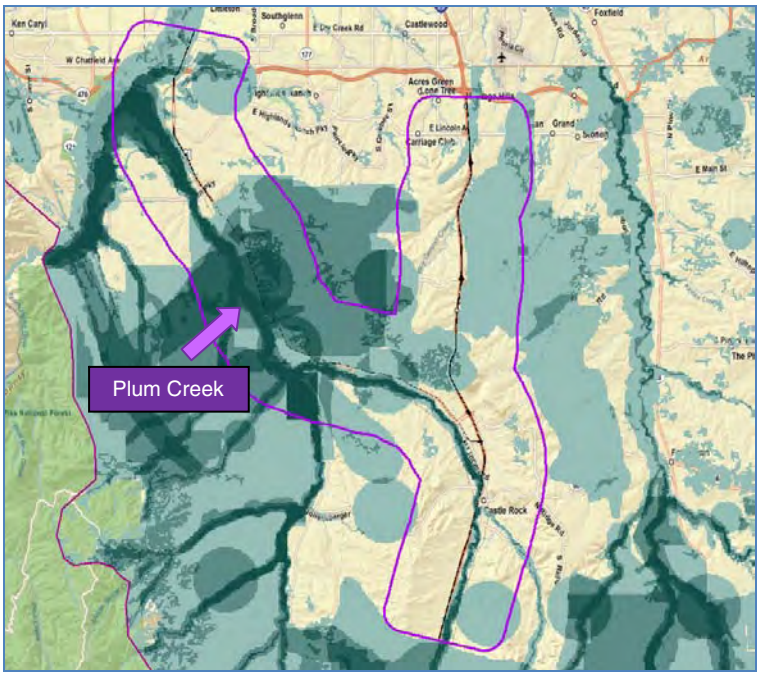

Dark areas indicate where higher concentrations of biodiversity and priority areas are located.

Figure C.6. Biodiversity and priority areas in the area of the South I-25 Corridor.

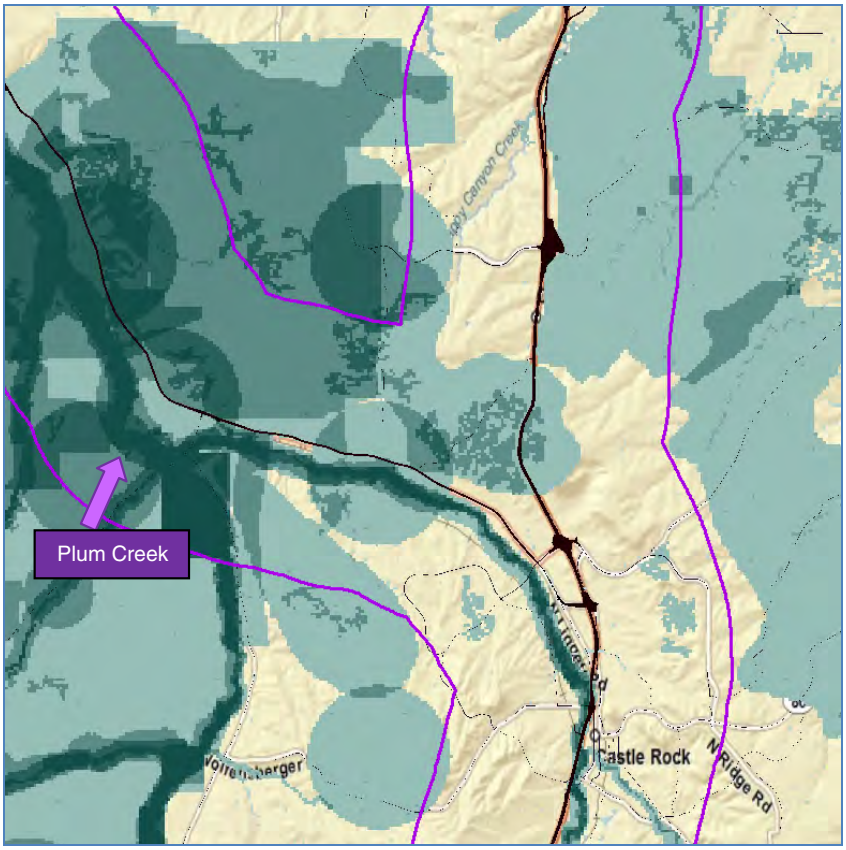

Figure C.7. South I-25 Corridor improvements overlaid on a map of biodiversity and priority areas.

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wetlands and PMJM critical habitat. The riparian areas along Plum Creek illustrate how the REF inputs show areas where multiple important natural resources coincide. This area is designated critical habitat for PMJM, and the area has confirmed locations of PMJM.

For the South I-25 Corridor, the research team intersected land use and transportation layers with the established natural resources. Using NatureServe Vista, the team evaluated each of the scenarios described: preproject and the postproject scenario (NatureServe 2012). Scenario evaluation is the process of comparing resources to the scenarios and viewing the results against the sets of predetermined resource retention goals. In the case of the Colorado pilot project, the team's goals were set at 100%. This simply reflects the need to know how much of any given conservation resource was affected. Depending on the preferences of the REF, the retention goals can vary widely. They can be derived from stakeholder preferences, an estimated amount of habitat needed to maintain a healthy population, or a legal threshold.

Step 4: Assess Transportation Effects on Resource Conservation Objectives Stated in the REF

4a. Weight the relative importance of resource types.
4b. Identify and rate how priority conservation areas and individual resources respond to different land uses and types of transportation improvements.
4c. Develop programmatic cumulative effects assessment scenarios that combine transportation plan scenarios with existing development and disturbances, other features and disturbances with impact, and existing secured conservation areas.
4d. Intersect the REF with one or more cumulative effects scenarios to identify which priority areas or resources would be affected; identify the nature of the effect and quantify the effect.
4e. Compare plan alternatives and select one that optimizes transportation objectives and minimizes adverse environmental impacts.
4f. Identify mitigation needs for impacts that are unavoidable.

Direct and Cumulative Impact Assessments

In the pilot project, the research team decided that wetlands, riparian areas, and known locations of PMJM were to take priority for protection. Wetlands and PMJM are protected by 404 and section 7 requirements, respectively. In Douglas County, the USFWS has accepted the county's designated riparian conservation areas (RCZ) as PMJM-critical habitat (Douglas County et al. 2005).

The land use and landcover maps developed for the assessment presented a total of nine classifications. In general, urban and transportation land uses will not support the long-term survival of most species occurrences, natural communities, and priority areas. The large extensions of ranchland in the pilot assessment area often harbor these areas but they easily transition to other land uses (namely urban uses), so the team decided to classify that as incompatible. Ranchland that had been permanently protected (such as with a conservation easement) was included in the protected areas and considered compatible with natural resources. In a real-life situation, assumptions about compatibility may be different and would take into account more detailed spatial information and expert/stakeholder opinion.

The intersection of the preproject scenario (current land use plus the South I-25 Corridor before improvements) will show many resources are incompatible with current land use. This may seem unintuitive: how do natural resources occur simultaneously with land uses that are incompatible, such as roads and urban development? Some land uses (e.g., low-density urban development) often harbor important natural resources, but it is assumed that the condition of a sensitive resource in a fragmented and developed setting is poor enough that long-term survival is unlikely. Whitetail deer will thrive in low-density urban areas; sharp-tailed grouse will not. In other cases, natural resources are mapped in such a way that they encompass many types of land use, not just natural areas. Priority areas and some species occurrences are examples of this. Understanding how current land use affects resources informs us about the current status of resources and the relative impact that a change in land use will create (as with the South I-25 Corridor).

Tables C.3 and C.4 illustrate the direct impacts of all land uses on the resources in the entire pilot assessment region.

- **Total area** represents the total amount of a resource found in the entire pilot analysis region;
- **ROW area** is the amount of resource found within a corridor approximately 300 feet on either side of the planned transportation improvements;
- **Preconstruction incompatible area** is the amount of resource already affected by the South I-25 Corridor transportation infrastructure before construction;
- **Postconstruction incompatible area** is the amount of resource affected after the transportation improvements are constructed; and
- **Total corridor direct impact** is the increase in impact created by the planned improvements (e.g., the amount of natural resources that the I-25 Corridor potentially will affect).

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Table C.3. Inventory of Resources Directly Affected by South I-25 Corridor Improvements

Resource	Total Area (acres)	ROW Area (acres)	Preconstruction Incompatible Area (acres)	Postconstruction Incompatible Area (acres)	Total Corridor Direct Impact (acres)
Douglas County (DoCo) wildlife crossings	422	136	10	34	24
DoCo wildlife high-value habitat	182,510	364	54	106	52
Colorado butterfly plant	2,055	166	15	41	26
DoCo wildlife conservation areas	87,425	454	44	103	59
DoCo riparian conservation area	18,300	56	1	3	2
Division of Wildlife (DOW) shrub-dominated wetlands key habitat area	52,701	210	136	136	0
DOW shortgrass prairie key habitat area	88,200	81	69	69	0
DOW ponderosa pine key habitat area	50,868	62	41	41	0
Riverine	2,630	19	2	3	1
Freshwater emergent wetland	3,449	1	0	0	0
Freshwater pond	2,424	1	0	0	0
Freshwater forested shrub wetland	2,337	13	2	3	1
PCA South Platte River	45,098	121	30	34	4
PCA Newlin Gulch	12,373	45	0	12	12
Plains sharp-tailed grouse	25,132	288	29	74	45
DoCo overland connection area	30,527	293	26	71	45
Preble's meadow jumping mouse (PMJM)	1,598	40	10	14	4
DoCo wildlife corridors	36,331	187	23	48	25

Table C.4. Inventory of Ecological Systems and Agricultural Area Directly Affected by South I-25 Corridor Improvements

Ecological System	Total Corridor Direct Impact (acres)
Agriculture: cultivated crops and irrigated agriculture	48
Southern Rocky Mountain ponderosa pine woodland	10
Rocky Mountain Gambel oak-mixed montane shrubland	24
Intermountain basins semidesert shrub steppe	7
Western Great Plains foothill and Piedmont grassland	74
Western Great Plains shortgrass prairie	14
Introduced upland vegetation-perennial grassland and forbland	77
Intermountain basins greasewood flat	2
Western Great Plains riparian	13

Intersecting the REF with the cumulative effects scenario identifies which natural resources have been most affected by the combined land uses that are considered incompatible with the long-term survival of natural resources. The products of a NatureServe Vista scenario evaluation are a report and several visualization layers that can be used in the REF process. The report summarizes, in total and by category, the performance of the scenario in terms of the number of acres and percentage of resources that met conservation goals. The report also includes amount and percentage of the original distribution, which remained unaffected by a change in land use (from rural to urban for example). The raster layers generated by the scenario evaluation identify areas in the planning region where conflicts exist: locations where natural resources intersect with land uses that do not support the health or survival of the natural resources. Vista creates a raster for all natural resource/land use conflicts and one for each individual resource.

Table C.5 illustrates the cumulative impacts of all land uses on the resources in the entire pilot assessment region. Figure C.8 is a spatial representation of the impacts listed in Table C.5.

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Table C.5. Inventory of Cumulative Impacts to Resources

Name	Total Resource Distribution Area (acres)	Preconstruction Compatible Area (acres)	Preconstruction Percentage of 100% Goal	Post construction Compatible Area (acres)	Post construction Percentage of 100% Goal
Natural Community (23 resources)					
Riverine wetland	2,630	2,124	80.76	1,975	75.10
Thinleaf alder forb riparian shrub	1,104	938	84.96	933	84.51
Mountain muhly herbaceous vegetation	86	86	100	86	100
Strap-leaf willow, coyote willow	888	786	88.51	779	87.73
Lake wetland	5,916	5,856	98.99	5,817	98.33
Freshwater emergent wetland	3,449	2,952	85.59	2,924	84.78
Freshwater pond	2,424	1,877	77.43	1,859	76.69
Freshwater forested shrub wetland	2,337	1,870	81.29	1,853	80.35
Other wetland type	427	301	65.93	295	64.04
Peachleaf willow alliance	207	49	23.67	49	23.67
Montane riparian willow carr	64	64	100	64	100
Plains cottonwood riparian woodland	6	5	83.33	5	83.33
Mixed foothill shrublands	243	243	100	243	100
Montane grassland	112	112	100	112	100
Mixed mountain shrubland	140	140	100	140	100
Narrowleaf cottonwood riparian forests	30	26	86.67	26	86.67
Foothills ponderosa pine savanna	40	40	100	40	100
Xeric tallgrass prairie	5,160	3,554	68.88	3,553	68.86
Foothills ponderosa pine scrub woodlands	6,254	3,978	63.61	3,978	63.61
Montane wet meadow	207	49	23.67	49	23.67
Xeric tallgrass prairie 2	3,974	3,794	95.47	3,607	90.76
Coyote willow mesic graminoid	1,364	1,036	75.95	1,030	75.51
Great Plains mixed grass prairie	2,628	2,600	98.93	2,596	98.78
Element Occurrence (19 resources)					
New Mexico cliff fern	1,999	1,922	96.15	1,912	95.65
Bells twinpod	2,420	2,150	88.84	2,150	88.84
Hops feeding azure	3,293	0	0	0	0
American yellow lady's slipper	2,004	444	22.16	440	21.96
Prairie violet	6,927	3,092	44.64	3,036	43.83
Prairie goldenrod	4,005	666	16.63	662	16.53
Rocky Mountain sedge	15	15	100	8	53.33
Colorado butterfly plant	2,055	1,810	88.08	1,792	87.20
Richardson alum root	4,007	2,944	73.47	2,821	70.40
Black-tailed prairie dog	4,608	4,560	98.96	4,538	98.48
Moss elfin	10,154	3,429	33.77	3,428	33.76

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Table C.5. Inventory of Cumulative Impacts to Resources (continued)

Name	Total Resource Distribution Area (acres)	Preconstruction Compatible Area (acres)	Preconstruction Percentage of 100% Goal	Post construction Compatible Area (acres)	Post construction Percentage of 100% Goal
Ovenbird	11	10	90.91	10	90.91
Fork-tip three-awn grass	46	34	73.91	34	73.91
Ottoe skipper	1,999	0	0	0	0
Mottled dusky wing	6,502	477	7.34	477	7.34
Preble's meadow jumping mouse (PMJM)	1,597	1,336	83.66	1,301	81.47
Plains sharp-tailed grouse	25,104	18,971	75.57	18,918	75.36
Northern pocket gopher	4,041	2,817	69.71	2,812	69.59
Northern redbelly dace	50	49	98	49	98
Priority Areas (16 resources)					
Douglas County (DoCo) wildlife conservation areas	87,425	84,127	96.23	83,855	95.92
DoCo riparian conservation area	18,287	16,647	91.03	16,489	90.17
PCA all other PCAs	51,077	47,272	92.55	46,784	91.60
Department of Wildlife (DOW) shrub-dominated wetlands key habitat area	19,655	13,950	70.97	13,426	68.31
DOW sand dune shrubland key habitat area	491	442	90.02	442	90.02
DOW shortgrass prairie key habitat area	67,043	60,092	89.63	55,672	83.04
DOW ponderosa pine key habitat area	40,329	27,943	69.29	27,771	68.86
PCA South Platte River	45,098	30,736	68.15	30,296	67.18
PCA Plum Creek at Louviers	230	198	86.09	198	86.09
PCA Newlin Gulch	12,373	10,792	87.22	6,970	56.33
PCA Wolhurst North	27	26	96.30	0	0
DoCo Chatfield proposed corridor	132	132	100	132	100
DoCo overland connection area	30,527	26,921	88.19	26,756	87.65
DoCo wildlife corridors	36,331	32,161	88.52	31,954	87.95
DoCo wildlife crossings	422	331	78.44	312	73.93
DoCo wildlife high-value habitat	182,510	149,824	82.09	148,423	81.32

Step 5: Establish and Prioritize Ecological Actions; Establish Mitigation and Conservation Priorities and Rank Action Opportunities

5a. Identify areas in the REF planning region that can provide the quantities and quality of mitigation needed to address the effects assessment and develop protocols for ranking mitigation opportunities.

5b. Select potential mitigation areas according to the ranking protocols.

Step 5 of the template deals with the process of identifying and creating off-site mitigation. It is important to note that the South I-25 Corridor project, as carried out by CDOT, chose to use a mitigation bank to address concerns about PMJM. This approach is recommended as part of the REF process because it allows an expert entity to consolidate multiple, perhaps disparate, projects and create a more effective solution. The I-25 Corridor impacts to wetlands and PMJM-critical habitat were mitigated through a habitat enhancement project on East Plum Creek that enhanced 25 acres of habitat. The habitat

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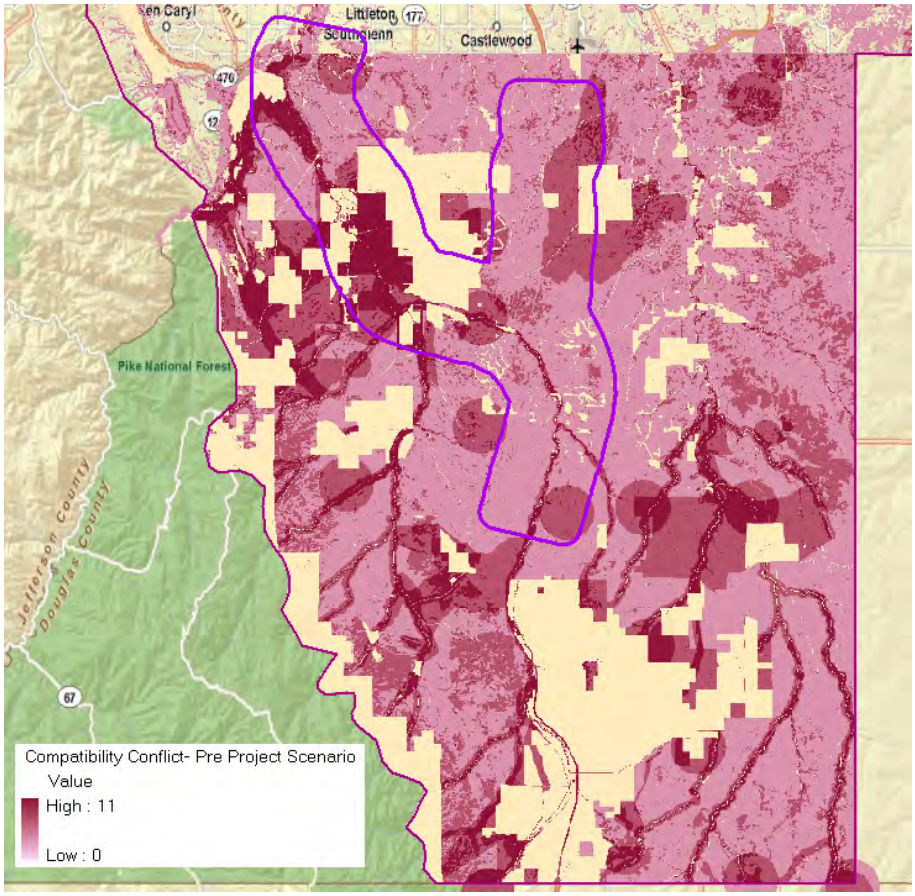

Red represents areas where resources are affected (darker red indicates where multiple resources are affected). Tan represents areas where resources are not affected.

Figure C.8. Map of cumulative impacts to resources.

enhancement project raised the water table enough to maintain the riparian vegetation necessary for quality PMJM habitat. In addition, CDOT and FHWA restored nearly 1 mile of East Plum Creek as part of a bridge construction project. Today, this restored habitat is part of a PMJM habitat conservation bank. In return for its mitigation work, CDOT received credits for future projects to occur in a defined service area.

The research team's proposed mitigation approach assumes that these options did not exist and proposes a mitigation option that builds on existing state and local priorities.

Most impacts to wetlands and PMJM occurred in an area within and north of the community of Castle Rock. Other affected sites consisted of small wetland areas draining the uplands saddled between US-85 and I-25. CDOT and the USFWS decided to focus their mitigation efforts on an area near the affected site on East Plum Creek, in an area heavily degraded by urban stormwater runoff (Bakeman n.d.). Bakeman's monitoring of the site revealed that PMJM populations benefited from the improved habitat conditions. However, the REF approach identified other nearby areas where other priority resources exist in greater number. If mitigation was not feasible or desired at CDOT's implementation site, the REF identified several other areas in addition to the wetlands and PMJM habitat. Figure C.9 shows the impact and mitigation site and the two alternative mitigation sites considered by the REF.

The research team used NatureServe Vista's Site Explorer to explore the effects of alternative land uses and policies on a site or set of sites. The tool allows the user to identify the natural resources that contribute to the REF of a particular site or set of sites. Sites can be landownership parcels or any unit that breaks up the analysis area into smaller subsections. In the case of the I-25 Corridor pilot project, landownership data were unavailable, so the team used a 10-acre grid to identify affected and potential offsite mitigation areas.

In addition, Vista's Site Explorer allows the user to identify land use and the elements' responses to those land uses and policies. The override menus at the bottom allow the user to specify alternative land uses and policies for the site that better meet their conservation objectives.

The Vista Site Explorer produces a site report that assists in determining how well the site is performing in meeting its

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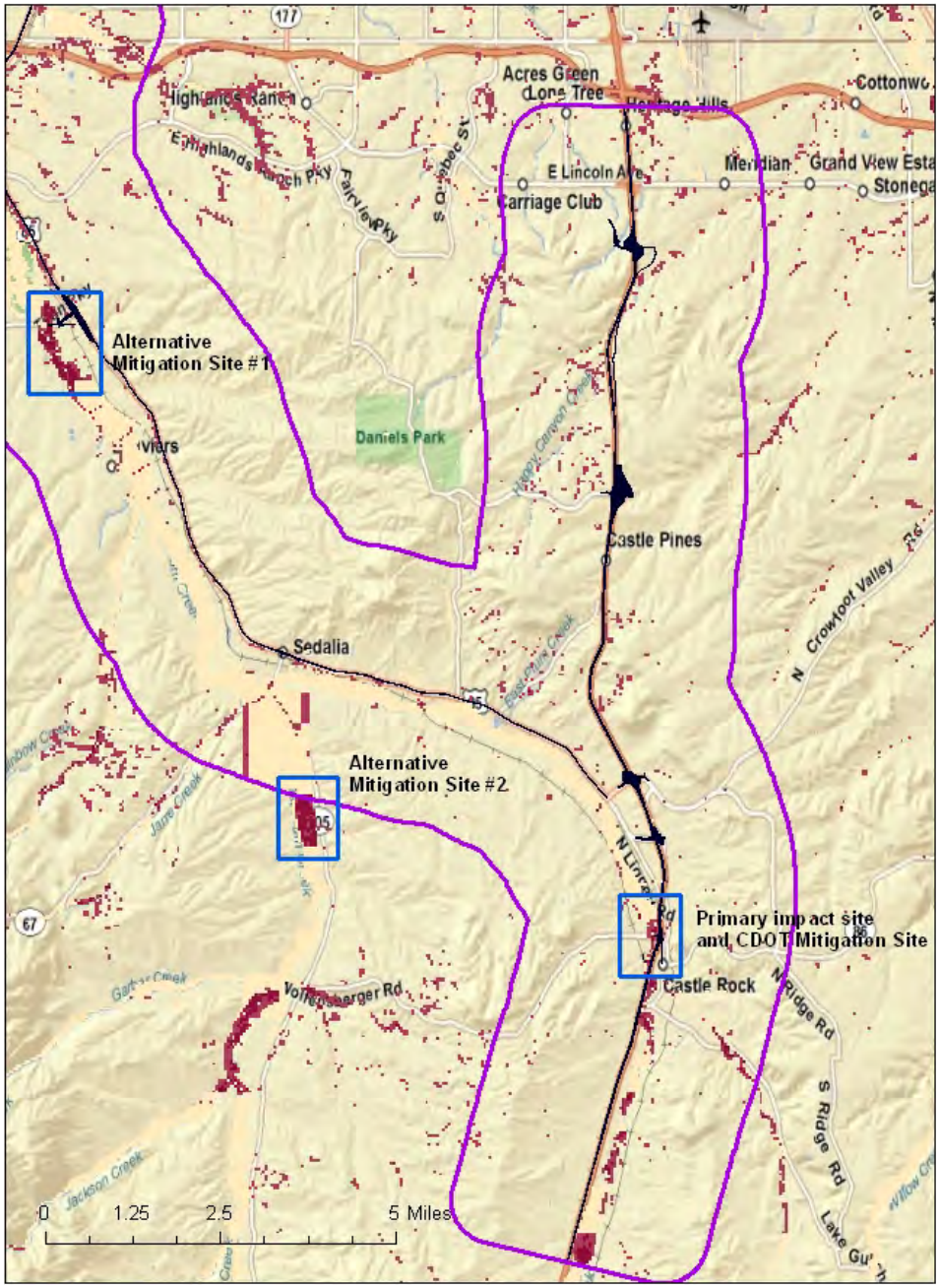

Figure C.9. The primary impact and CDOT mitigation sites are located within the town of Castle Rock. The two alternative mitigation sites are north and west of Castle Rock.

resource retention goals and, if those goals are not being met, to give a relative sense of the importance of the site for mitigation to better meet the goals with changes to the scenario factors. Specifically in this case, Vista Site Explorer provided an inventory of natural resources, the number and percentage of occurrences that are compatible, and the achievement of resource retention goals within the site and across the planning region. This provided a critical feedback loop for transportation planners, allowing them to develop multiple alternate off-site mitigation scenarios that meet the goals and can be shared with stakeholders and decision makers for additional input.

With Vista Site Explorer, the research team identified two areas with potential for mitigation. Figure C.10 shows an identified area north of Louviers on the main stem of Plum Creek that has wetlands and critical PMJM habitat, as well as an important Douglas County-designated wildlife crossing area. Figure C.11 shows an identified area on West Plum Creek,

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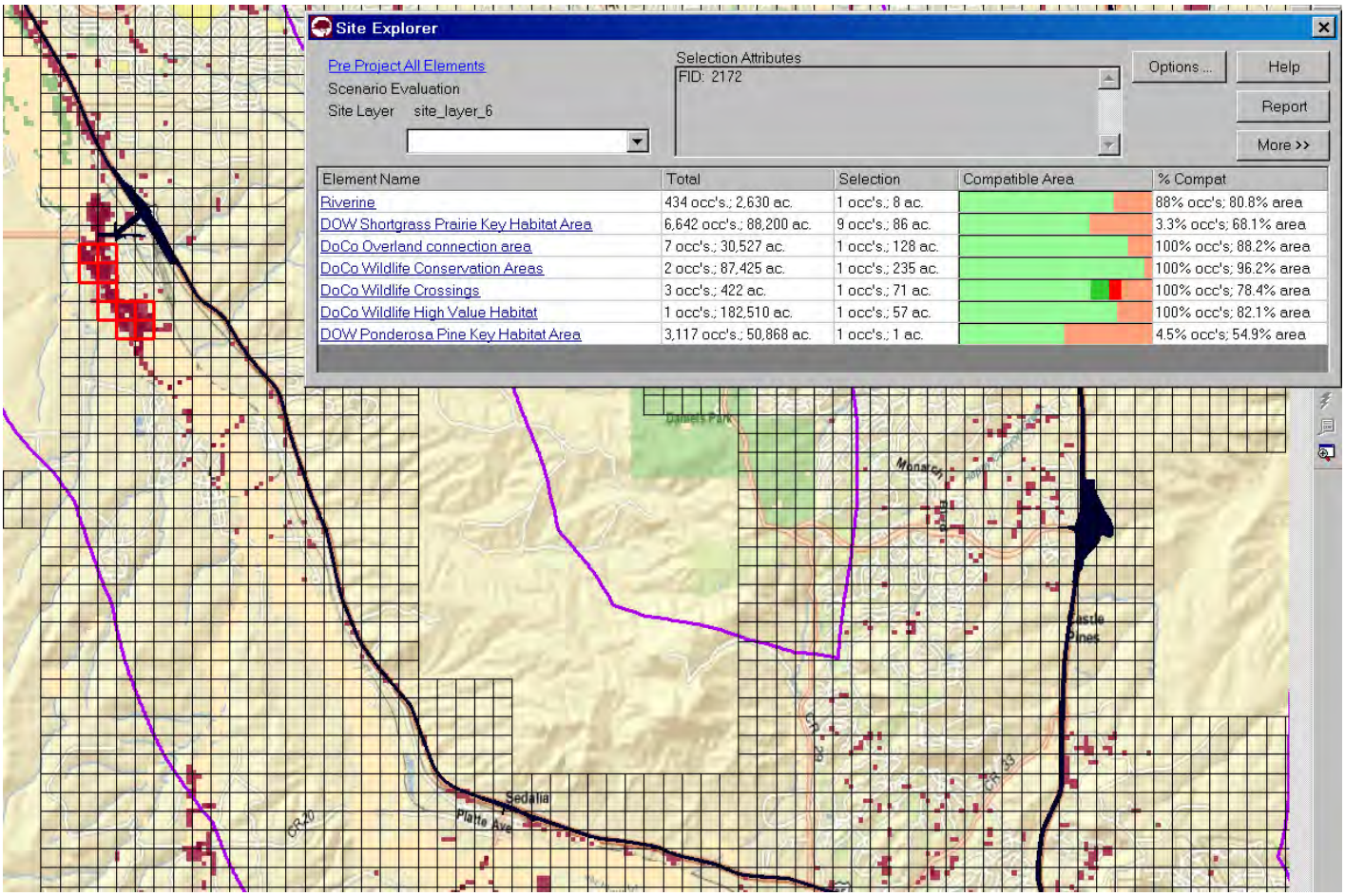

Figure C.10. Potential mitigation site north of Louviers.

just south of Sedalia, that in addition to the legally required features contains state-identified key ecological communities (thinleaf alder forb riparian shrub, coyote willow mesic graminoid) and other state and local priorities. The Vista Site Explorer override function allowed the research team to change the land use to one that is more compatible for natural resources. By identifying these areas, the team illustrates an approach to off-site mitigation that seeks to improve areas that have been strategically selected for conservation within the regional context.

Review and Comparison of CDOT Environmental Review

The primary documents used to review the process include the project EIS (FHWA and CDOT 2001) and relevant sections of the 2035 long-range transportation plan, such as the 2035 environmental technical report.

CDOT also provided the research team with three technical reports comparing the REF approach to the environmental review process that is described in the project technical reports; this was challenging because the review took place after construction plans had largely been finalized. The project technical reports rely heavily on field studies supplanted with air photo analyses, very fine scale analyses carried out to evaluate wetlands, species, and several wildlife connectivity studies. A biological assessment was done for PMJM; other species of concern also were addressed.

As the project consisted largely of lane widening, expanding interchanges, and small realignments, it had relatively small impacts to the environment. CDOT's action's sought to improve hydrological connectivity and increase the size and quality of wildlife crossings along I-85.

It is not the aim of this pilot study to criticize the approach or protocol taken by CDOT. All the research and work completed was done in compliance with Clean Water Act section 404 and ESA section 7. In addition, the studies CDOT oversaw took place in 1998, long before much of the data used in the current study were developed. Table C.6 summarizes the environmental impacts estimated by the EIS process.

CDOT's 2035 environmental technical report is the closest in comparison to the range and scope of the current document. CDOT's approach is not unlike the REF: the environmental technical report summarizes relevant state and federal statutes and compares existing and proposed transportation (primarily the state highway system) facilities against known

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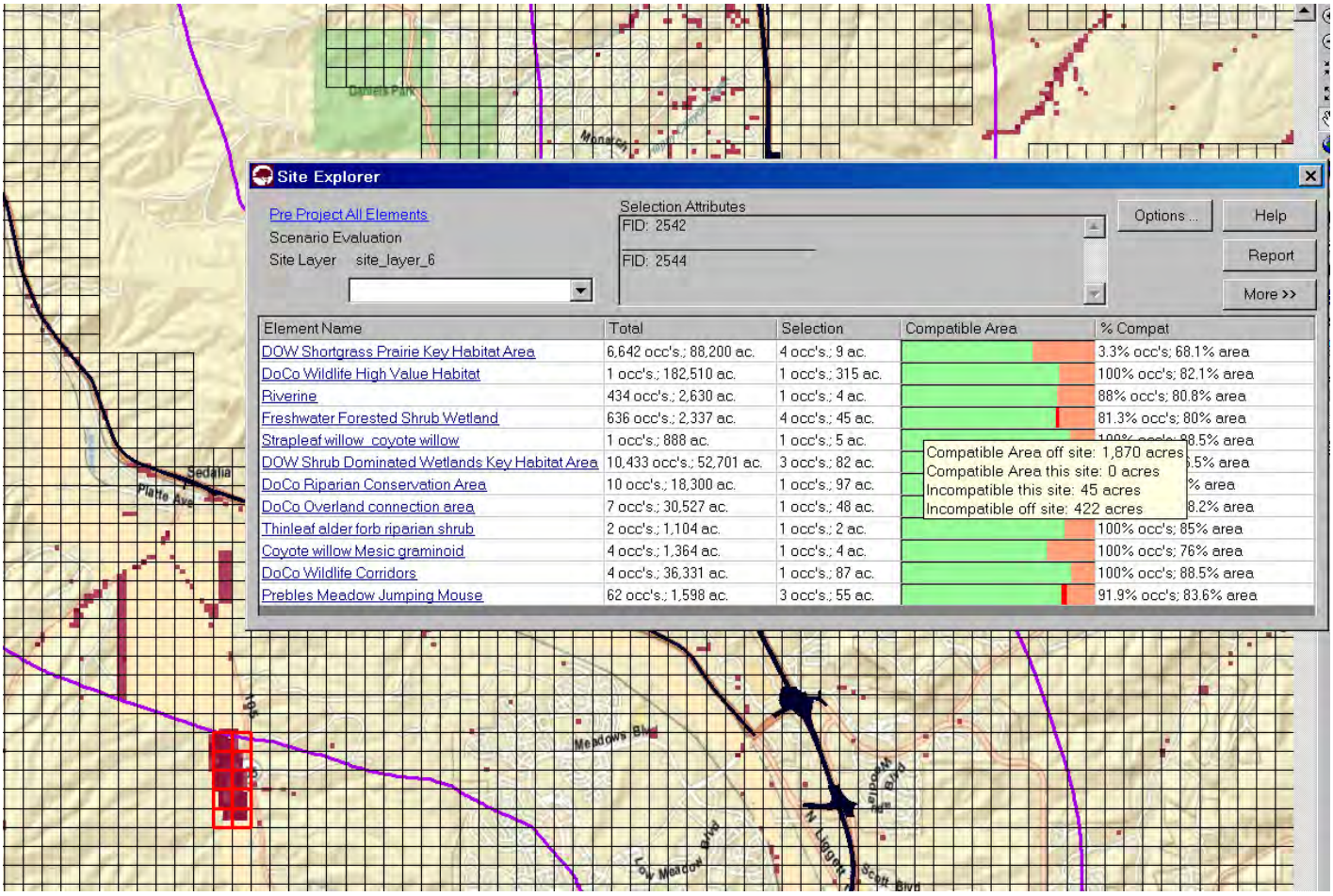

Figure C.11. Alternative mitigation site number 2.

inventories of natural and historic resources. Natural resource impacts focused on four priority resources: water quality, wetlands, migratory birds, and historic resources. The inventories were developed in consultation with state and federal agencies, and a list of known and potentially present resources within each corridor was developed. Mitigation strategies were developed for priority resources, although CDOT clarifies that most environmental mitigation is developed during the environmental review process at the project level. An exception to this are areas of proactive environmental mitigation, defined as "areas where there is the potential for a number of projects to impact a particular resource" and where it may be appropriate to identify and compensate for future impacts to a resource before project impacts occur. These proactive environmental mitigation programs include several that are relevant to the South I-25 Corridor: the East Plum Creek PMJM Bank and the Shortgrass Prairie Initiative. The latter received an Exemplary Ecosystem Initiative award from FHWA in 2002. Environmental forums were held around the state; the DRCOG corridor forum had many of the organizations present that would conceivably comprise the stakeholders in an REF process.

The environmental technical report does not identify specific projects, project locations, or designs. It also lacks spatial detail and a more comprehensive examination of affected resources than that provided by the REF.

The REF approach used in the pilot study uses basic assumptions about the extent and location of planned highway improvements. It intersects these changes with priority resources that are also spatially explicit. Although the REF did not include historic resources, hazardous material locations, or fully address water quality, these resources could be added and addressed in the framework.

CDOT's decision to use the East Plum Creek PMJM Bank as a tool for mitigation is in line with the recommendations of the REF. The PMJM banks proved to be an effective way for mitigation to occur, as opposed to the ad-hoc mitigation often used by DOTs. The two alternative mitigation sites that the project team identified are further from the site of impact but harbor additional state and priority resources identified by the REF. This would allow for a more strategic mitigation in terms of developing a mitigation scenario that benefits multiple key resources. The team's recommendations for mitigation illustrate a process

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Table C.6. Comparison of the Environmental Impacts Estimated by the EIS and the REF Pilot Project

Resource	I-25 Corridor	US-85 Corridor	REF Pilot Results (combined I-25 & US-85)
Neighborhood	None	None	Not evaluated
Environmental justice	None	None	Not evaluated
Relocation	None	Nine relocations	Not evaluated
Right-of-way (ROW)	10.1 ha (25.0 acre)	49.4 ha (122 acre)	1,927 acre
Recreational resources	None	Centennial Trail: 2 m (6.5 ft) High Line Canal Trail: 124 m (410 ft) Spring Gulch: 0.2 ha (0.6 acre)	Not evaluated
Land use	Changes to higher-density use	Changes to higher-density use	Similar findings
Air quality	None	None	Not evaluated
Water quality and quantity	Minimal impacts to water quality Impervious area: 1,048,801 m^2 (11,285,096 ft^2)	Potential improvements to water quality Impervious area: 711,452 m^2 (7,655,223 ft^2)	Impervious area added: 1,885,835 m^2
Vegetation	73.6 ha (182 acre)	68 ha (169 acre)	See Figure C.5
Wetlands	0.10 ha (0.25 acre) wetlands 0.19 ha (0.48 acre) other waters of United States	0.10 ha (0.25 acre) wetlands 0.46 ha (1.14 acre) other waters of the United States	2 acres
Geology	None	None	Not evaluated
Wildlife	67.5 ha (166.8 acre) loss of habitat	61.0 ha (151 acre) loss of habitat	52 acres of high-value wildlife habitat
Wild and scenic rivers	None	None	Not evaluated
Floodplains	Happy Canyon Creek nos. 1 and 2, Tributary A, Tributary D, Hangman's Gulch, and East Plum Creek nos. 1 and 2 are expected to be directly affected	Marcy Gulch, No Name no. 1, No Name no. 2, No Name no. 3, Indian Creek, Tributary A, Tributary B, and Tributary C are expected to be directly affected	13 acres of riparian area (floodplain ecological system)
Threatened, endangered, and other special-status species	Black-tailed prairie dog: 0.10 ha (0.24 acre) PMJM: 1.76 ha (4.36 acre)	Black-tailed prairie dog: 2.47 ha (6.1 acre)	4 acres of PMJM species occurrence area; 2 acres of designated critical habitat
Historic resources	Denver & Rio Grande Western Railroad (D&RGW RR): 870 m (2,850 ft)	Atchison, Topeka and Santa Fe Railway (ATSF) Railway: 4.3 m (14 ft) Cherokee Ranch: 5.1 ha (12.5 acre)	Not evaluated
Section 4(f) properties	D&RGW RR: 870 m (2,850 ft)	High Line Canal Trail: 124 m (410 ft) Spring Gulch: 0.2 ha (0.6 acre) ATSF Railway: 4.3 m (14 ft) Cherokee Ranch: 5.1 ha (12.5 acre) Cherokee Ranch conservation easement: 6.5 ha (15.9 acre)	Not evaluated
Archaeological resources	Potential impacts to two sites	Potential impacts to one site	Not evaluated
Paleontological resources	Potential impacts to one site	Potential impacts to one site	Not evaluated
Prime and unique farmland	No Prime and unique farmland impacts 1.34 ha (3.3 acre) of High-potential dry cropland	No prime and unique farmland impacts 17.4 ha (43.0 acre) of high-potential dry cropland	48 acres of cropland
Noise	25 receivers	7 receivers	Not evaluated
Visual character	Change in visual character	Change in visual character	Not evaluated
Hazardous waste sites	Additional investigation needed	Additional investigation needed	Not evaluated

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that might have been followed in the absence of a mitigation bank.

Michigan Pilot Project Report

Pilot Project Introduction

The goals of the Michigan pilot study were to:

- Evaluate efficacy of the Framework when applied to an alternative corridor assessment;
- Evaluate efficacy of NatureServe Vista for building an REF without a spatially based local, regional, or statewide conservation plan in place; and
- Evaluate efficacy of using several wetland data sets for mitigation.

Pilot Test Area Introduction

First, the project team set up meetings with key state and federal agency staff from the transportation and natural resource communities in Colorado, Michigan, and Oregon to introduce the team's results. Using the team's selection criteria and input from the meeting participants, a project in each state was selected for conducting the testing.

In Michigan, a series of sites were evaluated after a November 10, 2009, workshop that included Michigan Department of Transportation (MDOT) and environmental agency staff.

Potential pilot project areas discussed were

- Detroit-to-Chicago high-speed railroad corridor;
- I-94 corridor capacity enhancements;
- I-75 corridor improvement opportunities;
- Traverse City bypass;
- Petoskey bypass;
- M-6 (Grand Rapids South beltway);
- US-23;
- US-131 Corridor (St. Joseph County);
- M-5/Hagerty Road;
- M-31 at Grand Haven; and
- US-31 Blue Creek fen.

Michigan Pilot Project Chosen

The US-131 Corridor in St. Joseph County was chosen as the pilot project in Michigan. This transportation project was chosen based on several criteria. The US-131 project had to address several environmental concerns, including wetlands, floodplains, and federal- and state-listed species. One of the key aspects that made this project particularly attractive for analysis was the wealth of geospatial wetland data already available and additional wetland data that were in the process of being developed (circa 1800 and 2005 functional wetland assessment). The original corridor study considered several realignments, and a bypass around the city of Constantine that required a significant river crossing was being considered at the project level. Finally, St. Joseph County was considered to be representative of many rural counties in the Midwest: scattered natural resources, predominantly agricultural land, and projected low growth.

The US-131 Corridor is located in a rural region of the southwest Lower Peninsula of Michigan within the St. Joseph River watershed (Figure C.12). The existing US-131 highway is a statewide principal arterial extending 270 miles from the Indiana state line north to the city of Petoskey. According to a public hearing report developed by MDOT, the high volume of trucks using US-131 disrupts community activities and creates traffic mix problems. Truck volumes represented 14% of the average daily volume, which is double the typical commercial volume along rural routes that are not freeways. This high volume of trucks also causes vibrations and noise when the trucks travel through Schoolcraft, downtown Constantine, and its registered historic district. The Corridor Location Study Report was designed to present recommendations for the general location of an improved or relocated trunkline highway and the type of cross-section design that will best satisfy the MDOT's responsibility.

The most commonly voiced public comments about the corridor study dealt with the following issues:

- Maximum use of the existing ROW;
- Increase safety, and reduce congestion, noise and vibration levels in the central business districts;
- Minimize negative impacts to environmentally sensitive areas;
- Increase the efficiency of travel by separating US-131 traffic from local traffic; and

Figure C.12. Location of the pilot region.

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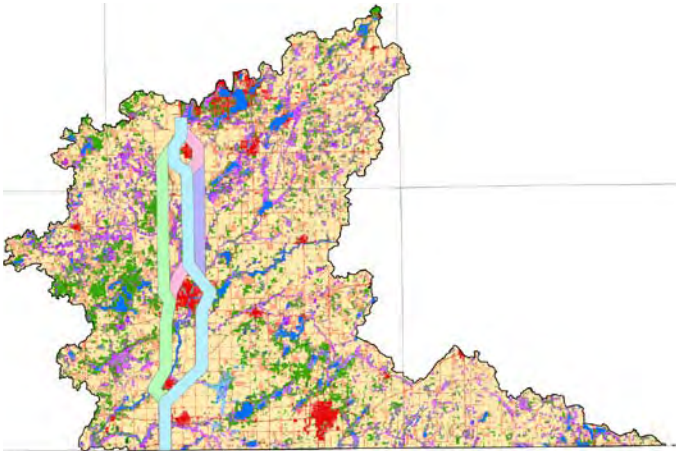


Figure C.13. Five alternative corridors and 2005 landcover.

- Address the potential economic impact on the villages of Schoolcraft and Vicksburg.

The principal planning objectives that needed to be addressed by the corridor study included:

- Maximize trunkline services and efficiency;
- Minimize impacts to farmland and environmentally sensitive areas;
- Contain future costs of construction; and
- Recognize local and regional development plans.

There were five alternative corridors (plus one no-build alternative) studied in 1997 that started at the southern St. Joseph County border and ended approximately 3 miles north of Schoolcraft in Kalamazoo County, just north of U Avenue. The length of the corridor study area stretched approximately 27 miles. Each study corridor was 1 mile in width (Figure C.13). Environmentally, the US-131 corridor location project involved wetlands, several river systems, and potential habitat for several federal- and numerous state-listed species.

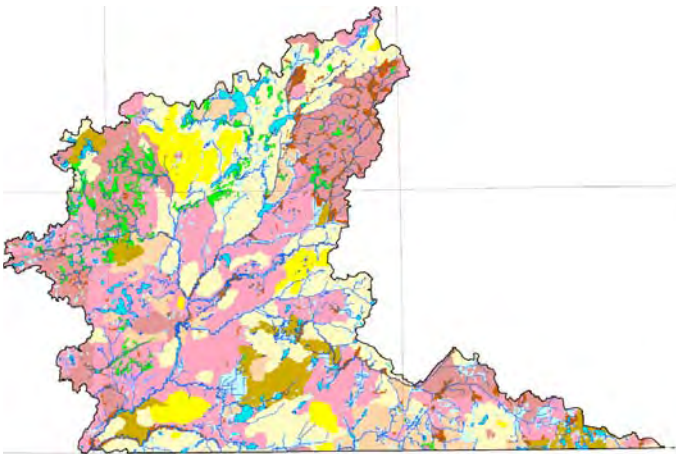
Pilot Ecological Background Information

The pilot project site is located within the Battle Creek Outwash Plain subsection. This subsection is located in the southwestern region of the Lower Peninsula and is best described as a broad flat outwash plain containing numerous small lakes and wetlands and small ridges of ground moraine. More than 80% of the outwash plain is sandy soil in the 0–6% slope class. Several major rivers flow through this relatively flat plain, including the St. Joseph River.

Well-drained soils (sand) on the outwash historically supported fire-dependent natural communities, such as tallgrass prairie and oak savannas. Tallgrass prairie areas as large as 20 square miles and nearly 50 prairies were known to occur in the subsection covering 29,549 acres (Table C.7). Overall, approximately 35% of the landscape supported fire-dependent natural communities. Poorly drained sections of the outwash supported swamp forest, and wet prairies, marshes, and extensive wet meadows were found along the rivers and streams. Isolated pockets of sandy end moraine or ground moraine often supported various types of oak savannas (Albert 1995) (Figure C.14).

Table C.7. Circa 1800 Vegetation Summary

Cover Type	Acres	Percentage
Beech-sugar maple forest	81,422	14.59
Black oak barren	37,060	6.64
Grassland	29,549	5.29
Mixed oak savanna	128,927	23.10
Mixed oak forest	27,840	4.99
Oak-hickory forest	141,976	25.44
Mixed conifer swamp	20,298	3.64
Mixed hardwood swamp	19,892	3.56
Black ash swamp	951	0.17
Bog	297	0.05
Shrub swamp/emergent forest	49,418	8.85
Wet prairie	3,511	0.63
Lake/river	16,977	3.04
Total	**558,118**	**100.00**



Green = mixed conifer swamp; light blue = emergent marsh; light yellow = mixed oak savanna; pink = oak dominated forest; red/brown = sugar maple forest; tan = black oak barren; yellow = prairie.

Figure C.14. Circa 1800 vegetation map.

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Current Land Use

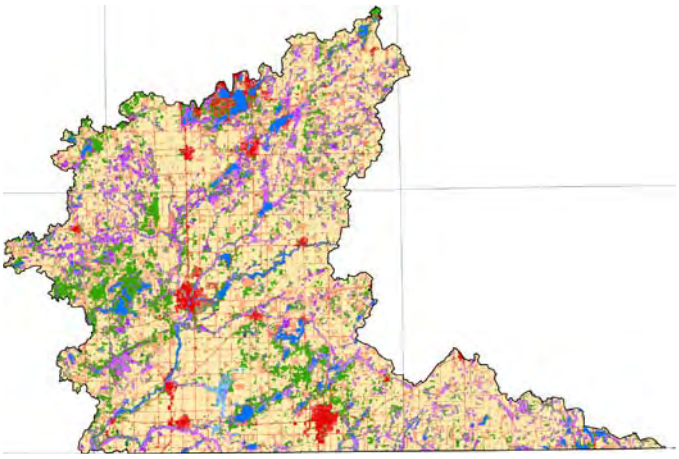
According to the 1997 St. Joseph County Master Plan, more than 234,823 acres are in agriculture use (64% of all land within the county). Most agricultural land is used for crops, pasture, and hay. Residential uses within St. Joseph County comprise only 3% of the area, open land 5%, water 3%, forestland 17%, and other 8%. Land use along the existing US-131 highway is primarily agricultural, with scattered single-family homes, multifamily homes, community facilities, and farmsteads in or surrounding the village of Constantine and the city of Three Rivers. Light industrial and commercial development is found along US-131, primarily at intersections with M-60, US-12, and within the Village of Constantine and city of Three Rivers (Figure C.15). Of the project area, 63% is in agricultural use (Table C.8). Today, most of the uplands and large areas of wetlands have been converted to agriculture, and numerous wetlands, especially riparian wetlands, are used for pasture.

Population Background

As mentioned, this project is located in a rural region of Michigan with a sparse population. According to the 2000 census, only 23,862 people resided within the six municipalities (three townships, Constantine, Three Rivers, and White Pigeon) or in the intersecting project area. However, these six municipalities are expected to grow approximately 19.14% to 28,429 by 2025 (final EIS).

The 1997 MDOT corridor study recommended corridor A based on:

- Eliminating the need for multiple bridges east of Schoolcraft and Constantine;



Dark blue = water; green = upland forest; light blue = nonforested wetlands; purple = wetland forest; red = urban; tan = agriculture.

Figure C.15. 2005 Land use and landcover in the pilot area.

Table C.8. 2005 Pilot Area Land Use and Landcover

Land Use and Landcover	Acres	Percentage
Developed, high intensity	1,258	0.23
Developed, medium intensity	2,976	0.53
Developed, low intensity	21,081	3.78
Developed, open space	6,371	1.14
Cultivated crops	293,138	52.52
Pasture/hay	57,181	10.25
Grassland/herbaceous	4,069	0.73
Deciduous forest	68,981	12.36
Evergreen forest	2,544	0.46
Mixed forest	2,957	0.53
Scrub/shrub	5,105	0.91
Palustrine forested wetland	50,442	9.04
Palustrine scrub/shrub wetland	16,345	2.93
Palustrine emergent wetland	5,176	0.93
Unconsolidated shore	473	0.08
Bare land	1,496	0.27
Open water	18,439	3.30
Palustrine aquatic bed	83	0.01
Total	**558,116**	**100.00**

- Minimal disruption to residential development;
- Minimal impact to prime farmland;
- Less disruption to future development between Schoolcraft and Vicksburg; and
- Maximum trunkline service and effectiveness.

Testing the Ecological Assessment Framework

The Michigan pilot project tested only steps 1–5 (below) of the C06B Technical Guidance and certain associated substeps.

Step 1: Build and Strengthen Collaborative Partnerships, Vision

1a. Identify planning region

The US-131 transportation corridor project was chosen as the pilot study because of its potential realignment and consequently its potential impact on wetlands, river systems, and a small number of state- or federal-listed species in the region. One of the reasons Michigan was chosen as a state in which to conduct a pilot project to test parts of the newly proposed transportation framework was, at least in part, because of

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(1) the relatively large percentage of wetlands remaining in the state, (2) the existence of a circa 1800 vegetation data layer, (3) ongoing 2005 National Wetlands Inventory (NWI) update and enhanced database, and (4) the development of a wetland functional assessment database for select watersheds in the Southern Lower Peninsula.

Ten subwatersheds were identified at the 12-digit hydrologic unit code (HUC) level that intersected with the existing US-131 highway located in St. Joseph County. A watershed approach was taken to define the planning region for this study primarily because this was the framework being used to develop the wetland functional assessment database. Many of the conservation elements incorporated into this study have statewide coverage; however, the wetland functional assessment has been completed in only select watersheds. Because the larger St. Joseph River watershed was already a priority, the former Michigan Department of Environmental Quality staff was willing to allocate some of their time to attribute the subwatersheds that intersected the US-131 highway.

Step 2: Characterize Resource Status; Integrate Conservation, Natural Resource, Watershed, and Species Recovery and State Wildlife Action Plans

2a. Identify the spatial data needed to create understanding of current conditions.

2b. Prioritize the specific list of ecological resources and issues that should be further addressed in the regional ecosystem framework.

2e. Produce geospatial overlays of natural resource data and supporting priorities (natural resource spatial data used for analysis).

After the spatial characteristics of the spatial data available in the pilot study area were reviewed (Table C.9), several data layers were removed for various reasons. Spatial data used for identifying conservation priorities in the region were: (1) federal- and state-listed species, (2) rare or exemplary natural communities, (3) large contiguous natural landscapes, (4) potential high-quality natural vegetation patches, (5) potential unique, (6) high-quality lakes, (7) potential unique stream segments, (8)potential high-quality stream segments, and (9) existing wetland functions (13 total).

Data Overview

The biggest data weakness within the US-131 study area is lack of systematic surveys in the planning region for listed species and rare/exemplary natural communities. As a result, the Natural Heritage Database consists of incomplete data, with last observed dates ranging from the late 1800s to 2009. Short of conducting systematic biological inventories, three actions would help address some of the shortcomings of the data contained in the Michigan Natural Features Inventory (MNFI) Biotics database. The NatureServe Biotics system is a customized database system developed by NatureServe for use by its member programs. It is an advanced GIS-based software tool for managing biodiversity information. Biotics is intended to promote interoperability throughout the NatureServe network of member programs, ensuring that data collected in each state and province can be compared, exchanged, and combined. Potential inventories could:

- Mine data from known sources of information, such as museums and universities;
- Address element occurrence backlog;
- Develop an inferred extent data layer for all known animal occurrences and historic plant records; and
- Develop predictive distribution models for all listed species (starting with the most significant).

Natural Resource Overlay Results

All of these data layers were imported into NatureServe Vista as individual conservation elements. Depending on the end user's interests, conservation elements can be categorized or weighted, and filters also can be used. For our purposes, a simple overlay of the eight conservation elements mentioned was created without weights. A map showing areas of varying conservation significance within the pilot region appears below (Figure C.16). The results clearly show that conservation values differ significantly from place to place within the pilot region, and that most natural resources are highly fragmented and scattered across the landscape. In general, areas with high conservation values are located along the floodplains of the major river systems, particularly in the northern half of the pilot region. Other places with high conservation value include areas in and around the Three Rivers and Gourdneck State Game Areas, as well as The Nature Conservancy's Tamarack Swamp preserve.

Step 3: Create Regional Ecosystem Framework

3a. Overlay the geospatially mapped long-range transportation plan

3b. Identify and show areas and resources potentially affected by transportation improvements and potential opportunities for joint action.

3c. Identify the high-level conservation goals and priorities and opportunities for achieving them.

For this project, the project used the 1997 alternative corridor study as their transportation plan to determine which alternative corridor would have the least amount of impact to the region's natural resources. The 1997 corridor study

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Table C.9. Natural Resource Spatial Data Considered in the Pilot Study

Data Layer	Source	Coverage	Brief Description	Data to Include
MNFI heritage database	MNFI	Statewide	Documentation of known rare animal, plant, exemplary natural community, and other unique natural feature occurrences. Data is incomplete for the state.	All known EO's except general records
Updated and enhanced NWI wetlands	DU	Intent is statewide in scope. Currently completed 40 counties.	All wetland polygons are delineated based on 2005 aerial photos, and attributed by wetland type and hydrogeomorphic descriptors.	All wetlands
Reference streams	IFR	Statewide	High quality stream segments identified based on a series of hydrologically based data.	Reference streams, no impact streams
Functional sub-watersheds	MNFI	Statewide	All sub-watersheds at the 12 digit HUC scale were evaluated based on a habitat, fragmentation, and pollution criteria.	Only scores < or = 3
Potential unique stream segments	MNFI	Lake Michigan Ecological Drainage Unit	Stream segments designated as potentially unique within the Lake Michigan EDU using a 5% rule.	All vsecs in shapefile
Potential high quality lakes	MNFI	Lake Michigan Ecological Drainage Unit	Lakes designated as potentially high quality based on land cover data.	All lakes in shapefile
Potential unique lakes	MNFI	Lake Michigan Ecological Drainage Unit	Lakes designated as potentially unique within the Lake Michigan EDU using a 5% rule.	All lakes in shapefile
Core natural vegetation areas of the SLP	MNFI	Southern Lower Peninsula ecoregion	Patches of natural vegetation >500 acres dissected by major roads with no buffer within the Southern Lower Peninsula ecoregion.	All patches in shapefile
TNC important bird areas of MI	TNC	Statewide	Large areas important to rare, declining and other significant bird species for breeding, foraging, and/or migrating.	All polygons in shapefile
TNC ecoregional priority areas	TNC	Statewide	Important areas for biodiversity as determined by the TNC ecoregional planning process.	All polygons in shapefile
MNFI patch analysis	MNFI	Statewide	All natural patches of vegetation are evaluated based on several spatial criteria by vegetation type.	Only patches rated as high quality
2005 functional wetland assessment	Formerly MDEQ; currently DNRE	Intent is statewide in scope. Currently completed about 10 watersheds.		Include all wetlands and functions
Circa 1800 functional wetland assessment	Formerly MDEQ; currently DNRE	Intent is statewide in scope. Currently completed about 10 watersheds.		Include all wetlands and functions

evaluated five alternatives, each beginning at the southern border of St. Joseph County along the existing US-131 highway, and ending approximately 3 miles north of the village of Schoolcraft. Each alternative corridor is approximately 1 mile in width (Figure C.17). Because of the unavailability of GIS shape files from the original corridor study, the approximate centerline of each of the five corridors had to be digitized from a hard copy map of the study area and buffered 1 mile to complete this analysis.

Step 4: Assess Transportation Effects on Resource Conservation Objectives Stated in the REF (Integrated Conservation/Restoration Priority and Transportation Plan)

4a. Weight the relative importance of resource types.

4b. Identify/rate how priority conservation areas and individual resources respond to different land uses and types of transportation improvements.

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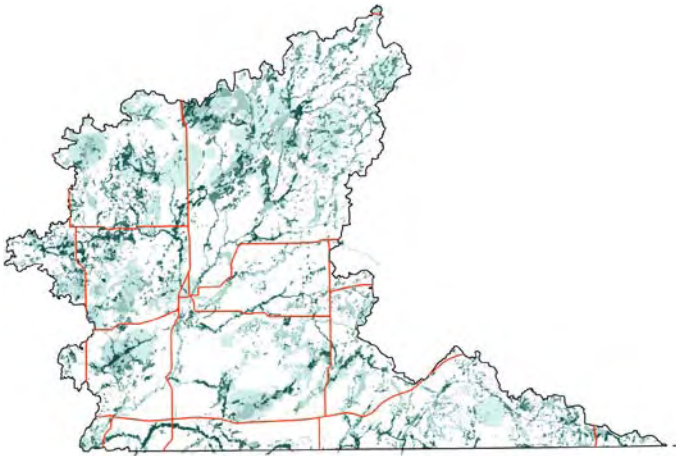

Darker colors indicate higher conservation value. Red lines indicate major roads.

Figure C.16. Conservation value summary map of pilot area.

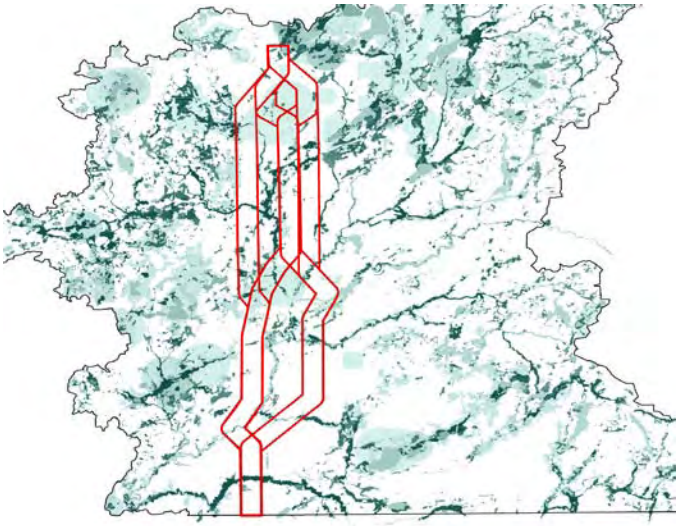

Figure C.17. Alternative US-131 corridors overlaid on conservation priority areas.

4c. Develop programmatic cumulative effects assessment scenarios that combine transportation plan scenarios with existing development and disturbances, other features and disturbances having an impact, and existing secured conservation areas.

4d. Intersect the REF with one or more cumulative effects scenarios to identify which priority areas or resources would be affected; identify the nature of the effect and quantify the effect.

4e. Compare plan alternatives and select one that optimizes transportation objectives and minimizes adverse environmental impacts.

4f. Identify mitigation needs for impacts that are unavoidable.

4g. Establish a preferred transportation plan and quantify mitigation needs.

For the purposes of the pilot study, all resource types used in the analysis were equally weighted. Resource types used in the analysis included: (1) federal- and state-listed species (79); (2) rare or exemplary natural communities (13); (3) large contiguous natural landscapes; (4) potential high-quality natural vegetation patches; (5) potentially unique lakes; (6) potentially high-quality lakes; (7) potentially unique stream segments; (8) potentially high-quality stream segments; and (9) existing wetland functions (13).

For this project, all five 1-mile-wide corridors were incorporated into NatureServe Vista as five different scenarios. Each corridor, or scenario, was then evaluated to measure its impact on each of the 9 resource types listed.

Alternative Corridor Scenario Impact Results

Several tables provided here summarize the impacts of each corridor by resource type (Tables C.10–C.14). Impacts are summarized by acres, occurrences, or both. Table C.10 shows that corridors A and B had the least amount of impact on

Table C.10. Summary of Aquatic and Terrestrial Element Impacts

	Corridor A	Corridor B	Corridor C	Corridor D	Corridor E
Aquatic Elements	**Acres Lost**				
Unique Lakes	0.00	0.00	9.50	4.75	4.75
Unique stream segments	21.25	21.75	21.25	71.25	71.00
High quality lakes	0.00	0.00	0.00	0.00	0.00
High quality stream segments	89.00	89.75	136.00	105.00	86.75
Total	**110.25**	**111.50**	**166.75**	**181.00**	**162.50**
Terrestrial Elements					
High quality natural patches	499.75	503.75	344.75	638.25	624.50
Large natural landscapes	1,945.75	1,963.50	2,097.25	1,889.00	2,215.75
Total	**2,445.50**	**2,467.25**	**2,442.00**	**2,527.25**	**2,840.25**

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Table C.11. Summary of Wetland Function Impacts

2005 Wetland Function	Corridor A		Corridor B		Corridor C		Corridor D		Corridor E	
	Acres Lost	Functional Capacity Lost	Acres Lost	Functional Capacity Lost	Acres Lost	Functional Capacity Lost	Acres Lost	Functional Capacity Lost	Acres Lost	Functional Capacity Lost
Rare imperiled wetlands	78	78	73	73	0	0	169	169	72	72
Amphibian habitat	974	818	902	758	779	654	930	781	968	813
Waterfowl waterbird habitat	1,063	786	1,022	756	1,143	846	1,181	874	1,097	811
Streamflow maintenance	1,018	865	1,041	885	1,219	1,036	1,281	1,101	1,137	978
Stream shading	345	314	355	323	214	195	463	422	348	316
Stream shading	43	38	48	42	165	145	185	162	42	37
Shorebird habitat	686	364	642	340	561	297	736	390	776	411
Sediment particulate retention	1,238	965	1,146	894	1,170	913	1,284	1,002	1,311	1,023
Nutrient transformation	1,288	1,198	1,219	1,133	1,277	1,188	1,353	1,258	1,364	1,268
Interior forest bird habitat	726	486	742	497	808	549	749	502	671	450
Ground water influence	1,507	859	1,443	823	1,497	853	1,382	788	1,502	856
Flood water storage	1,104	949	1,001	861	985	847	1,181	1,016	1,174	1,009
Fish habitat	1,098	944	1,091	938	1,211	1,041	1,277	1,098	1,190	1,023
Total	**11,166**	**8,664**	**10,724**	**8,323**	**11,028**	**8,564**	**12,170**	**9,562**	**11,651**	**9,068**

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Table C.12. Summary of Natural Community Impacts

Name	Corridor A		Corridor B		Corridor C		Corridor D		Corridor E	
	Acres Lost	EO's impacted	Acres Lost	EO's impacted	Acres Lost	EO's impacted	Acres Lost	EO's impacted	Acres Lost	EO's impacted
Emergent Marsh	0	0	0	0	0	0	0	0	0	0
Dry-mesic Southern Forest	0	0	0	0	0	0	0	0	0	0
Coastal Plain Marsh	0	0	0	0	0	0	0	0	0	0
Hardwood-Conifer Swamp	0	0	0	0	0	0	0	0	0	0
Mesic Southern Forest	0	0	0	0	0	0	0	0	0	0
Rich Tamarack Swamp	0	0	0	0	0	0	0	0	0	0
Southern Wet Meadow	159.3	1	159.3	1	0	0	159	1	159.3	1
Prairie Fen	0	0	0	0	0	0	0	0	0	0
Dry-mesic Prairie	0	0	0	0	0	0	0	0	0	0
Submergent Marsh	0	0	0	0	0	0	0	0	0	0
Intermittent Wetland	0	0	0	0	0	0	0	0	0	0
Mesic Prairie	0	0	0	0	0	0	0	0	0	0
Bog	0	0	0	0	0	0	0	0	0	0

Table C.13. Summary of Federal- and State-Listed Species Impacts by Category

Name	Corridor A		Corridor B		Corridor C		Corridor D		Corridor E	
	Acres Lost	EO's impacted	Acres Lost	EO's impacted	Acres Lost	EO's impacted	Acres Lost	EO's impacted	Acres Lost	EO's impacted
Mammals	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0
Birds	8.0	1	8.0	1	8.0	1	218.3	2	218.3	2
Insects	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0
Fish	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0
Mussels	1.3	1	1.3	1	1.3	1	0.0	0	0.0	0
Reptiles	0.0	0	0.0	0	1,364.5	1	0.0	0	0.0	0
Amphibians	15.0	2	15.0	2	15.0	2	15.0	2	22.5	3
Plants	12,674.8	17	12,970.0	15	13,160.0	16	10,212.8	14	13,015.0	19
Total	**12,699.0**	**21**	**12,994.3**	**19**	**14,548.8**	**21**	**10,446.0**	**18**	**13,255.8**	**24**

Table C.14. Summary of Overall Ecological Impacts

Name	Corridor A	Corridor B	Corridor C	Corridor D	Corridor E
	Rank	Rank	Rank	Rank	Rank
Wetland Functions	3	1	2	5	4
River systems	1	1	2	2	3
Lake systems	1	1	2	4	3
High Quality patches	2	3	1	5	4
Large Landscapes	2	3	4	1	5
Natural Communities	2	2	1	2	2
Species	2	3	5	1	4
Total	**13**	**14**	**17**	**20**	**25**

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aquatic elements, and corridors A, B, and C had the least impact on terrestrial elements. Table C.11 shows that corridors B and D had the least impact on wetland functions. Table C.12 shows that corridor C was the only corridor not to affect a known natural community. Based on the results of the GIS analysis using the NatureServe Vista software tool, both corridors A and B appear to have the least amount of negative impact overall on the priority conservation areas in the pilot region (Table C.14). Corridor A was also the corridor chosen by MDOT and its partners. The exercise confirms that MDOT and its partners chose one of the corridors that had the least amount of impact to natural resources for the US-131 project. The Vista tool and the accompanying geospatial natural resource data allowed the team to complete the corridor analysis relatively quickly. The team thinks that if the Vista tool and accompanying geospatial natural resource data were available for the original US-131 corridor study, environmental concerns could have been addressed more easily and earlier in the decision-making process.

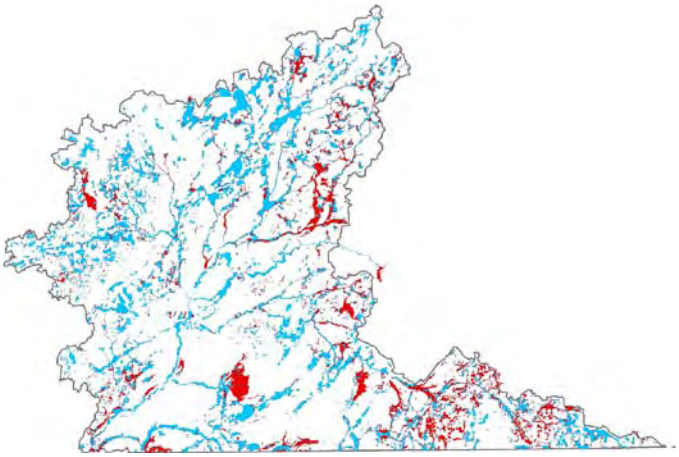
Step 5: Establish and Prioritize Ecological Actions; Establish Mitigation and Conservation Priorities and Rank Action Opportunities

5a. Identify areas in the REF planning region that can provide the quantities and quality of mitigation needed to address the effects assessment, and develop protocols for ranking mitigation opportunities.

5b. Select potential mitigation areas according to the ranking protocols.

For this project, wetlands were the only conservation element the research team attempted to address for ecological crediting or mitigation. One of the unique aspects of this pilot project was the availability of functional wetland data for the pilot region. The 2005 wetlands functional assessment, 2005 Coastal Change Analysis Program (C-CAP) landcover, and the circa 1800 wetlands functional assessment data layers were used to identify restorable wetlands in the pilot project area. All historical wetlands in the region that were converted to other land uses were identified. This was done by eliminating all existing wetlands from the circa 1800 functional assessment data layer, as well as any historical wetlands that currently are classified as urban land use (the team assumed that these are unrestorable sites) (see Figure C.18).

Once this was done, the team used new and existing wetland data layers to test the efficacy of a new tool available through NatureServe Vista, called the Mitigation Query Tool (MQT). The MQT was developed to identify places in a project area that have similar characteristics or values to the conservation element occurrences negatively affected by the proposed scenario. Again, for this project wetlands were the only conservation element used to test the efficacy of this tool for assisting mitigation actions.



Restorable wetlands are shown in red. Historical wetlands converted to urban areas and existing wetlands are shown in blue.

Figure C.18. Restorable wetlands.

For the purpose of this study, the research team identified three wetland polygons representing three different wetland types (riverine, forested, scrub-shrub, and emergent) within Corridor A (the corridor chosen by MDOT and its partners) that might be affected by the preferred road alignment. The team's goal was to identify as many wetland polygons outside corridor A that matched the wetland type and functions of each of the identified wetland polygons. One other attribute, proximity to existing wetlands, also was included in the query to further identify the best set of alternative wetland polygons for restoration. The MQT not only identifies the polygons that best match the query but also prioritizes each polygon.

Values of each wetland function of the chosen existing wetland polygons were identified and entered into the index window of the MQT. In addition, a value was entered into the proximity-to-protected-area box, which in this case represented proximity to existing wetlands. Values had to add to a sum of 1. Once this was calculated, the site window was populated. The site identification (ID) of the existing wetland being affected was entered. The only other value entered was the number of hectares for the type of wetland (because of the small amount [1.5 acres] of wetlands determined to be affected by the preferred alternative, all values entered were 1 hectare).

Wetland Mitigation Results

The MQT delivered at least a few potential sites for wetland restoration mitigation for each of the three existing wetland polygons within Corridor A chosen for this exercise. A similarity index is created by the MQT that measures the similarity between the affected existing wetland polygon (along with the selected weights) and the restorable wetland sites within the

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High priority = blue; low priority = pink; moderate priority = green.

Figure C.19. Priority restorable wetlands.

project area. The similarity index results demonstrate that for some of the wetland types, the MQT identified restorable wetland sites similar to those identified by MDOT. This is particularly true for the shrub-scrub wetland type. For others, such as riverine and forested wetlands, the MQT identified a different set of wetland sites.

For the riverine wetland chosen from Corridor A (parcel ID 67), the MQT similarity index scores of restorable wetlands ranged from 0 to 1,999.8. A total of 18 restorable riverine wetland polygons with scores greater than 0 were identified, totaling 58.4 hectares (Figure C.19). For the forested wetland chosen from Corridor A (parcel ID 144), the MQT similarity index scores of restorable wetlands ranged from 0 to 1,999.8. A total of 514 restorable forested wetland polygons with scores greater than 0 were identified, totaling 3,962 hectares (Figure C.19). For the scrub-shrub wetland chosen from Corridor A (parcel ID 54), the MQT similarity index scores of restorable wetlands ranged from 0 to 307,465,375.5. A total of 7 restorable scrub-shrub wetland polygons with scores greater than 0 were identified, totaling 377 hectares (Figure C.19).

Review and Comparison of MDOT Environmental Review

MDOT's 1997 US-131 Alternative Corridor Study is the closest in comparison to the range and scope of this report. That study identified Corridor A as the best alternative for US-131. The purpose of this pilot project was to test several components of a newly developed ecological assessment process and credits system for enhancements to highway capacity. For this pilot project, the team attempted to create an REF for a 10-watershed region surrounding the 27-mile US-131 highway alternative corridors and evaluate each of the five corridors based on the REF. As part of that analysis, a new wetland data were introduced to evaluate their efficacy for expediting the wetland regulatory process. Finally, these new wetland data were evaluated for their application to wetland mitigation.

The REF approach used in the pilot project intersected each of the five alternative corridors with spatially explicit priority natural resources within the study boundary. Although the REF did not include historic resources, hazardous material locations, or fully address water quality, these resources could be added and addressed in the framework. The REF developed as part of the project did not incorporate future conditions. Instead, the REF focused on prioritizing the conservation of existing natural resource areas and features. This pilot project demonstrates that NatureServe Vista can be used to develop an REF even in the absence of conservation plans at any scale. However, it is important to note that Vista was not designed to develop a conservation vision or determine the future desired condition for a given geographic area. That type of endeavor requires conservation planning and scientific expertise.

As part of developing the REF for this study region, a novel approach to characterizing wetlands, called wetland functional assessment, was introduced. The wetland functional assessment data were designed to assess wetland function at the watershed or subwatershed scale. This type of information is useful for understanding wetland functions lost over time, measuring the cumulative impacts to wetland functions of a proposed large-scale transportation project, and comparing the potential impacts of alternative transportation corridors.

In 1998, MDOT and its partners selected Corridor A for the new route for that stretch of US-131. In 2010, assessing not only the number of acres of wetlands that would be lost with each alternative, but also the functional capacity at risk—based on both the area it covers and the level at which a given wetland functions—MNFI's analysis based on NatureServe Vista outputs indicates that Corridor B would have had the least environmental impact of the alternatives available. This result also held true when considering several additional natural resources: (1) federal and state listed species, (2) rare or exemplary natural communities, (3) large contiguous natural landscapes, (4) potential high-quality natural vegetation patches, (5) potentially unique lakes, (6) potentially high-quality lakes, (7) potentially unique or (8) high-quality stream segments. (It turned out that MDOT approved development of only half of the proposed route. Fortunately, for the portion that was approved, Corridors A and B were identical).

With regard to wetland regulatory assurances, the jury is still out. Regulatory assurances of any kind are based on high-quality data, and nothing can take the place of recent field surveys. For the US-131 final EIS, MDOT biologists, from 2000 to 2002 conducted wetland field surveys for the full length of the five practical alternative routes stretching from the Indiana border north. During that time frame, routine on-site wetland determinations were conducted, and a total of 31 wetland sites were located. Although the wetland functional

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assessment and enhanced NWI data provide wetland regulators with additional information, it does not appear that these data layers can replace data collected during field investigations. For example, neither the wetland functional assessment data nor the enhanced NWI data attempt to evaluate the quality of a given wetland or its landscape context. However, these additional wetlands data have the potential to be useful for facilitating better mitigation.

According to MDOT, most environmental mitigation is developed during the environmental review process at the project level. Because corridors do not affect natural resources, but rather new or expanded road alignments and their associated ROWs, the research team used the wetlands that were going to be affected by the practical road alignment for mitigation analysis. The team compared the actual wetland restoration sites identified in the final EIS to the wetland polygons identified by the MQT. For the most part, the MQT identified different and broader sets of wetland restoration sites than did MDOT as part of the final EIS. Interestingly, MDOT's top ranking wetland mitigation site was also the top-ranked wetland mitigation site for the selected scrub-shrub wetland. The MQT is a new tool and is still in the early stages of development. This pilot project demonstrates that the MQT does appear to have potential for identifying priority wetland mitigation sites. In the end, MDOT ultimately decided to use a portion of a fen purchased for mitigating the 1.5 acres of wetland, instead of restoring historic wetlands. In the future, the research team would like to use the MQT to identify existing wetlands for mitigation from a conservation perspective and compare the results to the Cass County fen complex.

Based on the Michigan pilot project, it appears that the new ecological assessment process developed by the SHRP 2 C06B team has the potential for facilitating better transportation planning. The proposed new process for transportation planning demonstrated that more and better data can improve the transportation planning process. This is especially true at the corridor planning phase of the project. In reviewing the final EIS for the US-131 highway project, it is apparent that once the corridor was chosen, MDOT did a tremendous job of gathering and analyzing ecological data for each of the five preferred alternative routes, particularly for wetlands and threatened and endangered species. It is also apparent that MDOT selected the route for US-131 with the least amount of environmental impact.

The Michigan pilot project demonstrates that the regional ecosystem framework does help determine how much and what types of resources are located within a corridor, and thus what level of conflict might be encountered within each alternative corridor; of course, working at the corridor scale, the ecosystem framework cannot definitively say how much impact a particular route will have once a given corridor is chosen. Still, the results are conclusive: more and better data, considered early in the planning phase, lead to a better decision—a decision that not only potentially has better environmental outcomes and reduced costs as a result of selecting a corridor that requires less mitigation, but also one that can be reached more easily and earlier in the planning process.

Description of Wetland Data for Michigan Pilot Study

Wetland Data Summary

National Wetlands Inventory Update

Ducks Unlimited (DU) is being funded to update the 1980 NWI data for the entire state of Michigan. The update includes a review of the 1980 NWI and an updated NWI using spring color infrared aerial photographs from 1998 and summer natural color aerial photographs from 2005. Additional data used in the update include hydric soils, existing wetland restoration projects, and digital USGS topographic maps. A portion of the wetlands will be sampled in the field for quality control and assurance. To date, DU has completed the NWI update for 28 counties in the Lower Peninsula. DU just received funding to complete the remaining 40 counties in the Southern Lower Peninsula through the Great Lakes Fish and Wildlife Restoration Act Program. At the time this was written, the target date for completion was October 2011.

Enhanced Wetland Classification

The NWI database was expanded to include descriptors for landscape position, landform, water flow path, and water body types (LLWW descriptors) (Tiner 2005). The enhanced classification was applied to both wetlands circa 1800 and 2005.

Preliminary Assessment of Wetland Functions

The former Michigan Department of Environmental Quality currently is in the process of conducting a functional wetland assessment for the entire state. The process uses a landscape-level wetland assessment approach called "watershed-based preliminary assessment of wetland functions" (W-PAWF). W-PAWF applied general knowledge about wetlands and their functions to produce a watershed profile highlighting wetlands of potential significance for numerous functions (Tiner 2005). W-PAWF is based on the updated NWI and the enhanced wetland classification. To date, the former Michigan Department of Environmental Quality staff has completed the assessment for 10 small watersheds in the Southern Lower Peninsula.

The 13 wetland functions assessed as part of this study include:

1. **Floodwater storage:** Important for reducing downstream flooding and lowering flood heights, both of which aid in minimizing property damage and personal injury.

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2. **Streamflow maintenance:** Wetlands that are sources of groundwater discharge that sustain streamflow in the watershed. Such wetlands are critically important for supporting aquatic life, such as mussels and invertebrates, in streams.
3. **Nutrient transformation:** Wetlands that have a fluctuating water table are best able to recycle nutrients. Natural wetlands performing this function help improve the local water quality of streams and other water courses.
4. **Sediment and other particulate retention:** This function supports water quality maintenance by capturing sediments with bonded nutrients or heavy metals. Vegetated wetlands will perform this function at higher levels than those of nonvegetated wetlands.
5. **Shoreline stabilization:** Vegetated wetlands along all water bodies (lakes, ponds, streams, rivers) provide this function. Vegetation stabilizes the soil or substrate and diminishes the impact of wave action.
6. **Provision of fish habitat:** Wetlands that are considered essential to at least one part of the fish life cycle and have been identified as important for reproduction or foraging.
7. **Stream shading:** Palustrine forested or scrub-shrub wetlands that perform water temperature control because of their close proximity to streams and waterways.
8. **Provision of waterfowl and waterbird habitat:** Palustrine forested or scrub-shrub wetlands that perform water temperature control because of their proximity to streams and waterways.
9. **Provision of shorebird habitat:** Wetlands that provide important foraging habitat for shorebirds during breeding and migration. To provide the necessary conditions, these wetlands typically are not intermittently exposed or permanently flooded.
10. **Provision of interior forest bird habitat:** Wetlands that frequently are flooded for long periods of time often are used for nesting, reproduction, or foraging by interior forest bird species.
11. **Provision of amphibian habitat:** Wetland types that typically are fish free because of the high susceptibility of amphibians to fish predation.
12. **Conservation of rare and imperiled wetlands:** Wetlands that are considered rare either globally or at the state level by the MNFI. These wetlands are also likely to contain a diversity of flora and fauna, as well as threatened, endangered, or special concern species.
13. **Groundwater influence:** Areas that receive some or all of their hydrologic input from groundwater reflected at the surface. The DARCY model was the data source used to determine this wetland/groundwater connection, which is based upon soil transmissivity and topography. Wetlands rated for this function are important for maintaining stream flows and temperature control in water bodies.

Functional Capacity

The function wetland analysis also allows a basic assessment of lost wetland functions at the landscape or watershed level by comparing circa 1800 wetland data (based on hydric soils and circa 1800 vegetation) with 2005 NWI data. Assessing the impact of the cumulative loss of wetlands on specific functions can be accomplished by examining the change in area of functionally significant wetlands between the two time periods.

Oregon Pilot Project Report

Introduce Project to Natural Resource and Transportation Agencies

A series of sites were evaluated after a November 3, 2009, workshop including Oregon Department of Transportation (ODOT) and environmental agency staff. The workshop involved presentations on the Volume 1 project and methodology and introduced the pilot project. Discussion resulted in an initial list of more than 10 projects, which was narrowed by the group to 4 projects that for additional evaluation:

- South Medford Interchange;
- Pioneer Mountain–Eddyville;
- Kitsan Ridge; and
- North Fork Siuslaw Bridge.

Select Site for Pilot Test

1. Follow-up with each pilot state to get more information about data available for the areas proposed to conduct pilot projects.
2. Select an area in each state based on how well the area meets the pilot project selection criteria, whether or not a sufficient amount of the spatial data from the original project are available digitally (in GIS, CAD, or similar format).

The Pioneer Mountain–Eddyville project was chosen based on the criteria identified in the pilot project criteria document. It represented the largest and most complex project, it was completed recently enough that spatial data were likely to be available in a digital form, perhaps even in a GIS, and it included wetlands and endangered species habitat. The only other site seriously considered was Kitsan Ridge, but in the end, because the Kitsan Ridge project was older and spatial data from its EIS or planning did not exist, Pioneer Mountain–Eddyville was chosen.

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The Pioneer Mountain–Eddyville project EIS provides a succinct background description of the project:

> US-20, the Corvallis to Newport Highway, is a major route connecting the Willamette Valley with the central Oregon coast. It is an important commercial and recreational travel corridor. Commercial truckers and tourists heavily use the highway, and it provides local access for residents of rural Lincoln County. The wood products industries rely on the highway to bring their products from forest to mill to market. The section of US-20 between Pioneer Mountain and Eddyville is the last significant unimproved section of US-20 between Corvallis and Newport.

The existing highway followed the Yaquina River, a valuable fishery providing habitat for three federally listed species of salmon (the Coho, Chinook, and steelhead), and was adjacent to important, old forests providing habitat to two federally listed species (marbled murrelet and spotted owl). The proposed new route was away from the river, through young, second-growth commercial forest lands, with many fewer impacts. Figure C.20 shows the routes evaluated in planning for the project. Alternative D, or the southern-most route, was the one chosen to be built.

Testing the Ecological Assessment Framework

The Oregon pilot project tested only steps 1–6 (below) of the C06B Technical Guidance and certain associated substeps.

Step 1: Build and Strengthen Collaborative Partnerships, Vision

1a. Identify planning region

Defining Project Area

The first step in the analysis of direct impacts and cumulative impacts is to define the overall area for the analysis. The pilot area was located in Lincoln County in the Oregon Coast

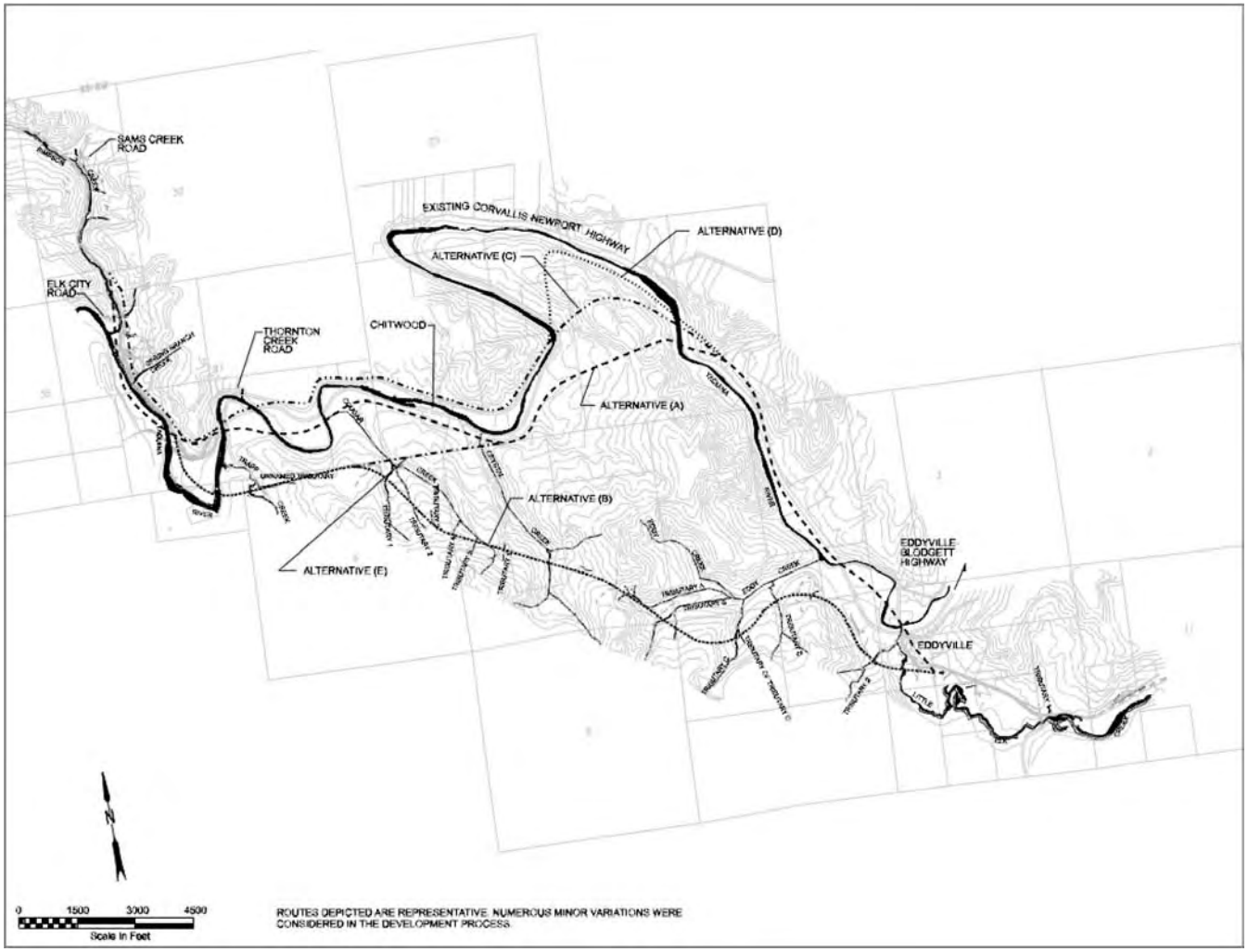

Figure C.20. Alternative routes considered and the built route.

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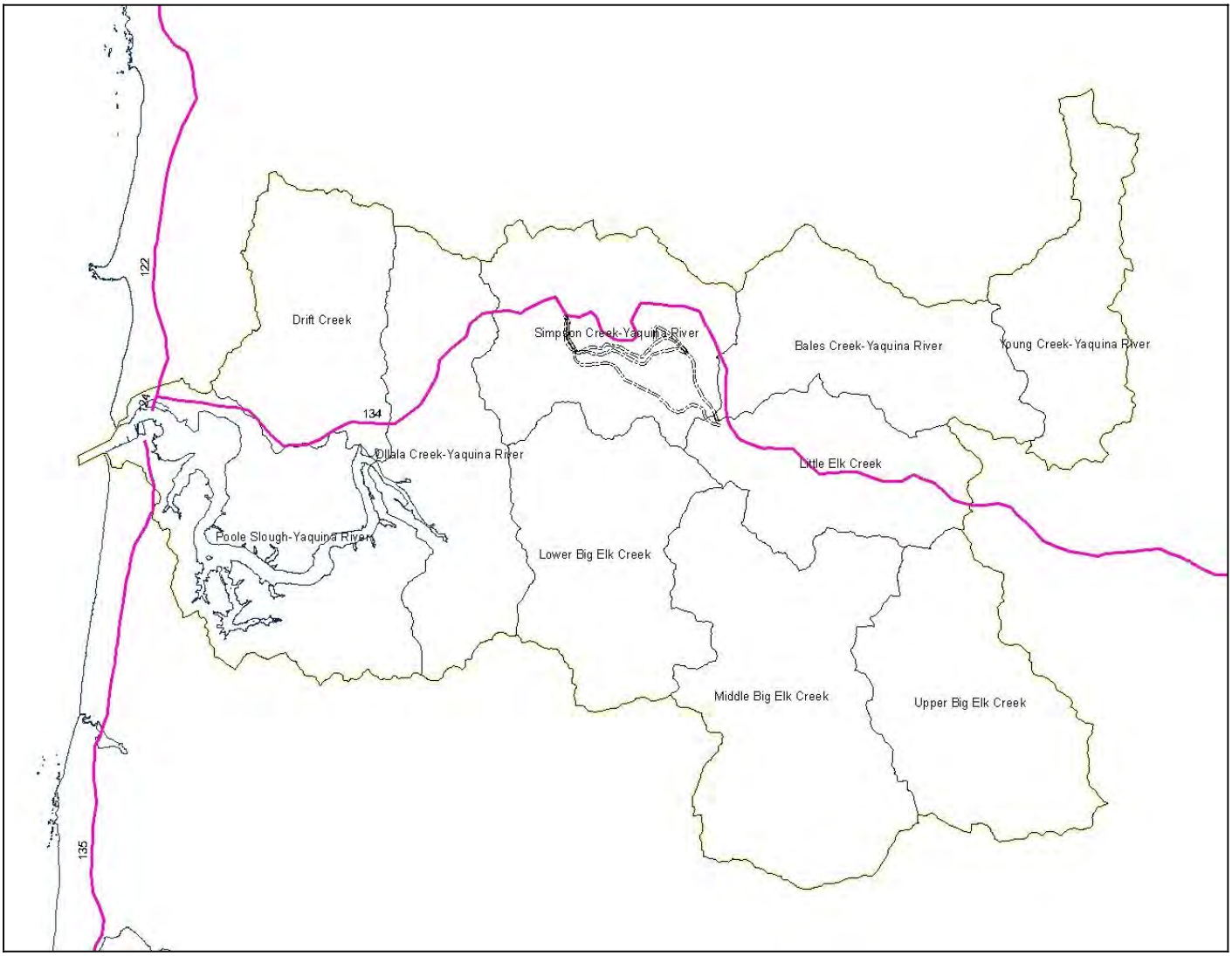
Range and was entirely within the Yaquina River watershed. The potential project areas included:

1. The North Coast Basin, composed of seven, fourth-field watersheds located along the northwest coast of Oregon, as identified by the Oregon Watershed Enhancement Board;
2. The Oregon Coast Range Ecoregion, which includes the coastal area in Oregon, as identified in the Oregon Conservation Strategy (Oregon Department of Fish and Wildlife 2006) and the Oregon Natural Heritage Plan (Oregon Natural Heritage Program 2003);
3. The Siletz-Yaquina Watershed, a fourth-field (eight-digit HUC 17100204) watershed identified by EPA; and
4. The Yaquina Watershed, the actual watershed of the Yaquina River, composed of three fifth-field (10-digit HUCs) subwatersheds: 1710020401, 1710020402, and 1710020403.

Because the project area was relatively small and occupied a forested landscape in a single large watershed, the Yaquina Watershed was selected for analysis. In some sites, local or potential impacts affect species over a broad range, so the analysis must include a larger area. For this project, the most significant impacts were local, so the smaller analysis area allowed for a more complete look at the species, habitats, and impacts. A description of the Yaquina Basin can be found at the North Coast Explorer portal (Oregon State University 2012). The basin is composed of 10 subwatersheds (sixth-field, 12-digit HUCs). The map showing these 10 subwatersheds and the overall site can be seen in Figure C.21.



State highways = purple; alternative routes = black dashed lines.

Figure C.21. Project area, the Yaquina Watershed, with subwatersheds (sixth-field, 12-digit HUCs) identified.

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Step 2: Characterize Resource Status; Integrate Conservation, Natural Resource, Watershed, and Species Recovery and State Wildlife Action Plans

2a. Identify the spatial data needed to create understanding of current conditions.

2b. Prioritize the specific list of ecological resources and issues that should be further addressed in the regional ecosystem framework.

2e. Produce geospatial overlays of natural resource data and supporting priorities.

Data Collection

The goal of this is to collect all data used in the original evaluation of the project selected, including the original infrastructure footprint, final project footprint, biological data, or other conservation data sets, EIS or EA, ROD, and other public concerns (noise, air quality, water quality, historic/cultural sites).

The first and one of the most difficult parts of the effort was to obtain the spatial data used for the development of the project EIS. The research team was surprised to learn ODOT did not have access to any of these data, in any digital format, and indeed had never received the data. ODOT received only the maps and documentation necessary for the production of the PDF. This meant that none of the biological, social, geological, or other data collected by the consultants on the project were available to the department for any other uses. It was also a shock to learn this is typical practice for projects across the country. This practice leads to a significant probability of important information being lost.

Because the project was under way for such a long time (a situation that will be explained here), there were two different consultants involved in the project. One, CH2M HILL, has staff on the research team, so the team was able to get access to the analysts who had developed and stored the data. However, none of the data were available in a GIS format, aside from (1) recently developed, detailed landform maps developed to attempt to predict landslide risk, and (2) maps showing wetlands from the project area (see Figure C.22). The maps of the alternative routes were available only in PDF format, and the at-risk species information considered in the analysis was summarized only at the sixth-field (12-digit) watershed. The pilot team was unable to obtain any data at all from the second consultant, David Evans and Associates.

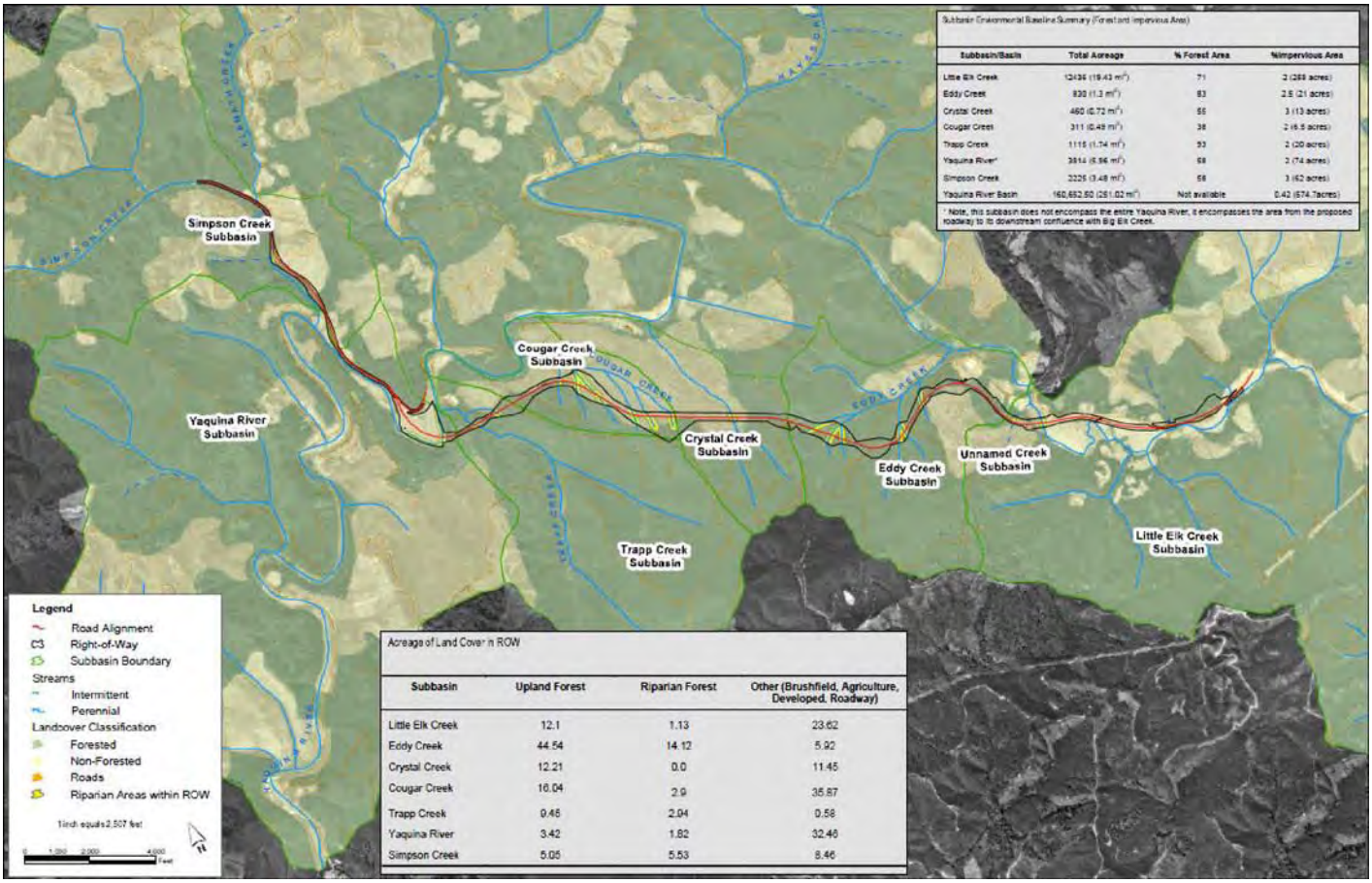

Figure C.22. Landcover and project area in EIS.

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Data were collected for at-risk species, habitats, and vegetation from files at the Oregon Biodiversity Information Center (ORBIC), which is the Oregon member of NatureServe and is part of the Institute for Natural Resources. Thus, agreements were not necessary to access this information. Data also were available at ORBIC or online from the two regional and one watershed assessments described in the regional framework section. The specific data used in the analysis are included as Table C.15.

Step 3: Create Regional Ecosystem Framework

3a. Overlay the geospatially mapped long-range transportation plan.

3b. Identify and show areas and resources potentially affected by transportation improvements, and potential opportunities for joint action.

3c. Identify the high-level conservation goals and priorities, and opportunities for achieving them.

Adopt or Develop Regional Ecological Framework

Follow the CEAA template methods for developing an REF or accepting a previously developed plan of conservation priority areas. This includes:

1. Identifying ecological resources to be considered in analyses and goals related to protection of those resources; using ecological data layers and conservation plans.

Table C.15. Data Sources Used in Analysis

Data Layer	Source	Coverage	Brief Description	Data to Include
ORBIC BIOTICS database	ORBIC	Statewide	Documentation of known rare animal and plant occurrences; data are incomplete for the state	All known EOs except general records
Listed species modeled distributions	ORBIC/Institute for Natural Resources (INR)/ National Oceanic and Atmospheric Administration (NOAA)	Terrestrial taxa; models developed by NOAA fisheries were used	Modeled species distributions using inductive and deductive species models	Coho, Chinook, spotted owl, marbled murrelet
Updated and enhanced NWI wetlands	INR	Statewide	All wetland polygons are delineated based on 1984–2005 aerial photos and attributed by wetland type	All wetlands
Draft wetland mitigation catalog	INR/The Wetlands Conservancy (TWC)	Willamette, North Coast basins; set to be completed for the remainder of the state by September 1, 2011	Proposed wetland mitigation catalog, representing priority wetlands conservation and restoration sites within each basin	Boundaries of areas and conservation targets within each
Streams with intrinsic potential	Oregon State University (OSU)/Pacific Northwest (PNW)/Coastal Landscape Analysis and Modeling Study (CLAMS)	CLAMS area (coast range)	Intrinsic capability for good quality anadromous salmonid habitat and links between the channel and terrestrial environment	High-quality stream segments
GNN forest structure attributes	OSU/PNW/Landscape Ecology, Modeling, Mapping & Analysis (LEMMA)	Statewide (forests)	Structure attributes of forests attributed to each pixel, based on Forest Inventory and Analysis (FIA), Current Vegetation Survey (CVS), and state plot data	Multiple 30-meter pixel rasters for each forest attribute
Land development change	OSU/PNW/CLAMS	CLAMS area (coast range)	Change in land use, building density, and development	Change from 1994 to present
The Nature Conservancy (TNC) ecoregional priority areas	TNC	Statewide	Important areas for biodiversity as determined by the TNC ecoregional planning process	All polygons in shapefile

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2. Collecting, incorporating, or developing current ecological data for area being evaluated. If possible, including or developing predictive species distribution data and priority wetland data. When new data are used, evaluating their acceptance (via interviews or meetings) by the relevant regulatory agencies.
3. Reviewing previous analysis or analyzing data to determine the terrestrial and aquatic elements and areas that will be included in the analyses.
4. Identifying and integrating land use and transportation planning information available spatially.

For the Oregon pilot project, the ecological resources to be considered in the analysis were adopted from the three analyses covering the project area, each of which are described below: (1) Coastal Landscape Analysis and Modeling Study (CLAMS), (2) The Nature Conservancy's (TNC's) Pacific Northwest Coast Ecoregional Assessment, and (3) The Mid-Coast Watershed Council's Watershed Assessment for the Yaquina basin. The first two of these were comprehensive, regional conservation analysis involving extensive research and assessment.

The first of this was the CLAMS (Coastal Landscape Analysis and Modeling Study 2012), a multidisciplinary research effort sponsored cooperatively through Oregon State University's (OSU's) College of Forestry, the US Forest Service's Pacific Northwest Research Station, and the Oregon Department of Forestry. Their main goal was to analyze the aggregate ecological, economic, and social consequences of forest policies of different landowners in the Coast Range. Because the coast range and the entire project area represent a forested landscape, these policies were the primary drivers of economic and ecological factors within the project area (Cohen et al. 2005). The CLAMS project looked at future biological and economic outputs for the region based on current plans, and selected species targets of various types.

The second study was TNC's Ecoregional Analysis for the Oregon Coast Range (Vander Schaaf et al. 2006). Although the plan was completed in 2006, TNC was able to provide a 2010 update of the information based on a new assessment developed to assist the Oregon Department of Forestry in the development of their 2010 Forestry Assessment (Cathcart 2010). TNC provided updated 2010 conservation targets, which were identified by sixth-field (12-digit) watershed. For the pilot study, all of the conservation targets (and the amounts of each target) were aggregated to the entire Yaquina Watershed project area.

In addition to the two conservation assessments, the Mid-Coast Watersheds Council has developed a watershed assessment that evaluates the impacts to the river and the fish species using it, with a strong focus on salmon and steelhead and cutthroat trout (Garono and Brophy 2001). Based on dissolved oxygen, with organic enrichment/oxygen depletion, the Oregon Department of Environmental Quality has found only one stream-reach along the Yaquina River, at the upper watershed, that was impaired (OR1240830446097_26.8_53.9 in the Young's Creek–Yaquina River HUC). A few other streams in the watershed were limited by sediment and temperature, both indications of nonsuitable habitat for the listed, endangered fish, particularly those in the project area.

Modeled species distribution data were available for the federally listed terrestrial species, the northern spotted owl and the marbled murrelet, from ORBIC. All of the federally listed aquatic species present in the site are salmon, managed by National Oceanic and Atmospheric Administration (NOAA) Fisheries. NOAA fisheries has developed internal models of fish habitat presence and importance (which sometimes can be obtained from NOAA) that usually are available in recovery plans. In the Oregon pilot study, the team used the NOAA data and the known distribution of the listed species as mapped by ORBIC's BIOTICS database (see Figure C.23).

Step 4: Assess Transportation Effects on Resource Conservation Objectives Stated in the REF (Integrated Conservation/Restoration Priority and Transportation Plan)

4a. Weight the relative importance of resource types.

4b. Identify/rate how priority conservation areas and individual resources respond to different land uses and types of transportation improvements.

4c. Develop programmatic cumulative effects assessment scenarios that combine transportation plan scenarios with existing development and disturbances, other features and disturbances having an impact, and existing secured conservation areas.

4d. Intersect the REF with one or more cumulative effects scenarios to identify which priority areas or resources would be affected; identify the nature of the effect and quantify the effect.

4e. Compare plan alternatives and select one that optimizes transportation objectives and minimizes adverse environmental impacts.

4f. Identify mitigation needs for impacts that are unavoidable.

Step 5: Establish and Prioritize Ecological Actions; Establish Mitigation and Conservation Priorities and Rank Action Opportunities

5a. Identify areas in the REF planning region that can provide the quantities and quality of mitigation needed to address

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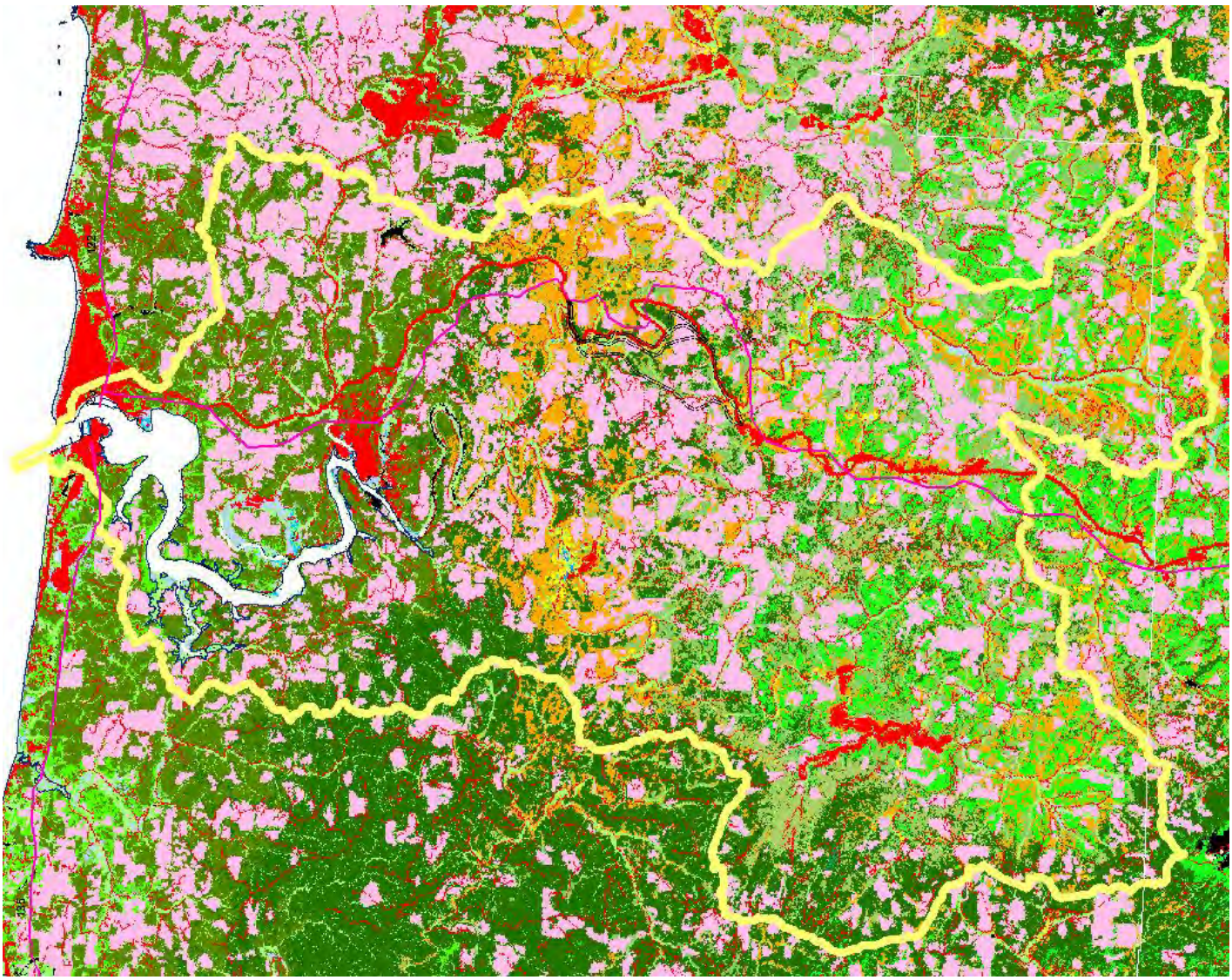

Blue = wetlands and riparian habitats; green = native conifer forests; orange = hardwood forests; pink = clearcuts and recently planted forests; red = agriculture and developed areas.

Figure C.23. Existing vegetation.

the effects assessment and develop protocols for ranking mitigation opportunities.

5b. Select potential mitigation areas according to the ranking protocols.

Step 6: Develop Crediting Strategy

6a. Diagnose the measurement need.

6b. Evaluate ecosystem and landscape needs and context to identify measurement options.

6c. Select or develop units and rules for crediting

6d. Test applicability of units and rules in local conditions.

Analyze the REF and Cumulative Impacts

The workflow templates were reviewed, beginning with the REF source inputs detailed above. A GIS DSS will provide the analytical functions to produce the outputs used for the following step. For the Oregon pilot project, ArcGIS (version 9.3) GIS and the Envision (version 5) DSS tools were used. ArcGIS is a widespread, commercially available product. Envision (formerly called Evoland) is a free, open-source decision support software tool relying on ArcGIS, available from Oregon State University's (OSU's) Department of Biological and Ecological Engineering. Envision is a GIS-based tool for scenario-based community and regional planning and environmental assessments. Envision combines a spatially explicit polygon-based representation of a landscape, a set of application-defined policies (decision rules) defining alternative scenario strategies, landscape change models, and models of ecological, social, and economic services to simulate land use change and provide decision makers, planners,

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and the public with information about resulting effects on indices of valued products of the landscape.

An important component of the GIS DSS approach to be used in the pilot projects is the application of suggested goal levels and indicators based on expert or stakeholder input. For this project, the targets and goals were adopted from the most recent assessment, completed in April 2010 by TNC and the Oregon Department of Forestry. Targets were also identified in the CLAMS project, although not conservation goals. Because the ecological targets located within the transportation project area (not the overall pilot planning area) were limited, the focus of the analysis was on the changes in the particular species and habitats based on the project area footprint. The analysis indicated that there are four species that are especially significant in the watershed, primarily because the Yaquina Basin is important for their existence. These are shown in Table C.16, listed in the order of importance for conservation, based on a Marxan run, with the percentage of their coast range habitat present in the watershed shown.

The conservation assessment identified three habitats as being most significant in the region: (1) upland prairie and savanna, (2) coastal Sitka spruce forest, and (3) dry Douglas-fir forest. Because the specific project area did not affect any of the miniscule amounts of the upland prairie and savanna remaining in the watershed, they were not considered in the analysis. Only the two conservation assessment forested types listed above, plus a third habitat, coastal western red cedar-western hemlock forests, for which 17.5% of the remaining coastal habitat occurs in this basin were considered in the analysis, since all three of these conifer forests were found in the project area.

The actual project impacts for the highway modifications were almost entirely through young, second- and third-growth conifer forests, so none of the priority habitats were affected. In addition, the former highway route was much closer to important fish, riparian, and old-growth conifer forests and was immediately adjacent to the largest habitat blocks in the watershed for the marbled murrelet, a federally listed species that was identified in the analysis as being the most important species.

Table C.16. Significant Species in the Yaquina Watershed Identified in the Impacts Analysis

Species Name	Percent Habitat/ Occurrences Present	Conservation Importance
Marbled murrelet	16.39	2.32
Purple martin	14.28	3.20
Bald eagle	5.30	3.50
Mountain quail	14.29	5.10
Northern red-legged frog	1.47	2.20

Findings regarding imperiled species were that most of the basin was historically dominated by mature conifer forests and is in private ownership, managed as industrial forest lands. As a result, the three coastal assessments evaluating areas of conservation significance for at-risk forest wildlife had conservation focused on other watersheds in the northern part of the Oregon Coast Range, specifically in areas where larger holdings of public forest lands allowed for viable forested conservation areas.

The few remaining small tracts of older forest in the watershed were located just north of the old route of Highway 20. As a result, the movement of the highway out of the Yaquina River Watershed, into young upland forest that had been clearcut recently, actually achieved as much conservation benefit as would be possible with a highway project in the basin.

Because almost all of the habitats lost represented industrial forest lands, most of the long-term impacts were potentially economic, representing a loss of potential timberlands, rather than ecological. As a result, a cumulative impacts analysis for species and habitats is not relevant for this project.

Because the pilot study was to test all of the steps, this was the process in which the Envision program was used. The analysis was limited to the top 10 species identified in the assessments, the priority habitats identified in the assessments, and all wetlands and at-risk start here species from the BIOTIC database at ORBIC. The BIOTIC database is the Oregon comprehensive location for biodiversity information. The software was developed by NatureServe, and it includes specific occurrence information for all at-risk species in the state.

It was found that there were no viable alternative scenarios identified that could increase the biological outcomes in the basin.

Analyze Permitting, Mitigation, and Other Crediting Opportunities

The last step in the analysis and scenario development was to evaluate the mitigation proposed and implemented, as compared with the mitigation identified by the alternative planning process. The mitigation proposed in the EIS for the project was an on-site mitigation project. The map of the proposal is included as Figure C.24.

Wetland mitigation analyses found that the proposal creates a 3.8-acre wetland adjacent to the project area and probably does a fairly good job of representing the wetland types that were to be affected during the project. However, the wetland type that was proposed to be restored was not high-priority wetlands, and this restoration proposal does not make a significant contribution toward the major conservation goals established by the resource agencies and the watershed council for the basin.

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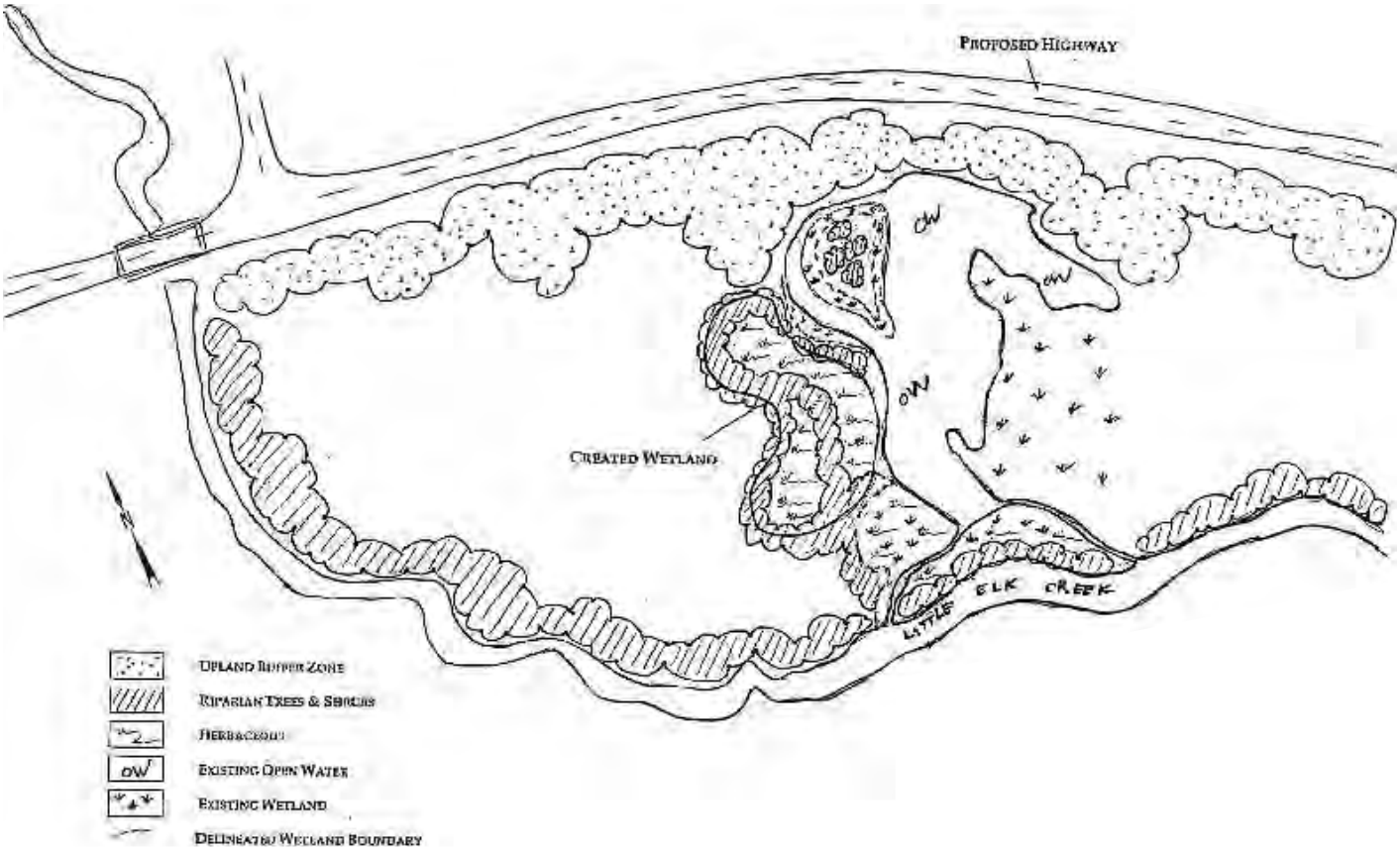

Figure C.24. Proposed wetlands mitigation plan from EIS.

Using the research team's proposed methodology, the team reviewed the wetland priority catalog for the Yaquina watershed, which currently is in draft status, meaning it has not had final reviews by the regulatory agencies. There are only three priority wetland restoration and mitigation sites identified in the basin, shown in Figure C.25. These sites are close enough to the wetlands in location and type that they could serve as suitable mitigation for the losses. They were selected using the data and methods of this project as high priority wetlands because of the size and overall importance to the at-risk fish in the watershed.

To evaluate the available crediting methodologies that may have supported the project better, the team used existing tools to evaluate the potential credits from two of these three potential mitigation sites. Parametrix staff visited the sites and identified the potential uplift on the conservation lands and the adjacent private lands. They determined that the lands already in conservation ownership had little priority for restoration, whereas the private lands in these sites had significant potential, with even a small piece of any of the three easily meeting the mitigation needs of this project.

The crediting analyses implemented included:

1. **Analysis of regulated resource crediting:** The project team reviewed the measurement challenges in the permitting stages to understand other mitigation actions in the region that generate mitigation demand both within the agency and among other permittees. A key component is understanding where measures are a barrier for consultation or permitting. Also critical was the availability of uplift in the priority mitigation areas.
2. **Analysis of credit markets:** The team will review DOT and non-DOT–based markets, when available, for credits; this include §404 or ESA banking.
3. **Recommendation based on future needs:** The interviews with DOT staff will indicate upcoming regulated and nonregulated needs that crediting potentially could address. Tools and methods will be recommended to address these needs.

Follow-up Meeting with Natural Resource and Transportation Agencies in Pilot States

The initial plan was to set up webinar with the team's transportation and natural resource partners to review and discuss results of analyses and comparison with original project outcomes. Given that the outcome of the Oregon pilot project indicated that the proposed alignment was optimal from a conservation standpoint, the team sent the results to all the partners who attended the initial meeting, along with a sum-

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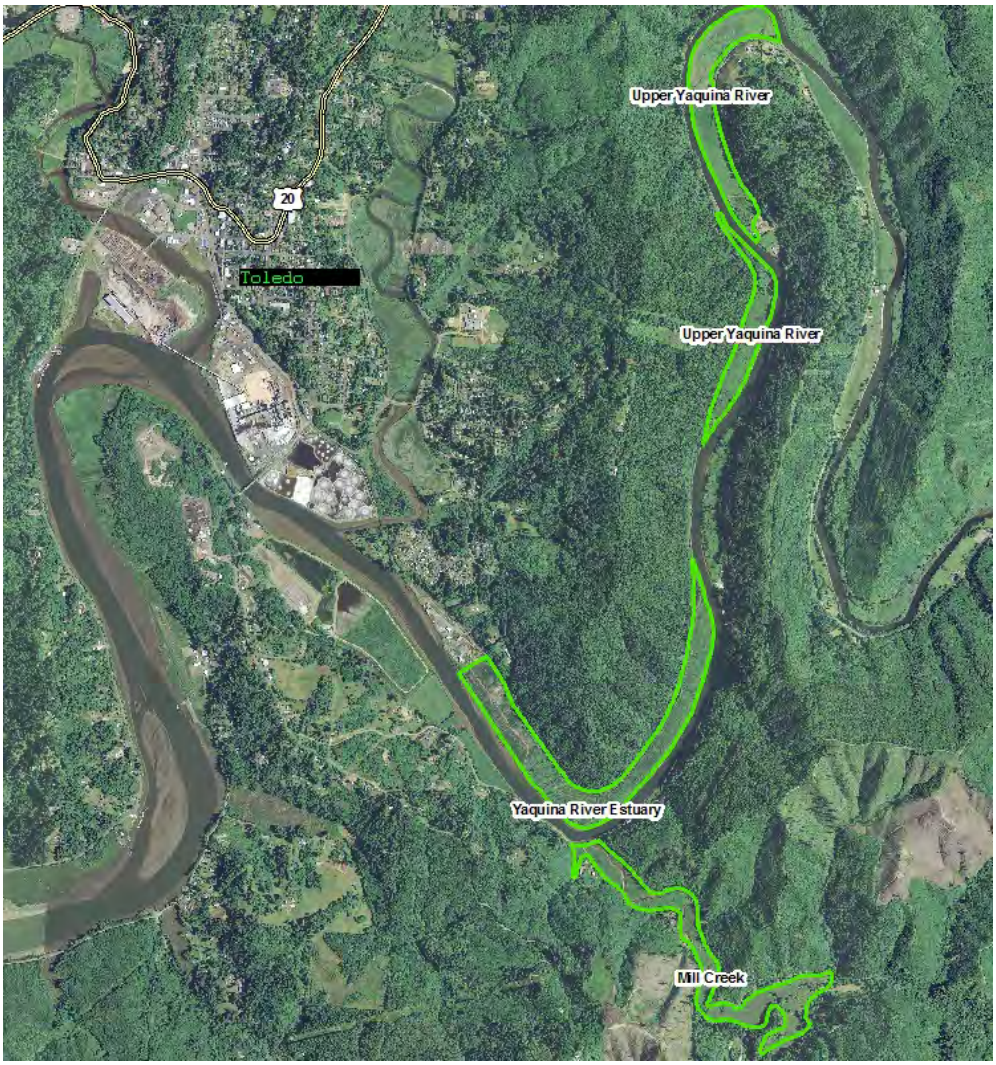

Figure C.25. Priority mitigation areas in Yaquina Basin.

mary of the overall project conclusions. A separate meeting was set up with the ODOT Mitigation Coordinator to discuss the mitigation findings and ways to implement these methods for identifying mitigation opportunities in the future.

Conclusions

The project was an excellent example of a department of transportation improving both transportation and conservation outcomes simultaneously. The only difference between the proposed or implemented project and a project designed by the methodology outlined here would be the wetland mitigation site selection and implementation.

There is an assumption that using this methodology with preselected and approved mitigation sites and up-front assurances that the transportation project was going to improve, rather than degrade species habitats, would have sped the process of obtaining approvals and thereby reduced the costs; however, this is difficult to actually measure.

Finally, the difficulty in obtaining state-funded data in this project was a major finding. It is strongly recommended that consultants be required to provide DOTs with a copy of all spatial data, databases, and analysis completed as part of project planning or EISs in their native electronic format. This would allow the information to be reviewed and provided to other agencies, and would help to build an overall improved natural resources information baseline.

Methodology for Developing a Parcel-based Wetland Restoration, Mitigation, and Conservation Catalog: A Virginia Pilot Project

Background and Introduction

The Virginia Wetland Restoration Catalog (WRC) initially was developed in 2006 as a joint project between the Virginia

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Department of Conservation and Recreation–Natural Heritage Program (VNHP) and the Virginia Department of Transportation (VDOT). VDOT sought a series of maps identifying possible mitigation sites. An initial pilot project was conducted for VDOT in one district to develop a sites list and corresponding maps, including natural resources information. A follow-on pilot project, extending the WRC throughout Virginia, was funded in part by the Virginia Coastal Program at the Virginia Department of Environmental Quality (DEQ).

The WRC focused on wetlands adjacent to, overlapping, and/or functionally associated with Natural Heritage Conservation sites to guide mitigation activities to areas known to have biodiversity conservation and water quality values. The largest sites with greatest biodiversity significance were selected for inclusion in the WRC. Methods entailed the review of selected conservation sites against 2002 Virginia basemap aerial photography, NWI wetland coverage, and other GIS data sets. All areas that appeared to be converted wetlands *and* had a high potential for restoration were delineated in an ArcView shapefile. A total of 122 wetland restoration opportunity sites were identified (15 B1 sites, 32 B2, and 75 B3), ranging in size from 1 to 2,482 acres.

Although Virginia Division of Natural Heritage (DNH) consulted with DEQ on the development of the WRC, to find the most useful and practical organization of it final output for their clients, the WRC has not been used extensively by DEQ. In addition, although the initial pilot project was supported by VDOT, the output was not used in selecting mitigation opportunities.

In this project, Virginia DNH sought a methodology to improve and expand on the WRC, which could be used to develop a wetland and stream mitigation catalog in any state. In Virginia, this methodology would identify more opportunities for wetland and stream mitigation, and guide selection of wetland mitigation opportunities, via a site ranking multiple data sets. This methodology was developed to apply statewide and was tested in an 11-subwatershed pilot area in the Lower Pamunkey River of Virginia.

This methodology first enables the development of a potential mitigation base layer to build on the wetlands identified in the USFWS' NWI, the most comprehensive data set of wetlands in the United States, which often is used to identify mitigation opportunities. Aside from the NWI, input data include National Hydrography Dataset (NHD) streams data, 303d Impaired Waters, 100-year floodplain data, and an analysis of USGS soils data (SSURGO) to tease out soils in partially hydric groups that display properties of hydric soil types. An analysis of these inputs led to a basemap that identified more options for wetland and stream mitigation from watershed to watershed.

This base layer was then prioritized, to assign all areas with a rank of their mitigation value. This rank is based on the likelihood of an identified area being wetland and additional contributions that an area would make to biodiversity conservation or water quality. Data sets used for this prioritization included Natural Heritage conservation sites, critical habitat for species of greatest conservation need from the Virginia Wildlife Action Plan, Natural Heritage Stream Conservation Units, community level aquatic biological data, and 303d Impaired Waters.

This methodology results in a map-based summary of mitigation opportunities ranked from 1 to 5 to clearly indicate their relative value as mitigation sites. To make this catalog more pragmatic for mitigation decisions, all opportunities on the landscape are tied to subwatershed and tax parcel ID. Although this methodology uses nationally available geospatial data sets and some Virginia-specific data, the research team is confident that other states have analogous data sets to augment national data and can follow this straightforward methodology for identifying and prioritizing mitigation opportunities.

Descriptions of Available Wetland Data Layers

The NWI is a product of the USFWS that was developed and has been updated by interpretation of aerial imagery to delineate the areal extent of wetlands, surface waters, and deepwater habitats and define them in terms of their type and function. Each wetland mapped by NWI is classified in the Cowardin et al. (1979) system, which includes special modifiers to identify wetlands that have been converted to farmland or modified to change water occurrence, distribution, and movement. Wetlands may be excluded from the data set because of the limitations of aerial imagery as the primary data source used to detect wetlands; thus additional wetland data sources will be used to supplement NWI in development of the catalog.

The National Hydrography Dataset (NHD), a product of the USGS, is a comprehensive set of digital spatial data representing the surface water of the United States using common features such as lakes, ponds, streams, rivers, canals, and oceans. NHD contains a flow direction network that traces water downstream or upstream, enabling detailed analysis of hydrography. Although NWI has mapped obvious surface waters with accuracy, narrow streams in heavily forested areas often are missing from the data set. The highest resolution (i.e., 24,000 scale) NHD product representing streams was used to supplement NWI in development of the catalog.

The Digital Flood Insurance Rate Map (DFIRM) Database, a product of the Federal Emergency Management Agency of the U.S. Department of Homeland Security, shows 100- and

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500-year floodplains with different zone designations. The data are primarily for insurance rating purposes, but the zone differentiation can be helpful for other floodplain management purposes. Although not entirely wetland, floodplains do contain wetlands and can be excellent choices for mitigation because of the ecosystem services they provide in terms of flood and erosion control and retention of sediments. The 100-year floodplain, also referred to as the base floodplain, was used to supplement NWI in development of the catalog.

The Soil Survey Geographic (SSURGO) Database, a product of the Natural Resources Conservation Service (NRCS) of the U.S. Department of Agriculture, is the most detailed level of soil mapping done by NRCS and duplicates the original, paper soil survey maps. SSURGO data are available for selected counties and areas throughout the United States and its territories. SSURGO is designed for use by landowners, townships, and county natural resource planning and management by those knowledgeable of soils data and their characteristics. Look-up tables are available that provide information about soils in the database. Using these additional tables, hydric and various degrees of flooded soils will be used to supplement NWI in development of the catalog.

The Regional Internet Bank Information Tracking System (RIBITS), developed by the USACE, is an Internet-based tracking system for wetland mitigation banking. Mitigation banking is the restoration, creation, enhancement, or preservation of wetlands to compensate for unavoidable wetland losses in advance of development actions. Banking typically involves the consolidation of small, fragmented wetland mitigation projects into one large contiguous site. Units of restored, created, enhanced, or preserved wetlands are expressed as "credits," which subsequently may be withdrawn to offset "debits" incurred at a project development site. This layer was added to the catalog because it represents actual sites identified for wetland mitigation.

The Impaired Waters of Virginia layer, developed by the Virginia DEQ as required by section 303(d) of the Clean Water Act, portrays waters that are too polluted or otherwise degraded to meet water quality standards. Impaired waters are prioritized for restoration and are attributed with the maximum amount of a pollutant the waters can receive and still safely meet these standards. This calculation is called the total maximum daily load (TMDL). Impaired waters can benefit from wetlands that filter nutrients; thus, this layer was included in the catalog.

GIS data do not always align properly because of different source information, scales, qualities, and development processes. To make certain important aquatic resources are not missed because of misalignments and thus not represented in the final product, additional stream-based layers were included in the catalog. Specifically, these were Natural Heritage Stream Conservation Units (SCU) from the Virginia Department of Conservation and Recreation, Threatened and Endangered Waters (T&E Waters) from the Virginia Department of Game and Inland Fisheries, Confirmed Reaches from the Virginia Wildlife Action Plan, and Healthy Waters Reaches from the Center for Environmental Studies (CES) at Virginia Commonwealth University (VCU).

GIS Development of Wetland-based and Parcel-based Catalogs

As described elsewhere in this document, the steps in developing the catalog are as follows:

1. Extract wetland-related information from the following spatial data sources: USFWS National Wetlands Inventory (NWI), USGS high-resolution National Hydrography Dataset (NDH), U.S. Department of Homeland Security-Federal Emergency Management Agency Digital Flood Insurance Rate Map (DFIRM) Database, USDA-NRCS Soil Survey Geographic (SSURGO) Database, VDCR-DNH Stream Conservation Units (SCU), Virginia Department of Game and Inland Fisheries Threatened and Endangered Waters (T&E Waters), Virginia Department of Game and Inland Fisheries, VCU-CES Healthy Waters, USACE Regional Internet Bank Information Tracking System (RIBITS), and EPA Listed Impaired Waters (303d).
2. Buffer all line feature classes by 2.5 meters to convert stream features to polygons that are 5 meters wide, a width derived by averaging the widths of lines representing streams on 1:24,000 scale USGS topographic quadrangles.
3. For each wetland source layer, create a text field named WSID (wetland source ID) and attribute polygons with codes that uniquely identify the wetland source layer and the individual polygons it contains. For example, the code NWI245 would identify the 245th record of the NWI wetland source layer. Unique identifiers from the source layer may be used for the numeric part of this code or unique numbers may be generated from the FID (shapefiles) or OBJECTID (geodatabases) fields of the feature layers while adding one to each value because these feature identifiers start at zero.
4. To prepare wetland source layers for union overlay, add an integer field named WS_1 or WS_2 or WS_n, for which n indicates the number of wetland source layers, and populate every record with either the numbers 1 or 0, depending on whether it is being added to predict wetlands or counteract possible misalignments among wetland and priority source features. Thus, populate NWI, NHD, DFIRM, and SSURGO source layers with the number 1 and populate SCU, T&E Waters, Confirmed Reaches,

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Healthy Waters, RIBITS, and Impaired Waters source layers with the number 0. After the union overlap, the WS_n fields attribute originating from each wetland source layer will be summed, with higher totals identifying wetlands indicated from multiple sources and where mitigation could provide multiple benefits, including ecosystem services such as natural flood control.

5. Erase developed areas from each wetland source layer using the most-current and highest-resolution landcover data available. The purpose of this process is to remove significant areas of commercial and residential development from the catalog. Individual buildings in otherwise undeveloped settings will be retained. Landcovers change over time, so wetland source layers might not represent current conditions at a particular location. For example, areas that were forested at the time NWI data were developed or last updated may have since been converted to residential development. Because developed landcovers make less functional and thus less desirable wetland mitigation sites, one might decide to erase developed areas from each wetland source layer using the most-current and highest-resolution landcover data available for the entire area of interest. For most large areas of the United States, the best available landcover data will come from the latest version of National Land Cover Data (NLCD). For coastal regions, NOAA Coastal Change Analysis Program data might be more current, which was the case at the time of Virginia's pilot WRC. Create a simplified polygonal layer from the four classes representing development in the NOAA C-CAP (or NLCD) layer, including the least developed class, Developed Open Space, because it is usually associated with residential development. A possibly undesirable consequence of including Developed Open Space is that golf courses and similar open, nonagriculture areas may be excluded from the WRC. Calculate the area of simplified polygons resulting from squares of four pixels; from the landcover layer, select every polygon equal to this size or smaller. Switch the selection to select the larger developed areas. Then add to this selection those smaller polygons that are within 16 meters (a little more than one-half the width of a pixel). Export the selection to a new shapefile and use it to erase developed areas from each wetland source layer.
6. Acquire GIS parcel data, preferably as polygons, covering the entire area of interest, which likely will involve multiple data sets because parcel data usually are maintained by localities. Some localities make GIS parcel data available through web services, whereas others require that you contact their GIS managers to request data. Some localities do not have parcels available as GIS layers; instead, they might have only scanned images of tax maps or, worse, only paper tax maps that the analyst will need to scan. These images can be brought into a GIS if enough control points exist for geographical referencing. Once georeferenced, the ArcScan extension for ArcGIS can be used to vectorize and clean scanned parcel maps. When all parcel layers have been assembled, attribute polygons with codes that uniquely identify the locality and the individual parcel it contains. For example, using federal information processing standards (FIPS) codes for localities, the code 085-113 would identify the 113th record of the Hanover County (FIPS 085) parcel layer. Merge all parcel layers into a single layer and dissolve by the unique codes assigned in the previous step. The parcel layer is now be ready for the union overlay.
7. Acquire watershed boundary data in the finest resolution available for the entire study area. Reduce the attribute fields to those desired in the final product, making certain to retain a field that uniquely identifies the watershed. A layer of sixth-order subwatersheds was used for the Virginia pilot study. These subwatersheds range in size from 10,000 to 40,000 acres, in contrast to fifth-order watersheds that can be as large as 250,000 acres.
8. Assemble layers that will be used to prioritize wetland mitigation sites. These priority source layers should cover topics that include plant and animal biodiversity; significant natural communities; natural lands that provide ecosystem services; natural corridors that buffer streams and connect large patches of natural land; existing mitigation banks; waters identified as impaired and in need of restoration; and farmed wetlands that can be converted to their natural state. Table C.17 shows the priority sources and weights used in Virginia's pilot Wetland Catalog (WC). Some priority data sources already include weights determined in the corresponding models, whereas single-value weights were assigned for this project using expert judgment. Each

Table C.17. Priority Source Layers and Weights Used in Virginia's WC

Priority Source	Weights
Natural Heritage Priority Conservation Sites	1–5
Virginia Natural Landscape Assessment Ecological Cores	1–5
Virginia Natural Landscape Assessment Landscape Corridors	1
Regional Internet Bank Information Tracking System	3
Impaired Waters (303d)	3
Healthy Waters	3
Farmed Wetlands	3

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priority source layer must have an attribute indicating the weight of the features it represents to be ready for the union overlay. For the Virginia pilot WC, each priority source layer had these weights stored in fields named PS_1, PS_2, or PS_n, where n indicates the total number or priority source layers. SCUs, Confirmed Reaches, and T&E Waters were not used directly as priority sources in the Virginia pilot WC because their biodiversity values were already incorporated in the PCS.

9. As a single process, perform a union overlay of the merged parcel layer with the watershed layer, all the wetland source layers, and all the priority source layers. Open the attribute table of the resulting layer and create an integer field named Wetland Overlap, and calculate it to be the sum of the WS_1 to WS_n fields from the wetland source layers. A high value in this field indicates concordance among the wetland source layers and signifies the level of confidence that a particular area is wetland based upon the various input layers. To simplify the layer and retain only those parcels that intersect wetlands, start by selecting blanks in the parcel ID field, which will select polygons where no parcel data overlapped wetland data, and then switch the selection so only records with parcel IDs will be selected. From the current selection, select values from the Wetland Overlap field greater than 0, which represent parcels with wetland intersections. Export the selected records to a new shapefile that, after processing in the next step, will be the first spatial product of this analysis.
10. To the attribute table of the product from Step 9, add an integer field named Mitigation Priority and calculate it equal to the sum of the weights from the priority source layers. Create another integer field named Composite Prioritization and calculate it to be the sum of the Wetland Overlap and Mitigation Priority fields. Finally, add another integer field named Reclass and reclassify scores from the previous field into five classes. The Jenks Natural Breaks classification method available in ArcGIS was used for the Virginia pilot study and seemed to work well. Table C.18 shows the first eight records of an example table. Notice that parcels that intersect only one combination of wetland and priority sources are represented by only one record, whereas parcels that intersect more than one combination, such as parcel 085-4, are represented by multiple records. These multiple records will be consolidated in the next step to create a table needed for the second spatial product of this analysis.
11. Open the attribute table of the first spatial product in ArcGIS and summarize the parcel ID field while selecting "first" for the Watershed ID field and "maximum" for all other fields. An example of the resulting table is shown in Table C.19. Comparing Tables C.18 and C.19, notice that this process did not change values for parcels that intersected only one combination of wetland and priority sources (i.e., the records with a value of 1 in the Freq field in Table C.19), but did summarize values for parcels that intersected multiple combinations (i.e., records with values greater than 1 in the Freq field in Table C.19). The four records for parcel 085-4 in Table C.18 have been consolidated into one record showing the maximum values of each integer field. Table C.19 is an example summary table created by summarizing Table C.18 by parcel ID while selecting "first" for Watershed ID and the "maximum" for the remaining fields. The Max Wetland Overlap and Max Mitigation Priority fields show only the maximum values from multiple-combination intersections and thus may not equal the sums of the maximum

Table C.18. Example of Attribute Table from First Spatial Product

Parcel ID	Watershed ID	WS_1	WS_2	WS_n	Wetland Overlap ($\sum WS_i = WS_1 + WS_2 + \cdots + WS_n$)	PS_1	PS_2	PS_n	Mitigation Priority ($\sum PS_i = PS_1 + PS_2 + \cdots + PS_n$)	Composite Prioritization ($\sum WS_i + \sum PS_i$)	Reclass
085-1	YO28	1	0	0	1	1	2	0	3	4	1
085-2	YO28	1	1	1	3	5	5	5	15	18	5
085-3	YO28	0	1	0	1	0	1	0	1	2	1
085-4	YO28	1	0	1	2	5	3	5	13	15	4
085-4	YO28	1	1	0	2	1	4	2	7	9	3
085-4	YO28	1	1	1	3	0	0	0	0	3	1
085-4	YO28	1	0	1	2	0	5	0	5	7	2
085-5	YO29	1	0	1	2	3	2	5	10	12	3

Notes: PS = priority source—populated with weights (see Table C.17) in which parcels intersect priority layers; WS = wetland source—populated with ones in which parcels intersect wetland source layers. Unique identifier fields from wetland and priority source layers are not shown in this table because of space limitations.

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Table C.19. Example Summary Table

Parcel ID	Watershed ID	Freq	Max WS_1	Max WS_2	Max WS_n	Max Wetland Overlap	Max PS_1	Max PS_2	Max PS_n	Max Mitigation Priority	Max Composite Prioritization	Max Reclass
085-1	YO28	1	1	0	0	1	1	2	0	3	4	1
085-2	YO28	1	1	1	1	3	5	5	5	15	18	5
085-3	YO28	1	0	1	0	1	0	1	0	1	2	1
085-4	YO28	4	1	1	1	3	5	5	5	13	15	4
085-5	YO29	1	1	0	1	2	3	2	5	10	12	3

Notes: For parcels that intersect multiple combinations of wetland and priority sources, the maximum values in this table do not necessarily sum to Max Wetland Overlap, Max Mitigation Priority, or Max Composite Prioritization, as explained in the text. Freq = frequency of records for a particular Parcel ID before the table was summarized (i.e., the number of records that were consolidated for that parcel ID).

wetland and priority source fields, respectively. Similarly, the Max Composite Prioritization may not equal the sum of the Max Wetland Overlap and Max Mitigation Priority fields.

Using the Parcel ID field as the common field, join the summary table created in Step 11 to the merged parcels layer used in the union overlay, thus allowing parcels to be symbolized by any of the attributes from the summary table. This is the second spatial product of this analysis. Most users will want to symbolize on the Max Reclass field to make a map in which all parcels are ranked one through five, with five indicating highest priority for wetland mitigation.

Incorporating Environmental Information in Project Delivery: Oregon, Michigan, and Colorado DOTs

The Task 4c team explained to DOT staff interviewees that the objective is to create guidelines for developing an adaptable process that states can use to support local processes for incorporating environmental needs earlier in the project delivery process.

Oregon Department of Transportation

Based on preliminary discussion with ODOT staff, changes need to occur in the statewide transportation improvement program (STIP; Oregon Department of Transportation 2012). Oregon's STIP is a 4-year transportation capital improvement program that identifies funding and scheduling of transportation projects and programs across multiple government entities. It is in need of a more efficient time and step in the process for connecting environmental issues and the project delivery process. Environmental information is still not well accounted for in the STIP, which is more about transportation needs than environmental needs. For example, greater emphasis would be placed on engineering required to straighten a curve than on the project's overall environmental impacts. STIP criteria are being modified to incorporate more environmental values and linkage to NEPA; however, better inclusion of environmental values is still not happening in the planning process, which is at the political rather than the project level. Opportunities may arise from legislative requests, such as in the Oregon Highway Plan. STIP also needs high-level performance standards, such as increasing the percentage of impervious areas treated. Regulators also need a role in the STIP process, particularly one that occurs much earlier collaboration, and the STIP process also needs to include state wildlife action plan and Oregon Conservancy Strategy (OCS) documents. STIP is also the level to evaluate programmatic or trade-off decisions across resources; new regulatory concerns should first be evaluated at the STIP level to prevent surprises.

The following themes and issues emerged from the interview:

1. **Better environmental information is needed on the front end of the project delivery process.** ODOT is developing a GIS environmental management tool for regulatory teams. The tool, developed with best available data, is close to being usable, although it is not yet complete. Additional data from other sources, coupled with greater coordination, would be very helpful.

   Under the current process, ODOT pulls data from wherever it can find it and then goes out onto the proposed site to more fully assess environmental impacts and constraints. The general lack of data causes problems with project design, especially in ways that could better accommodate discoveries when undertaking site analysis. Coordinating CAD files/engineering priorities with GIS/environmental/mitigation divisions between data sets will go a long way toward improving the project design process.

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2. **Coordination with, and changing expectations from, cooperating agencies is a continuing challenge.** Projects typically require cooperation among a range of state and federal agencies, which creates numerous blockages:
   a. *One of the big challenges is midcourse or "11th-hour" changes in agencies' requirements and expectations.* There needs to be a punctuated equilibrium approach, rather than a continual change approach. The best available science creates dynamic data sets; there should be some agreement among cooperating agencies that new standards will be applied to subsequent projects while allowing agreed-to performance standards for current projects to stand. Basic definitions can be lacking; expectation to treat 100% of stormwater on new facilities is an example. Does 100% mean all of the new surfaces or all of the existing and new surfaces? If it indicates 100% of existing and new surfaces, can the facility use a trade at another facility to meet this requirement?

      Risk aversion is a big driver for regulatory agencies' behaviors. They are consistently concerned about setting precedents with respect to agreed-upon standards and subsequently being perceived as not administering regulations as required. Although they have the legal power to require changes whenever they feel it is necessary, doing so while a project is under way creates significant delivery problems. Having clear, *durable* agreements among partners regarding mitigation requirements, priorities, and tools to be used would provide a much-needed level of certainty regarding project delivery obligations.
   b. *Regulatory agencies distrust ODOT based on historic environmental performance that influences current perceptions.* There is a general perception that ODOT is not doing as much as it can for the environment. ODOT is actively improving its environmental practices; however, although it may do well on 50 projects, it's the one in which ODOT doesn't perform to expectations that the agencies remember and tend to regard as the measure of ODOT's overall performance.
   c. *Scope creep, based on a lack of explicit rules and responsibilities, creates problems.* ODOT works with at least two intergovernmental coordinating entities: the Collaborative Environmental and Transportation Agreement for Streamlining (CETAS) and the Bridge Delivery Program's Programmatic Agreement Reporting and Integration Team (PARIT). When there is not enough other business to take care of, partner agencies have a tendency to become involved over and above what is called for. This stems from lack of specific rules and clear understanding among agencies regarding the limitations of their authorities. Agencies sometimes go looking for new issues to call their own. As an example, some agencies have inappropriately defined what needs to be done offsite as well as onsite with respect to wetlands mitigation. FHWA also sees collaboration or cooperation as ODOT being too permissive with regulatory agencies. Remember the FHWA portion of the equation. Regulatory agencies also have a tendency to try to reach back to impacts that predate regulation and address them.
   d. *Issues coming down the line.* There is always a need to be planning ahead for such issues as the Clean Drinking Water Act, greenhouse gas emissions.
3. **ODOT is using a business case to change how it does business, but this approach is not well understood either externally or internally.** The business case can help ODOT be more proactive and consistent with respect to environmental needs. Regulatory partners do not seem to appreciate how business "works" with entities such as ODOT. However, they are not alone with respect to this lack of understanding the business aspect of project delivery: it is also an issue with various departments within ODOT. The need to remember state level laws, such as the Jobs and Transportation Act §18, is a good example. The law has reporting and benchmarking requirements.
4. **Collaboratively developing appropriate decision processes or tools will greatly enhance outcomes.** Potential areas of focus include:
   a. *A tool that could identify regional priorities.* There appears to be a good sense of regional priorities; however, the current process of determining those priorities is ad hoc. For instance, ODOT has done a good job of assessing priorities with respect to vernal pools, but it would be useful to be able to apply a consistent process to other resources. It is beneficial to be plugged in at the STIP level.
   b. *A tool that could evaluate trade-offs.* For example, agencies are often uncertain regarding what needs to be done offsite versus onsite regarding wetlands mitigation. Actions often are defined by best available technology or what is feasible, which is insufficient to meet environmental goals. Because the future of natural resources is active management, rather than taking a hands-off approach, understanding trade-offs is important to project decision making. Trade-offs cannot be made strictly at the project level; they must be strategized and occur at a higher level.
   c. *Partner agency agreement on the developed tools.* If the agencies do not clearly acknowledge and accept the tools, ODOT will wind up back at square one with respect to having to go through approval on a project-by-project basis.
5. **Project follow-up is constrained in multiple ways.** Until there is clearer direction on responsibility and the value of

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tracking ecosystem service provision, post-project activities will remain outside ODOT's purview.

a. *There is no federal nexus for maintenance activities.* This creates conditions for ODOT in which the maintenance and operation shop practices are different from those of construction. Spraying of chemicals not allowed in construction is not regulated in maintenance cases. The use of herbicides in riparian areas is another example; in this case the 4(d) rule does not apply. Thus, ODOT faces uncertainty over how to design or proceed with maintenance projects.
b. *Monitoring is controversial in terms of investment and outcome.* The agency uses habitat as a surrogate for environmental quality. ODOT has been pushed by agencies to invest in more monitoring, but ODOT has pushed back on the demand because, if species do not reappear where they should, there is little ODOT can do about the situation. Because monitoring information currently is seen to be of limited use for ODOT's purposes, the Department sees little point in making the investment. Agencies often require monitoring in ways that do not make sense to ODOT. In these instances, having correct monitoring demonstrated and having the partner agencies provide guidance—what the agency needs to know, how to go about providing it, and providing feedback to improve monitoring—would increase efficiency. What guidance has been provided has been too ad hoc or appears to be a one-size-fits-all approach. It would improve efficiency to be able to use a single methodology that all agencies could agree to.
c. *Tracking annual mitigation/compliance costs is not precise.* Such costs are not separated as a part of doing business. As a result, those costs have low accuracy. It was not clear from the interviews whether or not this is a significant issue for either ODOT or cooperating agencies.
d. *Because ODOT is a small "frequent filler," it doesn't make sense to invest in a mitigation bank, but it complicates design and delivery.* Because the agency is a frequent filler, it has to respond to constant demands and requirements from regulatory agencies. The best solution for the agency would be to have an eastside Cascades/westside Cascades bank to do advanced mitigation, but that is unlikely. A conservation registry might be one way to better meet ODOT's needs.
e. *Terrestrial species are not typically considered.* Although ODOT is trying to do a better job of incorporating their requirements, there is no regulatory hook to include them in project design; and it is regulation that forces such inclusion. In the absence of regulations, if the state has a governor who does not support inclusion of terrestrial species, it will not happen.

6. **Links to local land use planning are weak.** When asked about how land use planning factors into design considerations, the response was that issues are mostly political, which can lead to directions that indicate little understanding or consideration of environmental impacts. An explicit example was an interchange design that did not maximize design opportunities on adjacent property according to the developer/stakeholder. The issue was elevated politically beyond ODOT's staff control or oversight, and directions were given to redesign the interchange. The redesign wound up creating greater environmental impacts. ODOT has created a process to get local land use entities to become more engaged in project design for intersections and interchanges, but that process does not currently incorporate environmental considerations.

Pursuant to the Jobs and Transportation Act §18, ODOT is charged with developing rules that account for using environmental performance measures in project design. It is also responsible for developing measures for four project objectives: saving money, saving time, protecting the environment, and reducing the state's dependence on foreign oil. The interviews indicated that having measurement tools would help ODOT meet these obligations.

Michigan Department of Transportation

The nature of MDOT's business has changed significantly in the last 5 years. Their major capacity projects are at border crossings with Canada, which involves some major natural resources, such as the Detroit River between Detroit and Windsor. For financial reasons, there has been a moratorium on developing new capacity projects.

MDOT has been successful at avoiding impacts, so they have not had as many projects recently as they used to, when they had hundreds of acres of impacts on floodplains and wetlands habitat. Two of their recent border projects were in urban areas and thus involved impacts on fewer natural resources, and they did not have to deal with permits for natural resource management.

Quality of Agency Relations on Natural Resource Management

Coordination with Cooperating Agencies

Coordination has become a very smooth process—the Department has had little conflict in the past 5–6 years with resource agencies and has been a partner-oriented organization; the Department has been working with other agencies from a program standpoint. Every year the Department has a natural resource agency meeting, which is very successful at attracting resource agency staff and driving mutual learning. Everything is not rosy but definitely is improving.

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Relationship-Building with Resource Agencies

The Department focused on having communication building events with other agencies to build trust and fairness, asking: What is it that you're looking for out of this project? MDOT has been very sensitive to conflict resolution, collaboration throughout the process, and trying to get right input at the right time to avoid having to rework or quit a project. Several years ago, there was an issue with T&E with regard to a butterfly. The situation showed that such issues must be taken seriously and provided a wake-up call.

Use of Different Staff Teams for Banking and Mitigation Issues

MDOT was working on the banking system until the financial crisis. Six banking projects are up and running or in the works. Having multiple wetland banks available now allows them to be used for any wetland impacts. The process is now streamlined, very unlike the former 2-year process; the credits are assigned, approval is given, and the project can proceed.

Use of Business Case to Change How Agency Operates

Costs have gone from $200,000/acre to $30,000/acre. Previously, the Department had to buy and overly design parcels to get a wetland on one. The Department used to do a great deal of earth moving, but construction and acquisition costs are both down. The Department has been working hard to institute tracking, with the result that it can now produce reporting on results.

The Department has had a fair amount of failure and thought a more process-based analysis of failures was needed: "How were we going to track results?" This is essential to start figuring out the Department's overall progress.

Money always helps. The team developed partnerships with other agencies in which they funded GIS projects, which is part of relationship building.

The team is working with public money and owes it to the public to figure out how to spend money smartly and get the best results possible, the feeling being that "If we're going to have experiments, let's have real ones, and let's prioritize them, through dialogue."

Collaborative Development of Appropriate Decision Processes and Tools

The new approach is explicit. The Department conveys the following: "While we are going through this process you're going to be with us, rather than bringing you in at the end, where you express your conflict."

One-stop shopping for most natural resource concerns is the norm, with one agency designated to work with state permit laws and most of the federal laws. The thought is "We pay for these people out of our budget, so they are highly motivated to work with us."

Improving Relations with Federal Agencies

New things coming down the line: the Department now worries more about regulatory changes than about new resources. There is not a lot of listed T&E. The current economy means there are massive shifts of population out of the state, which means there may be more habitat than ever. The Department does not have a lot of requests for on-stream mitigation but is hoping lessons learned about process and business practices from issues with wetlands will be useful.

Interactions with USACE on Sn 10 are increasingly successful, with improved communication. The USACE has an annual meeting in March to discuss current issues, which helps generate very rapid follow-up regarding problems.

The assumption agreement with EPA says it will have review and account for authority to review 404 assumptions. The Department has encountered some problems when not directly in contact with NEPA staff, but that has been an internal relations issue. Verbalizing the problems has helped.

Improving Relations with Engineering Staff

One project on the Grand River involved a large bridge crossing and illustrates changes that have occurred: "Ten years ago we would talk to engineers about *spanning the floodplain* and they would laugh. This does not happen anymore . . . [now there is] no question that they would span the floodplain."

Having internal staff consistently working on changing attitudes has helped educate the engineers. In addition, staff turnover has changed the entire organization; in government, hiring periods are cyclical, so a great number of workers retired 5–8 years ago, which brought younger workers who are much more accepting of environmental laws. Much of the improvement in attitudes about the environment have had to do with society and educational changes. "We just don't have the fights we used to have."

The 404 merger process and concurrence point were really helpful in developing this approach: "Having a stepwise process has really helped, and we have applied it to a lot of different areas here. Negotiation is a high priority."

Emerging and Local Contextual Issues

Tourism is the number 2 industry, and water resources are essential to tourism. From a transportation standpoint, stream and fish resources will become more of an issue. The Department has matured to a level of confidence in handling wetland mitigation and does not want to have to repeat past mistakes when working on stream mitigation. The Department needs to lean on the partnerships built

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(e.g., with fishery agencies) because they generate tremendous benefits to both regulatory and transportation departments for a results-oriented approach.

Currently, stream work is mostly upgrading facilities, correcting scour, building bigger bridges, culvert sizing, best practices for fish passage, and sometimes stream relocation.

Not having a watershed-based approach to streams is a problem. The Department needs to ask, "What is the overall plan?" The Department needs to concentrate on an approach that sees the plan as a system and not just think about a little piece of that plan.

The Department continues to experience conflict with regard to airports. Airports usually are on cheap land, which usually is wet; if a runway needs extension, problems can occur. Because there is not a stepwise process to the problem solving, the answer often is "we will not do that mitigation."

The Department needs to share its experiences with mitigation. One problem encountered with wetland mitigation sites has been performance measures that are highly unrealistic for sites, with no scientific grounding for requirements.

Colorado Department of Transportation

CDOT's process is that as projects come off the STIP to regions, regional environmental staff review and decide if statewide program help is needed. The staff is tasked to ensure CDOT is meeting federal and state wildlife laws; ensure statewide consistency; identify ways to streamline or find mitigation and banking/programmatic projects that are helpful; and try to coordinate across region. It also manages section 7 consultation and state and federal wildlife processes.

Programmatic Tools in Place

1. **Shortgrass prairie, 58,000 acres** acquired in natural state:
   a. Deeded to TNC to manage to cover up to 20 years of maintenance activities along highways (primarily used for plowing, signs, intersection improvements, rest stops).
   b. Debits are recorded in acres, and CDOT keeps a running tab of disturbed acres; must track both temporary and permanent impacts and can reuse temporary acres if they hit the limit. Impacts are measured only through design. Consultation is now done with just a letter.
   c. The department will reconsult with USFWS when the acreage is used up or when 20 years elapses.
   d. Everything east of the Shortgrass line is considered shortgrass habitat and can be mitigated by the program.
2. **The South Platte Water Related Activities Program** (SPWRAP) adjusts depletions to the Platte River. The state put money into the fund to buy water rights and restore habitat for species mostly in Nebraska; there is a similar program for the Colorado River across the divide in the western portion of the state.
3. Have a **liaison at USFWS** just for section 7 issues who is always available for consultation when looking at all species on the list provided by USFWS and checking the impacts for a specific project. The same checks should be done with the Forest Service list and state-listed species. The ideal liaison would be amenable to working together and doing it well.
4. **Banking** is a growing option, with support given by regulators and CDOT. Habitat data are primarily from the university and the Natural Heritage Program.

Emerging Issues and Concerns

1. **Canada lynx:** The most difficult species to deal with; barrier effects and migration patterns are being studied; also being considered is how much effect there is on crossing the roads? To date, CDOT has tried to get the region to mitigate by reducing the barrier effect, taking out cement for the guard rail or guard rails for cable rails, and working closely with the Division of Wildlife, looking for places to put gaps in barriers. Progress is wavering because of a lack of hard numbers on effects. If the population of lynx continues to grow, conflicts will arise—especially along I-70.
2. **Cutthroat trout:** For this species it is best to clean runoff.
3. **Conflicting regulatory drivers:** Loveland Pass is an example of a stormwater detention and treatment facility that is needed, but these facilities block Canadian lynx passage.
4. **Mitigation costs are not tracked:** The shortgrass prairie initiative was paid for in full at purchase, and costs are not accounted for in projects when the credits are used. Other species, such as the southwest willow flycatcher, are avoided through scheduling.
5. **Coordination efforts:** The existence of multiple working groups on resource issues can make coordination challenging.
6. **Prairie dog:** There are several species at risk, but the black-tailed prairie dog is the primary concern in the east. There is local opposition to moving the animals but a potential for listing in the longer term. Currently, the primary action is euthanizing the animals.
7. **Preble's meadow jumping mouse (PMJM):** This species will affect growth in the Denver/Colorado Springs area.
8. **Migratory birds:** These birds need better options; exclusion practices are hard, and timing is an issue.

Most species of concern, such as sagebrush grouse, mountain plover, boreal toad, are in remote areas, where transportation projects are not needed. The boreal toad is a particular challenge, because it is affected by salting, sediments, and

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stormwater. There is no real way to avoid such problems when they are an issue.

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APPENDIX D

Ecosystem Based Tool Database

The tool database was built by reviewing the tools documented in the Ecosystem Based Management (EBM) Tools Network, reviewing the tools that were referenced in many of the articles and research cited in the literature review, and using the team's knowledge to evaluate the tools. The tools included in the database are described in detail in Table D.1.

Table D.1. Ecosystem Based Tool Database

ID	Tool Name	Description
1	Nonpoint Source Pollution and Erosion Comparison Tool (N-SPECT)	N-SPECT helps coastal managers and local officials predict potential water quality impacts to rivers and streams from nonpoint source pollution and erosion.
2	Ecosystem Management Decision Support (EMDS)	EMDS integrates the logic engine of NetWeaver to perform landscape evaluations and the decision-modeling engine of Criterium DecisionPlus for evaluating management priorities.
3	Better Assessment Science Integrating Point and Nonpoint Sources (BASINS)	BASINS is a customized ArcView geographic information system (GIS) application designed to be used by regional, state, and local agencies to perform watershed- and water-quality–based studies and as a system for supporting the development of total maximum daily loads (TMDLs).
4	Information System of Plans (ISoP)	In most development situations, the existence of multiple plans and many distinct government agencies and interest groups is normal. The many plans that affect overlapping geographic areas are created by different stakeholders and are inconsistent in at least some respects. Tools can be developed to treat these plans as an ISoP and use them to advantage. The ability to access and compare multiple plans yields more information pertinent to making a decision than can be found in any one plan, which of necessity suppresses disagreement and multiple perspectives. The result is an ISoP that is a persistent, interactive, and continually changing set of information that puts plans to work rather than on a shelf.
5	Land Use Evolution and Impact Assessment Model (LEAM)	LEAM is a computer-based tool that simulates change across space and time. Planners, policy-makers, interest groups, and laypersons use LEAM to visualize and test the impact of policy decisions. The LEAM system is designed to enhance understanding of the connections between urban, environmental, social, and economic systems.
6	C-Plan Conservation Planning System	C-Plan is designed around the concept of a decision-support system. Together with a GIS, it maps the options for achieving an explicit conservation goal in a region, allows users to decide which sites (areas of land or water) should be placed under some form of conservation management, accepts and displays these decisions, and then lays out the new pattern of options that result.
7	Conservation Assessment and Prioritization System (CAPS)	CAPS is a computer software program designed to assess the ecological integrity and biodiversity value of every location based on natural community-specific models to help prioritize lands for conservation action based on their assessed ecological value.
8	FRAGSTATS	FRAGSTATS is a spatial pattern analysis program for categorical maps.

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Table D.1. Ecosystem Based Tool Database (continued)

ID	Tool Name	Description
9	Habitat Priority Planner (HPP)	HPP is a spatial decision support tool designed to assist users in prioritizing important areas in the landscape or seascape for conservation or restoration action. What makes this tool unique is the ease with which the scenarios can be displayed and changed, making this a helpful companion when working with a group.
10	Impervious Surface Analysis Tool (ISAT)	National Oceanic and Atmospheric Administration (NOAA) Coastal Services Center has developed the ISAT to help managers and planners make a determination about the impact of impervious surface coverage on local water quality.
11	CommunityViz	CommunityViz is a GIS software extension designed to help people visualize, analyze, and communicate about important planning decisions. Widely adopted by land-use planners, it supports informed, collaborative decision making by illustrating and analyzing alternative planning scenarios.
12	TransCAD	TransCAD is a GIS system designed specifically for use by transportation professionals to store, display, manage, and analyze transportation data. TransCAD combines GIS and transportation modeling capabilities in a single integrated platform.
13	NEPAssist	NEPAssist is a GIS application that automates and web-enables the collection and coordination of information inherent in the environmental review process mandated by the National Environmental Policy Act (NEPA).
14	INDEX Planning Support Software	INDEX is an integrated suite of interactive GIS planning support tools for assessing community conditions, designing future scenarios in real time, measuring scenarios with performance indicators, ranking scenarios by goal achievement, and monitoring implementation of adopted plans.
15	Automated Geospatial Watershed Assessment (AGWA)	AGWA is designed to provide qualitative estimates of runoff and erosion relative to landscape change.
16	Artificial Intelligence for Ecosystem Services (ARIES)	ARIES is a web-based technology offered to users worldwide to assist rapid ecosystem service assessment and valuation (ESAV). Its purpose is to make environmental decisions easier and more effective. ARIES helps users discover, understand, and quantify environmental assets and what factors influence their values, in a geographical area and according to the needs and priorities set by its users.
17	Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST)	InVEST is a software tool that can model and map the delivery, distribution, and economic value of life-support systems (ecosystem services).
18	Land Change Modeler (LCM)	The LCM is an optional software extension for ArcGIS as well as another GIS platform, IDRISI Taiga, which is also produced by Clark Labs. The LCM is a useful tool for analyzing and predicting landcover change and assessing the implications of that change for biodiversity.
19	CoastRanger	CoastRanger MS has been designed to explain the consequences that different management approaches have on coastal processes, natural environments, and flood and coastal erosion risk. The software highlights the range of interests that need to be balanced on the coast and demonstrates the difficult decisions that have to be made in some areas.
20	Land Transformation Model (LTM)	The LTM model uses landscape ecology principles and patterns of interactions to simulate the land use change process and forecast land use change.
21	RESTORE	RESTORE integrates models of watershed function and economic characterizations of restoration options with stakeholder-determined constraints and priorities to provide a tool for stakeholders to identify feasible restoration strategies and evaluate the ecological and economic effectiveness of these strategies at addressing watershed-level function.
22	Watershed Analysis Risk Management Framework (WARMF)	WARMF is a physically based watershed modeling framework and decision support system for watershed management. It is suitable for applications including watershed stewardship, land use planning, climate change impact, mercury transport, and TMDLs.
23	Watershed Treatment Model (WTM)	The WTM assesses uncontrolled pollutant loads from two broad categories of pollutant sources: primary and secondary. Primary sources are related to the urban stormwater runoff loads from major land uses (i.e., commercial, residential, agricultural). Secondary sources (i.e., sanitary sewer overflows, septic system failure, and channel erosion) are pollutant sources dispersed through the watershed whose magnitude cannot easily be estimated from available land use information.

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Table D.1. Ecosystem Based Tool Database (continued)

ID	Tool Name	Description
24	Protected Area Tools (PAT) for ArcGIS 9.2	One of the technical challenges within the process of evaluating and filling protected area gaps is the development and use of GIS-based, user-friendly tools that support the protected area gap process. The development of a Protected Area Gap Decision Support System (DSS) was conceived as part of an ongoing process to help fill the technical void that exists.
25	Virginia Natural LandScape Assessment (VaNLA)	VaNLA, a component of the Virginia Conservation Lands Needs Assessment (VCLNA), is a landscape-scale GIS analysis for identifying, prioritizing, and linking natural habitats in Virginia.
26	Virginia Natural Land Network (NLN)	A component of the VaNLA, the NLN identifies large, unfragmented cores, patches of natural land with at least 100 acres of interior cover. Cores provide habitat for a wide range of species, from interior-dependent forest species to habitat generalists, as well as for species that use marsh and maritime habitats.
27	CEDAR and CEDAR GIS	CEDAR allows users to enter and retrieve project data from a single source. The focus of the application is to facilitate environmental staff duties, with special attention given to meeting the needs of district staff who handle the majority of the project clearance activities. CEDAR provides the ability to assess potential environmental resource conflicts through the internal comprehensive GIS, with which users can digitize project areas and spatially analyze the areas to identify potential resource conflicts.
28	Natural Heritage Data Explorer (NHDE)	NHDE is a website application that provides an interactive map service that allows the user to display a variety of data layers, including county boundaries, roads, streams, watershed boundaries, conservation lands, and topographic and aerial photography for the entire state.
29	Land Conservation Data Explorer (LCDE)	The LCDE is a public portal that allows users to view and query existing Natural Heritage land conservation information, including Green Infrastructure GIS models/layers, Conservation Lands, National Wetlands Inventory data, and various reference layers, including roads, jurisdictional boundaries, and hydrology.
30	Wetland Restoration Catalog	This catalog identifies potential wetland restoration sites based on their historic wetland characteristics and their inclusion in, or adjacency to, Natural Heritage Conservation Sites.
31	One N.C. Naturally Conservation Planning Tool	The One N.C. Naturally Conservation Planning Tool was envisioned to streamline the process of identifying and prioritizing the areas in North Carolina's landscape that are essential for conservation.
32	Virginia Coastal Geographic	ArcServer-based website that provides a gateway to Virginia's coastal resource data and maps, focusing on geospatial data and information related to coastal laws and policies, facts on coastal resource values, and direct links to collaborating agencies responsible for current data.
33	Miradi	The Miradi software tool helps conservation practitioners implement the Open Standards for the Practice of Conservation. Miradi provides an easy-to-use, interview-style interface that walks a project team through each step of the process of designing, managing, and monitoring their project according to the best practice standards established and tested by the world's major conservation organizations.
34	NatureServe Vista	NatureServe Vista is a software extension tool for conducting conservation planning and integrating conservation with other assessment and planning activities, such as land use, transportation, energy, and natural resources management.
35	MARXAN	MARXAN is software designed to aid systematic reserve design on conservation planning. With the use of stochastic optimization routines (simulated annealing), it generates spatial reserve systems that achieve particular biodiversity representation goals with reasonable optimality.
36	QuantM	QuantM is comprehensive route optimization software designed for transportation planners.
37	Circuitscape	Circuitscape is software program that borrows algorithms from electronic circuit theory to predict patterns of movement, gene flow, and genetic differentiation among plant and animal populations in heterogeneous landscapes.
38	Florida Efficient Transportation Decision Making (ETDM)	The ETDM process was a response to the congressional passage of the Transportation Equity Act for the 21st century. The ETDM process redefined how the state of Florida accomplishes transportation planning and project development. The overall intent of the ETDM process is to improve transportation decision making in a way that protects the human and natural environments.

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Table D.1. Ecosystem Based Tool Database (continued)

ID	Tool Name	Description
39	Colorado Planning and Environmental Linkages (PEL) Tool	The PEL tool was designed for transportation planners to facilitate an improved approach to transportation decision making that considers environmental, community, and economic goals across the targeted corridor.
40	Texas Ecological Assessment Protocol (TEAP)	TEAP is a planning- and screening-level assessment tool that uses existing data available from the statewide GIS grid to identify ecologically important resources throughout Texas. The results of the TEAP can be used in project planning (i.e., scoping, alternatives analysis), to determine appropriate areas to conduct detailed field investigations, and in mitigation discussions to avoid ecologically important areas, minimize impacts to those areas, and compensate for unavoidable impacts.
41	Florida Environmental Screening Tool (EST)	EST provides a vital foundation to the transportation/conservation process, supporting agency participation and community involvement throughout the project life cycle. The EST is an Internet-accessible application that provides tools to input and update information about transportation projects, perform standardized analyses, gather and report comments about potential project effects, and provide information to the public.
42	Google Earth/Google Maps	Google Earth is a free desktop product that displays aerial imagery and other GIS data on a desktop computer. Google Earth provides high-resolution imagery for most, if not all, urban areas in the United States. Increasingly, users are able to add their own data (such as KML or KMZ files) to Google Earth interface.

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APPENDIX E

Ecosystem Service Accounting Tools

Ecosystem Services are the benefits provided by an ecosystem. Examples include clean air and water, water supply, habitat, climate regulation, recreation and aesthetic value, food, fiber and fuel, and natural hazard mitigation (e.g., floods). Placing a quantitative value on ecosystem services enables these benefits to be weighed against value generated by other uses of the land. This appendix contains numerous accounting tools and methods that have been developed to value various ecosystem services (summarized in Table E.1). These methods may help practitioners in implementing steps five and six of the Integrated Ecological Framework—(5) Establish and Prioritize Ecological Actions and (6) Develop a crediting Strategy.

Applied River Morphology
D. Rosgen
1996

Provides a detailed explanation of the Rosgen stream classification system and "how it might be used to incorporate the observed processes of river mechanics into restoration designs" (Rosgen 1996). Presents probable channel evolution scenarios based on existing channel and valley features to suggest potential future stream conditions. Based on field data but may have a geographic information system (GIS) component. Descriptive and quantitative output.

- *Intended use:* Nationwide rivers and streams
- *Ability to calculate multiresource credit:* No
- *Sensitivity:* Unknown
- *Capability of being integrated into multiresource credit:* Unknown

Artificial Intelligence for Ecosystem Services (Aries)
University of Vermont

A federally funded information science tool developed for web distribution that provides users a guided and intelligent way to assemble data, values, and issues.

- *Intended use:* To help organizations or jurisdictions identify issues and opportunities for understanding ecosystem services. A decision support system.
- *Ability to calculate multiresource credit:* Unknown
- *Sensitivity:* Unknown
- *Capability of being integrated into multiresource credit:* Unknown

Basinwide Estimation of Habitat and Fish and Populations in Streams
A. C. Dolloff, D. G. Hankin, and G. H. Reeves
1993

A sampling design for estimating total fish abundance and total fish habitat area within a watershed known as Basinwide Visual Estimation Technique (BVET). Based on field data but may have GIS component. Quantitative output.

- *Intended use:* Small streams. Not limited to any single geographic region, but was developed and has been most used in the western United States.
- *Ability to calculate multiresource credit:* No
- *Sensitivity:* Unknown
- *Capability of being integrated into multiresource credit:* Unknown

Beneficial Use Reconnaissance Program (BURP) Field Manual for Streams
Idaho Department of Environmental Quality, Burp Tac
2004

Initiated to help determine the existing uses and beneficial use support status of Idaho's water bodies. BURP monitoring emphasizes sampling, analysis, and assessment of biological assemblages and physical habitat structure of streams to ultimately support characterization of stream integrity and overall quality. The BURP Field Manual provides information needed for consistency and comparability of monitoring efforts among Idaho Department of Environmental Quality personnel

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and other entities interested in following these methods. A descriptive, ordinal scale with quantitative output.

- *Intended use:* Idaho streams
- *Ability to calculate multiresource credit:* Unknown
- *Sensitivity:* Unknown
- *Capability of being integrated into multiresource credit:* Unknown

BushBroker
Victoria Department of Sustainability and Environment, Australia
2006

A trading scheme for registering and trading native vegetation offset credits. Native vegetation credits are listed on the BushBroker register and these can be bought by another party and subsequently used as an offset for the approved clearing of native vegetation.

- *Intended use:* Auction-based tool for managing offset mitigation
- *Ability to calculate multiresource credit:* No
- *Sensitivity:* Unknown
- *Capability of being integrated into multiresource credit:* Unknown

BushTender Program
Victoria Department of Sustainability and Environment, Australia

This survey protocol develops habitat scores based on field site studies that can be conducted on large tracts of land. The resulting score has been used in trials for auction-based conservation financing.

- *Intended use:* Auction-based tools for restoration of native range and forest land
- *Ability to calculate multiresource credit:* Possible; currently creates a landscape level score for trading based on biodiversity
- *Sensitivity:* Coarse spatial scale, focused on a single ecosystem
- *Capability of being integrated into multiresource credit:* Unknown

Business and Biodiversity Offset Program (BBOP)
Forest Trends

An international partnership among companies, governments, and conservation experts to explore biodiversity offsets and develop the principles and methodologies required to support best practice in voluntary biodiversity offsets. BBOP has published a set of 10 principles on biodiversity supported unanimously by the 40 member organizations of the BBOP Advisory Committee, together with supporting material in the form of interim guidance on the design and implementation of offsets.

- *Intended use:* To develop best practice on biodiversity offsets for the BBOP partners
- *Ability to calculate multiresource credit:* No
- *Sensitivity:* Unknown
- *Capability of being integrated into multiresource credit:* Unknown

California Carbon Project Protocols
California Climate Action Reserve

There are a number of protocols developed for different credit actions. Most relevant is the December 2008 forest protocol applicable nationally. This quantifies only carbon sequestration.

- *Intended use:* Carbon credit calculator
- *Ability to calculate multiresource credit:* Unknown
- *Sensitivity:* Unknown
- *Capability of being integrated into multiresource credit:* Unknown

California Rapid Assessment Method (CRAM)
Southern California Coastal Water Research Project

A wetland functional assessment that looks at conditions and stressors. Allows for differing levels of detail based on use. The first step is classifying the wetland, then assigning scores for buffer and landscape context, hydrology, physical structure, and biotic structure.

- *Intended use:* Wetland assessment
- *Ability to calculate multiresource credit:* No
- *Sensitivity:* Unknown
- *Capability of being integrated into multiresource credit:* Yes

Casco Bay Watershed Wetlands Characterization Method
E. Hertz and J. Sartoris
2001

The purpose is to provide a watershed-based wetlands characterization method using GIS. Listed uses include to inform and support wetlands conservation and protection programs at the state, local, and national levels; as an aid in municipal and regional planning, including open space, habitat, and water quality planning; and to provide information on wetlands and affiliated upland systems for use in compensatory mitigation situations. Nominal scale output units.

- *Intended use:* Maine freshwater and marine wetlands
- *Ability to calculate multiresource credit:* No
- *Sensitivity:* Unknown
- *Capability of being integrated into multiresource credit:* Unknown

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City Green
American Forests

An ArcGIS package of models that calculates ecosystem services and economic value for stormwater, carbon storage and sequestration, air pollution removal, and water quality; also does analysis on user-defined landcover layer.

- *Intended use:* Analysis tool for decision makers
- *Ability to calculate multiresource credit:* Unknown
- *Sensitivity:* Unknown
- *Capability of being integrated into multiresource credit:* Unknown

Combined Habitat Assessment Procedure (CHAP) and Habitat Evaluation Procedures
Bonneville Power Administration and NW Habitat Institute

Used to quantify the impact of hydroelectric projects and benefits of mitigation in the Pacific Northwest. CHAP is an evolution that allows for crediting out-of-kind habitats. Based on species-habitat associations.

- *Intended use:* Integrated ecosystem services accounting
- *Ability to calculate multiresource credit:* Yes
- *Sensitivity:* The system is sensitive to direct impacts from projects but can only measure change based on presence/absence of habitat elements. Function-based accounting, but the functions are limited to those provided by species. Has more potential benefit as an assessment.
- *Capability of being integrated into multiresource credit:* Yes

Method for the Evaluation of Inland Wetlands in Connecticut
A. P. Ammann, R. W. Frazen, and J. L. Johnson
Connecticut Department of Environmental Protection
1986

To provide a method of wetland evaluation for use by public officials and others who have some familiarity with wetlands; to be used for wetland policy formation and analysis. This method is now known as the Connecticut Method. Ordinal scale output.

- *Intended use:* Connecticut inland wetlands and watercourses
- *Ability to calculate multiresource credit:* No
- *Sensitivity:* Unknown
- *Capability of being integrated into multiresource credit:* Unknown

Delaware Rapid Assessment
A. D. Jacobs
2005

To assess the current condition of the wetland site and identify stressors that are present that are lowering the condition of the site. Ordinal scale output.

- *Intended use:* Nontidal wetlands of the outer coastal plain regions of Maryland and Delaware
- *Ability to calculate multiresource credit:* No
- *Sensitivity:* Unknown
- *Capability of being integrated into multiresource credit:* Unknown

Descriptive Approach (Highway Methodology)
USACE New England Regulatory Program
1999

To identify and display wetland functions and values acceptable for the U.S. Army Corps of Engineers New England District Regulatory Program. This method can be used for any project for which the characterization of wetland resources is necessary for Section 404 permit requirements.

- *Intended use:* New England wetlands
- *Ability to calculate multiresource credit:* No
- *Sensitivity:* Unknown
- *Capability of being integrated into multiresource credit:* Unknown

Developing Rapid Methods for Analyzing Upland Riparian Functions and Values
T. Hruby
Environmental Management Vol. 43 No. 6
2009

A rapid assessment method for nonwetland riparian habitat in Washington state. Indicators are used to identify the potential of a site to provide a function, the potential of the landscape to support the function, and the value the function provides to society.

- *Intended use:* To implement upland riparian laws in Washington
- *Ability to calculate multiresource credit:* No
- *Sensitivity:* Unknown
- *Capability of being integrated into multiresource credit:* Yes

Development of a Floristic Quality Assessment Methodology for Wisconsin
Wisconsin Department of Natural Resources
2003

Developed to provide an intensive measure of wetland biological integrity based on the condition of the plant community.

- *Intended use:* For use with the Wisconsin wetland monitoring program
- *Ability to calculate multiresource credit:* No
- *Sensitivity:* Unknown
- *Capability of being integrated into multiresource credit:* Yes

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Eastern Kentucky Stream Assessment Protocol (eKY)
USACE
2002

The eKY Protocol was developed to address the need for a headwater stream assessment procedure to assess potential impacts of projects proposed in the Eastern Kentucky Coalfield Region by applicants seeking authorization from the U.S. Army Corps of Engineers pursuant to Section 404 of the Clean Water Act. In addition, the assessment protocol had to suggest requisite levels of compensatory mitigation efforts to offset the adverse impacts and identify applicable monitoring variables and success criteria to evaluate the success of mitigation efforts. Descriptive, ordinal scale, nominal scale, and quantitative output.

- *Intended use:* Eastern Kentucky coalfield physiographic region; first- to third-order streams
- *Ability to calculate multiresource credit:* Yes
- *Sensitivity:* At the stream reach (minimum 100 m in length), plus a macroinvertebrate bioassessment index for headwater streams of the Eastern Coalfield Region
- *Capability of being integrated into multiresource credit:* Unknown

Ecological Site Inventory
Bureau of Land Management

A descriptive tool used by Natural Resources Conservation Service to describe the baseline ecological conditions as part of natural resources planning. There are not quantitative elements, so an extensive review was not conducted.

- *Intended use:* Qualitative tool
- *Ability to calculate multiresource credit:* No
- *Sensitivity:* Unknown
- *Capability of being integrated into multiresource credit:* Unknown

EcoMetrix
Parametrix

An integrated function-based ecosystem services accounting methodology that integrates resources and methodologies allowing for decision-making analysis, crediting and trading, and environmental performance measurement monitoring.

- *Intended use:* Integrated ecosystem services accounting
- *Ability to calculate multiresource credit:* Yes
- *Sensitivity:* The methodology is very sensitive to direct impacts from projects—both restoration and development related, but can be used at the landscape scale. Function-based accounting based on ecosystem services identified by the Millennium Assessment. Can be tailored to meet geography, habitat, and policy requirements.
- *Capability of being integrated into multiresource credit:* Yes

Ecosystem Diagnosis and Treatment Model
Mobrand Biometrics, Inc. and ICF Jones and Stokes

Ecosystem Diagnosis and Treatment (EDT) is a system for rating the quality, quantity, and diversity of habitat along a stream relative to the needs of a focal species, such as Coho or Chinook salmon.

- *Intended use:* The methodology includes a conceptual framework for decision making and a set of modeling tools that organize environmental information and rate the habitat elements with regard to the focal species. In effect, it describes how the fish would rate conditions in a stream based on scientific understanding of their needs.
- *Ability to calculate multiresource credit:* No
- *Sensitivity:* Unknown
- *Capability of being integrated into multiresource credit:* Yes

Ecosystem Valuation Methods
Virginia Department of Forestry

A package of models on a website that allows landowners to calculate potential ecosystem credits from their lands. Best available models are approved by agencies for use but are still early in development.

- *Intended use:* Water quality
- *Ability to calculate multiresource credit:* Not likely because of the "still in development" nature of the models
- *Sensitivity:* Unknown
- *Capability of being integrated into multiresource credit:* Unknown

Environmental Monitoring and Assessment Protocols (EMAP)
Environmental Protection Agency

A series of assessment methods and guidance for monitoring ecological conditions and risks.

- *Intended use:* Broad set of assessment tools for various resources
- *Ability to calculate multiresource credit:* Unknown
- *Sensitivity:* Unknown
- *Capability of being integrated into multiresource credit:* Unknown

Envision
Oregon State University

Envision is a GIS-based tool (beta version) for developing alternative-futures analysis used to model the landscape

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impacts of various policy scenarios on land use change and accompanying biophysical impacts. Strongest applications are mapping the cumulative effects of multiple actions at multiple sites as the tool tracks impacts over time. Has the ability to plug in evaluative models (e.g., credit calculators).

- *Intended use:* Created to conduct research about the nature and properties of coupled human and natural environmental systems in the context of climate change
- *Ability to calculate multiresource credit:* Unknown but has connections to other credit calculators
- *Sensitivity:* Unknown
- *Capability of being integrated into multiresource credit:* Unknown

EPA Oregon Stream Methodology
EPA

Identifies perennial and ephemeral streams in Oregon. Uses field indicators that identify evidence of flow.

- *Intended use:* Water quality assessment
- *Ability to calculate multiresource credit:* No
- *Sensitivity:* Unknown
- *Capability of being integrated into multiresource credit:* No

EPA Region 10 In-stream Biological Monitoring Handbook
EPA and G. A. Hayslip
1993

To supplement the rapid bioassessment protocols (RBPs) (see Plafkin et al. 1989 Rapid bioassessment protocols for use in streams and rivers: benthic macroinvertebrates and fish and Barbour et al. 1999) by illustrating how Region 10 States have adapted the RBPs for the northwestern United States; to define the minimum components necessary to conduct stream bioassessment; and to encourage consistency of sampling methods to facilitate data sharing. Ordinal scale, nominal scale, and quantitative output.

- *Intended use:* Wadeable streams and rivers in Region 10 (WA, OR, and ID)
- *Ability to calculate multiresource credit:* Unknown
- *Sensitivity:* Unknown
- *Capability of being integrated into multiresource credit:* Unknown

Evaluation for Planned Wetlands (EPW)
C. C. Bartoldus, E. W. Garbish, and M. L. Kraus
1994

To determine whether a planned wetland has been adequately designed to achieve defined wetland function goals. This method has also been used to assess conditions of existing wetlands. Ordinal scale output.

- *Intended use:* U.S. wetlands
- *Ability to calculate multiresource credit:* No
- *Sensitivity:* Unknown
- *Capability of being integrated into multiresource credit:* Unknown

Fairfax County Stream Physical Assessment Protocols
Fairfax County Stormwater Management Branch
2001

Fairfax County developed a stream protection strategy as part of ongoing progress toward a watershed management program. The strategy includes methods that build on and incorporate extant bioassessment programs and allow the Stormwater Management Branch to better anticipate, prevent, prioritize, and correct adverse impacts to the county's stream resources. The strategy incorporates biological sampling (e.g., benthic macroinvertebrates and fish) and rapid physical habitat and geomorphology assessments. Descriptive, ordinal scale, nominal scale, and quantitative output.

- *Intended use:* Fairfax County small streams
- *Ability to calculate multiresource credit:* No
- *Sensitivity:* Unknown
- *Capability of being integrated into multiresource credit:* Unknown

Field Manual for Ohio's Headwater Habitat Streams
R. Davic
2002

The Field Evaluation Manual for Ohio's Primary Headwater Habitat Streams is intended to promote standardized assessment of actual and expected biological conditions in primary headwater habitat (PHWH) streams in Ohio. The principal regulatory or administrative impetus for development of the protocols was pursuant to water quality standards (designated uses, water quality criteria, antidegradation) for the national pollution discharge elimination system (NPDES) program. The methods outlined in the Manual are designed to statistically differentiate among three quality classes (designated uses) of PHWH streams in Ohio: Class III PHWH stream (cool-cold water adapted native fauna); Class II PHWH stream (warm water adapted native fauna); Class I PHWH stream (ephemeral stream, normally dry channel). Descriptive, ordinal scale, nominal scale, and quantitative output.

- *Intended use:* Ohio; however, this method can be applied to other areas that have cold-cool spring-fed adapted biological communities of headwater salamander and benthic macroinvertebrate communities.
- *Ability to calculate multiresource credit:* No
- *Sensitivity:* Unknown

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- *Capability of being integrated into multiresource credit:* Unknown

Fire Regime Condition Class
FRCC
2005

To provide tools for fire, vegetation, and fuels assessment and management at both the landscape and stand levels. Methods are used to describe general landscape fire regime and vegetation-fuel characteristics. Descriptive, ordinal scale, and nominal scale output.

- *Intended use:* Forests nationwide
- *Ability to calculate multiresource credit:* No
- *Sensitivity:* Unknown
- *Capability of being integrated into multiresource credit:* Unknown

Florida Wetland Quality Index
T. E. Lodge, H. O. Hillestad, S. W. Carney, and R. B. Darling
1995

A method for determining compensatory mitigation requirements for affected wetlands within the Everglades.

- *Intended use:* To evaluate mitigation site compliance with regulatory requirements
- *Ability to calculate multiresource credit:* No
- *Sensitivity:* Unknown
- *Capability of being integrated into multiresource credit:* Yes

Florida Wetland Rapid Assessment Procedure
South Florida Water Management District
1999

A rapid-assessment procedure designed to assess mitigation projects with a habitat emphasis. It yields a single score that may be interpreted as condition.

- *Intended use:* Assessing mitigation projects
- *Ability to calculate multiresource credit:* No
- *Sensitivity:* Unknown
- *Capability of being integrated into multiresource credit:* Yes

Floristic Quality Assessment Index (FQAI)
F. Swink and G. Wilhelm
1979

To provide an objective standard (Floristic Quality Assessment Index) for describing the quality of plant communities. Used to make relative comparisons in environmental and natural resources management. Ordinal scale output.

- *Intended use:* Any vegetation community. Initially for Chicago, Illinois, but subsequently has been modified for use in a few additional states.
- *Ability to calculate multiresource credit:* No
- *Sensitivity:* Unknown
- *Capability of being integrated into multiresource credit:* Unknown

Freshwater Wetland Mitigation Quality Assessment Procedure
New Jersey Department of Environmental Quality
2001

A wetland functional assessment that evaluates the relative probability that a constructed freshwater wetland will develop to approximate the functioning of natural wetlands over time.

- *Intended use:* An informatory tool only
- *Ability to calculate multiresource credit:* No
- *Sensitivity:* Unknown
- *Capability of being integrated into multiresource credit:* Yes

Gravel Bed Instream Flows
L. Schmidt and J. Potyondy
2004

To provide a methodology for estimating essential water flow regimes needed for the self-maintenance of gravel-bed stream channels. Quantitative output.

- *Intended use:* Intermountain west. Perennial, unregulated, snowmelt-dominated, gravel-bed streams with alluvial reaches. This method is unlikely to work in arid environments with ephemeral channels where hydrographs are flashy.
- *Ability to calculate multiresource credit:* No
- *Sensitivity:* Unknown
- *Capability of being integrated into multiresource credit:* Unknown

Guidance for Rating the Values of Wetlands in North Carolina
North Carolina Department of Environmental and Natural Resources
1995

A wetland functional assessment that assesses six wetland functions only for their effect on wetland values (societal benefit).

- *Intended use:* Tool for making 401 Water Quality decisions on impacts and mitigation
- *Ability to calculate multiresource credit:* No
- *Sensitivity:* Unknown
- *Capability of being integrated into multiresource credit:* Yes

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Guidebook for Hydrogeomorphic (HGM)-Based Assessment of Oregon Wetland and Riparian Sites
P. R. Adamus and D. Field
2001

An HGM reference-based assessment restricted to Willamette Valley ecoregion riverine impounding and slopes/flats wetlands. Addresses both functions and values for these subclasses.

- *Intended use:* Wetland assessment
- *Ability to calculate multiresource credit:* No
- *Sensitivity:* Unknown
- *Capability of being integrated into multiresource credit:* Yes

Guidelines for Evaluating Fish Habitat in Wisconsin
T. D. Simonson, J. Lyons, P. D. Kanehl
1993

To establish a standardized general protocol "that can be used when conducting any stream habitat survey, evaluation, monitoring program, appraisal, or special project. When precise, defensible methods are needed to substantiate management objectives, priorities, or effectiveness [of management treatments]" (Simonson et al. 1993). Descriptive, ordinal scale, nominal scale, and quantitative output.

- *Intended use:* Wisconsin and adjacent states. Permanent, wadeable streams.
- *Ability to calculate multiresource credit:* No
- *Sensitivity:* Unknown
- *Capability of being integrated into multiresource credit:* Unknown

The Habitat Assessment Model: A Tool to Improve Wildlife Habitat Management
G. Wockner, R. Boone, N. T. Hobbs, and D. Freddy
2005

To aid managers in discerning the relationships between wildlife populations (for elk and mule deer) and habitat sustainability. The model produces a range of population values with related management implications (e.g., grazing, burning) that can be used in the planning process. Developed to resolve fence and forage conflicts on private and public lands. Quantitative output.

- *Intended use:* Colorado terrestrial habitat
- *Ability to calculate multiresource credit:* No
- *Sensitivity:* Unknown
- *Capability of being integrated into multiresource credit:* Unknown

Habitat Equivalency Analysis (HEA)
NOAA

Developed to calculate the credits needed to identify impacts for Natural Resource Damage Assessments under a series of statutory authorities, including CERCLA (Superfund). Assigns a habitat functional score to each habitat unit in a site and multiplies that by the area. Time to being fully functional is also accounted for using a standard discount rate. The assessments allow for out-of-kind and off-site assessments, but are used only in response to and not in anticipation of natural resource damages.

- *Intended use:* Integrated ecosystem services accounting
- *Ability to calculate multiresource credit:* Allows for measurement for mitigation but not necessarily credits per se
- *Sensitivity:* Unknown
- *Capability of being integrated into multiresource credit:* Unknown

Habitat Evaluation Procedure (HEP)
USFWS
1980

Assess the quality and quantity of available habitat for selected wildlife species by comparing the same area at different points in time or different areas at one point in time. Ordinal scale output.

- *Intended use:* All regions regularly inhabited by species for which habitat suitability index (HSI) models are available
- *Ability to calculate multiresource credit:* No
- *Sensitivity:* Unknown
- *Capability of being integrated into multiresource credit:* Unknown

Hawaii Stream Bioassessment
M. Kido
2002

To provide the tools and informational framework required to conduct meaningful water quality assessments aimed at restoring or maintaining the "biological integrity" of Hawaii's streams. Descriptive, ordinal scale, nominal scale, and quantitative output.

- *Intended use:* Hawaii streams
- *Ability to calculate multiresource credit:* No
- *Sensitivity:* Unknown
- *Capability of being integrated into multiresource credit:* Unknown

Heat Source Model
Oregon Department of Environmental Quality

Currently the Shade-a-Lator tool within the Heat Source model is being used to calculate temperature credits in the Willamette. Requires data from GIS and field collection.

- *Intended use:* Water quality assessment
- *Ability to calculate multiresource credit:* Yes

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- *Sensitivity:* Focuses on a single component of water quality.
- *Capability of being integrated into multiresource credit:* Unknown

Hydrogeomorphic Method (HGM)
U.S. Army Corps of Engineers/EPA/FHWA

National methodology for wetland impacts and mitigation.

- *Intended use:* Wetland assessment
- *Ability to calculate multiresource credit:* No
- *Sensitivity:* Unknown
- *Capability of being integrated into multiresource credit:* Yes

Idaho Small Stream Ecological Assessment Framework
C. S. Grafe
2002

To assess aquatic life use support for small streams using biological indicators, habitat data, and numeric water quality criteria. The document provides detailed technical information concerning the development and integration of the Stream Macroinvertebrate Index (SMI), Stream Fish Index (SFI), and Stream Habitat Index (SHI) used in the aquatic life use support determination. Ordinal scale, nominal scale, and quantitative output.

- *Intended use:* Medium and large rivers in mountainous settings in Idaho
- *Ability to calculate multiresource credit:* No
- *Sensitivity:* Unknown
- *Capability of being integrated into multiresource credit:* Unknown

Index of Biological Integrity (IBI): Birds, Fish, Invertebrates, and Plants
J. Karr
1981

To assess biological integrity of a habitat using one of the four (birds, fish, invertebrates, and plants) as indicators of relative condition of a selected habitat. Ordinal scale and quantitative.

- *Intended use:* Nationwide in most habitat types
- *Ability to calculate multiresource credit:* Yes
- *Sensitivity:* Sensitive for the four specific biotic groups (birds, fish, invertebrates, and plants) in relation to habitat
- *Capability of being integrated into multiresource credit:* Unknown

Influence of Land Use on the Integrity of Marsh Bird Communities of Chesapeake Bay, USA
W. V. Deluca, C. E. Studds, L. L. Rockwood, and P. P. Marra
Wetlands, Vol. 24 No. 4
2004

To evaluate the biological integrity of marsh bird communities and assess estuarine wetland condition. This method is known as the Index of Marsh Bird Community Integrity. Ordinal scale output.

- *Intended use:* Chesapeake Bay (Maryland, Virginia, and Delaware) tidal wetlands
- *Ability to calculate multiresource credit:* No
- *Sensitivity:* Unknown
- *Capability of being integrated into multiresource credit:* Unknown

Instream Flow Incremental Methodology (IFIM)
K. Bovee
2004

IFIM is a tool to assess in-stream flow problems, ranging from simple diversions to complex storage and release schemes. It provides resources managers with a decision support system for determining the benefits or consequences of different water management alternatives. Descriptive, ordinal scale, nominal scale, and quantitative output.

- *Intended use:* National
- *Ability to calculate multiresource credit:* No
- *Sensitivity:* Unknown
- *Capability of being integrated into multiresource credit:* Unknown

Interim Guidelines to Avoid and Minimize Wildlife Impacts from Wind Turbines—Potential Impact Index (PII)
USFWS
2003

PII is a protocol that allows the user to evaluate potential development sites using checklists and rank them against a reference site. Objectives are to: (1) assist developers in deciding whether to proceed with development; (2) provide a procedure to determine preconstruction study needs to verify use of potential sites by wildlife; and (3) provide recommendations for monitoring potential sites after construction to identify, quantify, or verify actual impacts (or lack thereof).

- *Intended use:* To assist the wind energy industry in avoiding or minimizing impacts to wildlife and their habitats
- *Ability to calculate multiresource credit:* The Physical Attributes, Species Occurrence and Status, and Ecological Attractiveness groupings in this protocol should serve as a model framework; the terrain features, species, and conditions used in these groupings will be dictated by local conditions and should be developed by wildlife biologists familiar with the region in which this protocol is being used.

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- *Sensitivity:* Acknowledges that each proposed development site is unique because of local differences in wildlife concentration and movement patterns, and requires detailed, individual evaluation.
- *Capability of being integrated into multiresource credit:* Unknown

InVEST
Natural Capital Project

A package of models in an ArcGIS extension that calculates ecosystem services based on land use/landcover and packaged assumptions about service provision by landcover type.

- *Intended use:* Integrated ecosystem services accounting
- *Ability to calculate multiresource credit:* Yes
- *Sensitivity:* Scoring is based on landscape scale data inputs. Not sensitive to direct impacts caused by implementing projects.
- *Capability of being integrated into multiresource credit:* Yes

King County Functional Equivalency Evaluation System (KC-FEES)
King County Department of Natural Resources and Parks and Department of Development and Environmental Resources
2008

A methodology to provide a standardized procedure for assessing the functions provided by wetlands and aquatic areas, the amount those functions are reduced by impacts, and the amount of mitigation required to offset the loss.

- *Intended use:* Establishes a system for determining the amount of mitigation needed to offset adverse impacts to wetlands and aquatic areas. The system also is designed to award and deduct credits through the King County Mitigation Reserves Program.
- *Ability to calculate multiresource credit:* Yes
- *Sensitivity:* A standardized procedure at the site level for assessing wetland and aquatic function
- *Capability of being integrated into multiresource credit:* Yes

LandServer
Pinchot Institute for Conservation

LandServer is a tool for landowners, managers, and governments to identify ecosystem service production opportunities on their lands. The tool is under development with a current pilot test running in the Chesapeake region. It is a secondary data GIS-based tool that works to identify payment for ecosystem services options for landowners.

- *Intended use:* Mid-Atlantic and then national
- *Ability to calculate multiresource credit:* Yes
- *Sensitivity:* Unknown
- *Capability of being integrated into multiresource credit:* Via monetary equivalents

Maryland Green Infrastructure Assessment: A Comprehensive Strategy for Land Conservation and Restoration
T. Weber
2003

To help identify and prioritize those areas of greatest statewide ecological importance and those at greatest risk of loss to development. Nominal scale output.

- *Intended use:* Maryland
- *Ability to calculate multiresource credit:* No
- *Sensitivity:* Unknown
- *Capability of being integrated into multiresource credit:* Unknown

MDT Montana Wetland Assessment Method
J. Berglund
1999

To evaluate wetland function and values. Designed to address highway and other linear projects but can be applied to other types of projects, including mitigation. Nominal and ordinal scale output.

- *Intended use:* Montana wetlands
- *Ability to calculate multiresource credit:* No
- *Sensitivity:* Unknown
- *Capability of being integrated into multiresource credit:* Unknown

Methods for Assessing Wetland Functions. Volume I: Riverine and Depressional Wetlands in the Lowlands of Western Washington
Washington State Department of Ecology
1999

An HGM reference-based assessment restricted to depressional and riverine class wetlands located in Washington's western lowlands.

- *Intended use:* Wetland assessment
- *Ability to calculate multiresource credit:* No
- *Sensitivity:* Unknown
- *Capability of being integrated into multiresource credit:* Yes

Methods for Assessing Wetland Functions. Volume II: Depressional Wetlands in the Columbia Basin of Eastern Washington
Washington State Department of Ecology
2000

An HGM reference-based assessment restricted to depressional class wetlands located in Washington's Columbia Basin.

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- *Intended use:* Wetland assessment
- *Ability to calculate multiresource credit:* No
- *Sensitivity:* Unknown
- *Capability of being integrated into multiresource credit:* Yes

Revised Methods for Characterizing Stream Habitat in the National Water-Quality Assessment Program (NAWQA)
U.S. Geological Survey Water-Resources Investigations Report 98-4052
F. A. Fitzpatrick, I. R. Waite, P. J. D'Arconte, M. R. Meador, M. A. Maupin, and M. E. Gurtz
1998

To assess status and trends in water quality nationwide and develop an understanding of the major factors influencing observed conditions and trends. Descriptive and quantitative output.

- *Intended use:* Nationwide streams
- *Ability to calculate multiresource credit:* No
- *Sensitivity:* Unknown
- *Capability of being integrated into multiresource credit:* Unknown

Methods for Evaluating Stream, Riparian, and Biotic Conditions
W. S. Platts, M. F. Walter, and M. G. Wayne
1983

Platts et al. (1983) presents standard techniques for measuring aquatic, riparian, and biotic attributes and stresses the precision and accuracy of each measurement. In this way, the authors aim to provide the field practitioner with tools and information to build on and evaluate for assessing particular aquatic habitat and biological features. Later publications expand upon Platts et al. (1983) with a "comprehensive set of the latest methods for . . . use in managing, evaluating, and monitoring riparian conditions." Descriptive, ordinal scale, nominal scale, and quantitative output.

- *Intended use:* Nationwide
- *Ability to calculate multiresource credit:* No
- *Sensitivity:* Unknown
- *Capability of being integrated into multiresource credit:* Unknown

Methods for Stream Habitat Surveys, Aquatic Inventories Project
Oregon Department of Natural Resources

Developed to monitor habitat conditions for Oregon streams.

- *Intended use:* Streams and rivers
- *Ability to calculate multiresource credit:* No
- *Sensitivity:* Unknown
- *Capability of being integrated into multiresource credit:* Yes

Overview of the Michigan Rivers Inventory (MRI) Project
P. W. Seelbach and M. J. Wiley
1997

Identify and describe naturally occurring, ecologically distinct, spatial units in river (Michigan Valley Segment Ecological Classification-Inventory). Uses include inventory, research (sampling designs based on stratification of river valley segment types), and basis for resource management. Descriptive output.

- *Intended use:* Lower Michigan. Currently being revised for application for entire states of Michigan, Illinois, and Wisconsin.
- *Ability to calculate multiresource credit:* No
- *Sensitivity:* Unknown
- *Capability of being integrated into multiresource credit:* Unknown

Minnesota Habitat and Water Chemistry Protocol
Minnesota Pollution Control Agency (MPCA)
2002

To support assessment of water quality and development of biological criteria for Minnesota streams. These procedures are also applicable for U.S. EPA Environmental Monitoring and Assessment Program (EMAP) stations and sites suspected of being affected by a source of pollution. Descriptive and ordinal scale output.

- *Intended use:* Minnesota wetlands
- *Ability to calculate multiresource credit:* No
- *Sensitivity:* Unknown
- *Capability of being integrated into multiresource credit:* Unknown

Minnesota Routine Assessment Method (MnRAM)
Minnesota Board of Water and Soil Resources

Wetland functional assessment. Starts with assessment of vegetation then asks 72 questions to develop functional indices.

- *Intended use:* Wetland assessment
- *Ability to calculate multiresource credit:* Unknown
- *Sensitivity:* Unknown
- *Capability of being integrated into multiresource credit:* Unknown

Minnesota Routine Assessment Method (MnRAM) (Updated Version)
Minnesota Board of Water and Soil Resources
2007

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The original 1992 version of MnRAM was developed to provide a practical assessment tool that would help local authorities make sound wetland management decisions as they assumed responsibility for regulating wetland impacts. The current version represents a more refined procedure that provides numeric, rather than the original descriptive, ratings. It may be applied to existing wetlands or potential restoration sites. Descriptive and ordinal scale output.

- *Intended use:* Northern Great Plains Prairie Pothole Region wetlands within watershed context, including open water bodies and streams
- *Ability to calculate multiresource credit:* Unknown
- *Sensitivity:* Unknown
- *Capability of being integrated into multiresource credit:* Unknown

Montana Stream Mitigation Process
U.S. Army Corps of Engineers–Omaha

Uses indicators of riparian functions to assign a broader range of trading ratios.

- *Intended use:* Water quality assessment
- *Ability to calculate multiresource credit:* Unknown
- *Sensitivity:* Unknown
- *Capability of being integrated into multiresource credit:* Unknown

Montana Wetland Rapid Assessment Method
Montana Department of Environmental Quality
2005

A wetland rapid assessment that looks at ecological integrity (condition) of a wetland.

- *Intended use:* Field-based screening level assessment tool used to help identify and prioritize wetlands within a watershed or region for protection and restoration
- *Ability to calculate multiresource credit:* No
- *Sensitivity:* Unknown
- *Capability of being integrated into multiresource credit:* Yes

Multi-Scale Assessment of Watershed Integrity (MAWI)
R. D. Smith
2003

To provide a baseline (current condition) assessment of riparian ecosystem integrity at the watershed scale. Once completed, the assessment can be used to evaluate potential impacts of future development on riparian areas within a watershed or to help prioritize areas for riparian restoration. Ordinal scale output.

- *Intended use:* Watersheds of California (i.e., watersheds that drain to the Pacific Ocean) and riparian ecosystems and streams, including adjacent upland areas
- *Ability to calculate multiresource credit:* No
- *Sensitivity:* Unknown
- *Capability of being integrated into multiresource credit:* Unknown

Method for the Comparative Evaluation of Nontidal Wetlands in New Hampshire
A. P. Ammann and A. L. Stone
1991

To provide a method of wetland evaluation for use by public officials and others who have some familiarity with wetlands but who are not necessarily wetland specialists. Known as the New Hampshire Method, this is used for planning, education, and wetland inventory. Ordinal scale output.

- *Intended use:* New Hampshire nontidal wetlands
- *Ability to calculate multiresource credit:* No
- *Sensitivity:* Unknown
- *Capability of being integrated into multiresource credit:* Unknown

A Watershed-based Wetland Assessment Method for the New Jersey Pinelands
R. A. Zampella, R. G. Lathrop, J. A. Bognar, L. J. Craig, and K. J. Laidig
1994

GIS-based method (the New Jersey Watershed Method) for assessing watershed and wetland integrity and the potential impact to this integrity. Created to enable a comparative assessment of all watersheds and wetlands in the New Jersey Pinelands. Ordinal scale output.

- *Intended use:* New Jersey Pinelands; could apply to other riverine wetland types
- *Ability to calculate multiresource credit:* Unknown
- *Sensitivity:* Unknown
- *Capability of being integrated into multiresource credit:* Unknown

North Carolina Coastal Region Evaluation of Wetland Significance: A Report of the Strategic Plan for Improving Coastal Management in North Carolina
L. A. Sutter, J. B. Stanfill, D. M. Haupt, C. J. Bruce, and J. E. Wuenscher
1999

Designed to predict the relative ecological significance and assess the level of water quality, wildlife habitat, and hydrologic functions of individual wetlands using a watershed-based model in GIS software. Nominal scale output.

- *Intended use:* North Carolina coastal region wetlands
- *Ability to calculate multiresource credit:* Unknown
- *Sensitivity:* Unknown

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- *Capability of being integrated into multiresource credit:* Unknown

A Numerical Method and Supporting Database for Evaluation of Maine Peatlands as Candidate Natural Areas
R. B. Davis and D. S. Anderson
1999

A quantitative method of evaluation of the natural features of peatlands, providing the fundamental tool for establishing peatland protection priorities. Nominal and ordinal scale output.

- *Intended use:* Maine peatlands
- *Ability to calculate multiresource credit:* Unknown
- *Sensitivity:* Unknown
- *Capability of being integrated into multiresource credit:* Unknown

Nutrient Trading Tool (NTT)
Powered by the APEX Model
USDA Natural Resource Conservation Service (NRCS)

Developed by NRCS to calculate nitrogen credits. Has expanded to include phosphorous, and can also calculate sediments. It is powered by the APEX model, which is a runoff based model. No field-level data are required. A farmer can input crop types, fertilizer use, irrigation patterns, and best management practices (BMPs). Future add-ons will include water quantity and carbon calculations.

- *Intended use:* Water quality assessment
- *Ability to calculate multiresource credit:* Yes
- *Sensitivity:* Site-level *Sensitivity* that incorporates condition and management practice.
- *Capability of being integrated into multiresource credit:* Yes

NutrientNet
Powered by EPIC
World Resources Institute

NutrientNet is a web-based platform customized for each watershed to support nutrient trading. It has a credit calculator, registry, and exchange function. Very similar to Nutrient Trading Tool but perhaps not as powerful.

- *Intended use:* Water quality assessment
- *Ability to calculate multiresource credit:* Yes
- *Sensitivity:* Unknown
- *Capability of being integrated into multiresource credit:* Unknown

Ohio Rapid Assessment Method for Wetlands, Version 5.0
Ohio EPA, Division of Surface Water
2001

The Ohio Rapid Assessment Method is designed to aid in the determination of wetland categories as defined in Ohio's Wetland Antidegradation Rule. The use of the Ohio Rapid Assessment Method should not be considered as a substitute, and is not intended to be a substitute, for detailed studies of the functions and biology of a wetland.

- *Intended use:* The method is designed to identify the appropriate level of regulatory protection a particular wetland should receive. It is not designed or intended to be used to determine a particular wetland's ecologic or human value.
- *Ability to calculate multiresource credit:* No
- *Sensitivity:* Unknown
- *Capability of being integrated into multiresource credit:* Yes

Oregon Rapid Wetlands Assessment Protocol (ORWAP)
Adamus

Being developed as a rapid functional assessment combining visual assessments and collection of spatial data. Considers both wetland functions and conditions.

- *Intended use:* Wetland assessment for regulatory compliance
- *Ability to calculate multiresource credit:* No
- *Sensitivity:* Unknown
- *Capability of being integrated into multiresource credit:* Yes. Currently being integrated into the EcoMetrix method library.

Agate Desert Vernal Pool Final Draft Functional Assessment Methodology
P. Adamus
2007

The Oregon Vernal Pool Method is meant to provide a technique that (1) assesses four major functions and seven values of vernal pool wetlands; (2) is standardized and rapid (in the sense that the procedure can be completed in 1 day or less); (3) is well-documented with scientific literature, mainly from Oregon; and (4) can be used to prioritize vernal pool complexes and compare them before and after restoration or impact. Ordinal scale output.

- *Intended use:* Oregon individual vernal pools and vernal pool complexes in nonforested lowlands
- *Ability to calculate multiresource credit:* No
- *Sensitivity:* Unknown
- *Capability of being integrated into multiresource credit: Unknown*

Pfankuch Channel Stability
D. J. Pfankuch
1975

To provide information about the resistance of a channel to erosive forces acting upon its bed and banks and to suggest

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the capacity of streams to recover from changes in flow or increases in sediment. Nominal and ordinal scale output.

- *Intended use:* U.S. Forest Service Northern Region
- *Ability to calculate multiresource credit:* No
- *Sensitivity:* Unknown
- *Capability of being integrated into multiresource credit:* Unknown

Physical Habitat Simulation System (PHABSIM)
U.S. Geological Survey

The purpose of PHABSIM is to simulate a relationship between streamflow and physical habitat for various life stages of a species of fish or a recreational activity. The basic objective of physical habitat simulation is to obtain a representation of the physical stream so that the stream may be linked, through biological considerations, to the social, political, and economic world.

- *Intended use:* Discharge and habitat assessment
- *Ability to calculate multiresource credit:* No
- *Sensitivity:* Unknown
- *Capability of being integrated into multiresource credit:* Yes

Proper Functioning Condition
Bureau of Land Management

Uses the Ecological Site Inventory results to calculate conditions for riparian areas. There do not appear to be quantitative, objective, or clear measures attached to this. It is more of a framework. No detailed review was conducted.

- *Intended use:* Riparian assessment tool
- *Ability to calculate multiresource credit:* No
- *Sensitivity:* Unknown
- *Capability of being integrated into multiresource credit:* Unknown

Qualitative Habitat Evaluation Index (QHEI)
Midwest Biodiversity Institute for Ohio Environmental Protection Agency

To provide a rapid, reproducible measure of stream habitat generally corresponding to the physical stream factors that affect fish communities and other aquatic life. Results in an index (scale 0 to 100), representing an evaluation of a stream's macrohabitat characteristics that are important to fish communities relative to streams within a given watershed or region.

- *Intended use:* Habitat assessment
- *Ability to calculate multiresource credit:* No
- *Sensitivity:* Unknown
- *Capability of being integrated into multiresource credit:* Yes

Rapid Assessment Method for Oregon Tidal Fringe Wetlands (RAM)
P. Adamus
2006

To provide a technique that (1) assesses 13 recognized wetland functions and values of tidal marshes, (2) is standardized and rapid (in the sense that the procedure can be completed in 1 day or less), (3) is well-documented with scientific literature, and (4) can be used to compare tidal wetlands before and after restoration or impact. Ordinal scale output.

- *Intended use:* Oregon tidal wetlands
- *Ability to calculate multiresource credit:* No
- *Sensitivity:* Unknown
- *Capability of being integrated into multiresource credit:* Yes

Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates, and Fish, second edition
M. T. Barbour, J. Gerritsen, B. D. Snyder, and J. B. Stribling
U.S. Environmental Protection Agency
1999

Developed to provide "a practical technical reference for conducting cost-effective biological assessments of lotic systems."

- *Intended use:* Rapid assessments of streams and rivers.
- *Ability to calculate multiresource credit:* No
- *Sensitivity:* Unknown
- *Capability of being integrated into multiresource credit:* Yes

Rapid Stream Assessment Technique Field Methods (RSAT)
J. Galli
1996

To provide a simple, rapid reconnaissance-level assessment of stream quality conditions on a watershed scale. Descriptive and ordinal scale output.

- *Intended use:* Maryland Piedmont nonlimestone streams with a watershed of approximately 100–150 square miles
- *Ability to calculate multiresource credit:* No
- *Sensitivity:* Unknown
- *Capability of being integrated into multiresource credit:* Unknown

The Baldwin County Wetland Conservation Plan: Final Summary Document
C. Stallman, K. McIlwain, and D. Lemoine
2005

Assess wetlands in the project area to categorize them as suitable for conservation, enhancement, or restoration (known as Remote Functional Wetland Assessment Model [RFWAM]). Nominal and ordinal scale output.

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- *Intended use:* Alabama Gulf Shore depressional, riverine, and flat wetlands
- *Ability to calculate multiresource credit:* Unknown
- *Sensitivity:* Unknown
- *Capability of being integrated into multiresource credit:* Unknown

Remotely Sensed Indicators for Monitoring the General Condition of "Natural Habitat" in Watersheds: An Application for Delaware's Nanticoke River Watershed Ecological Indicators
R. W. Tiner
2004

To characterize and assess trends in the general ecological condition of watersheds using a set of remotely sensed indicators of "natural habitat integrity." Ordinal scale output.

- *Intended use:* Nationwide; all habitats within a watershed
- *Ability to calculate multiresource credit:* No
- *Sensitivity:* Unknown
- *Capability of being integrated into multiresource credit:* Unknown

Riparian Community Type Classification of Utah and Southeastern Idaho—Inventory
W. G. Padgett, A. P. Youngblood, and A. H. Winward
1989

Provides a riparian community type classification system for use in the inventory of lands administered by the USDA Forest Service in Utah and southern Idaho. Descriptive output.

- *Intended use:* Utah and southeast Idaho riparian communities
- *Ability to calculate multiresource credit:* No
- *Sensitivity:* Unknown
- *Capability of being integrated into multiresource credit:* Unknown

Rouge River Project Rapid Assessment Method
D. Tilton, B. Fahey, and D. Merkey
1997

Provides a regional evaluation of the condition of wetland (river and lake) resources to aid in the development of a watershed management plan. Nominal scale output.

- *Intended use:* Michigan Rouge River watershed
- *Ability to calculate multiresource credit:* No
- *Sensitivity:* Unknown
- *Capability of being integrated into multiresource credit:* Unknown

Savannah's Standard Operating Procedure: Mitigation
U.S. Army Corps of Engineers, Savannah

Uses indicators of wetland functions and stream functions to assign a broader range of trading ratios.

- *Intended use:* Wetlands and surface water assessment
- *Ability to calculate multiresource credit:* Unknown
- *Sensitivity:* Unknown
- *Capability of being integrated into multiresource credit:* Unknown

Soil Management Assessment Framework
S. S. Andrews, D. L. Karlen, C. A. Cambardella
2004

To enhance and extend current soil assessment efforts by presenting a framework for assessing the impact of soil management practices on soil function. Ordinal scale output.

- *Intended use:* Agricultural lands; intended as a national framework, to be modified as necessary for more local use
- *Ability to calculate multiresource credit:* No
- *Sensitivity:* Unknown
- *Capability of being integrated into multiresource credit:* Unknown

South Australian Biodiversity Assessment Tool (SABAT)
Government of South Australia, Department of Water, Land and Biodiversity Conservation

The Biodiversity Significance Index (BSI) factors three components into its assessment of biodiversity values: Conservation Significance (CS), Landscape Context (LC), and Habitat Condition (HC). The value of SABAT: a standardized/objective indexing framework, vegetation association benchmarks, compares apples with oranges in standardized "fruit units," provides for regional/state/larger BSI, makes complex evaluations simple, spatial database in-field operations, provides "condition" benchmark for ongoing monitoring, allows roll-up for regional Monitoring and Evaluation framework.

- *Intended use:* Southern Australia: multiple habitat types
- *Ability to calculate multiresource credit:* Yes
- *Sensitivity:* Unknown
- *Capability of being integrated into multiresource credit:* Unknown

Southern California Riparian Ecosystem Assessment (SCREAM)
E. Stein, M. Sutula, and A. Olson-Callahan
2004

To assess hydrology, sediment processes, habitat support, and biogeochemistry components of riparian habitat using

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a watershed-based model in GIS software. Ordinal scale output.

- *Intended use:* Southern California riparian areas
- *Ability to calculate multiresource credit:* Unknown
- *Sensitivity:* Unknown
- *Capability of being integrated into multiresource credit:* Unknown

Spatial Wetland Assessment for Management and Planning (SWAMP)
L. Sutter
2001

To assess the level of water quality, wildlife habitat, and hydrologic functions of individual wetlands using a watershed-based model in GIS software. Nominal scale output.

- *Intended use:* Ashepoo-Combahee-Edisto River Basin, South Carolina tidal and riverine wetlands
- *Ability to calculate multiresource credit:* No
- *Sensitivity:* Unknown
- *Capability of being integrated into multiresource credit:* Unknown

Stream and Riparian Habitats Rapid Assessment Protocol
R. R. Starr and T. McCandless
2001

Provides a comprehensive stream and riparian corridor assessment and inventory protocol for use by trained practitioners to rapidly identify, assess, and prioritize physical stream corridor conditions. Ordinal scale, nominal scale, and quantitative output.

- *Intended use:* Chesapeake Bay stream and riparian habitats
- *Ability to calculate multiresource credit:* No
- *Sensitivity:* Unknown
- *Capability of being integrated into multiresource credit:* Unknown

Stream Assessment in the Virginia Coastal Zone: Development of a Significant New Database and Interactive Assessment Application
S. McIninich, G. Garman, L. Smock, C. Viverette, W. Shuart, and E. Franks
2004

Development of a multivariate model of reference stream conditions for the Virginia Coastal Zone using biological, ecological, and geomorphological variables.

- *Intended use:* Virginia Coastal zone stream assessment
- *Ability to calculate multiresource credit:* No
- *Sensitivity:* Unknown
- *Capability of being integrated into multiresource credit:* Yes

Stream Channel Reference Sites: An Illustrated Guide to Field Technique
C. C. Harrelson, C. L. Rawlins, and J. P. Potyondy
1994

Provides techniques from numerous published sources for collecting a minimum set of high-quality data necessary to quantify the physical character of streams for monitoring, impact assessment, inventory, response to management actions, etc. Descriptive and quantitative output.

- *Intended use:* Nationwide wadeable streams
- *Ability to calculate multiresource credit:* No
- *Sensitivity:* Unknown
- *Capability of being integrated into multiresource credit:* Unknown

Stream Corridor Assessment Survey Protocols (SCA)
K. T. Yetman
2001

To rapidly assess the general physical condition of a stream system and identify the location of a variety of common environmental problems within the stream's corridor. Not intended to be a detailed scientific survey, it provides a rapid method of examining an entire drainage network to target future monitoring, management, or conservation efforts. One of the main goals is a prioritized list of problems to be corrected throughout an entire watershed. Descriptive, ordinal scale, nominal scale, and quantitative output.

- *Intended use:* Maryland wadeable streams and rivers
- *Ability to calculate multiresource credit:* Unknown
- *Sensitivity:* Unknown
- *Capability of being integrated into multiresource credit:* Unknown

Stream Impact Assessment Manual for the Northern Virginia Stream Bank
Wetland Studies and Solutions, Inc.
2006

The purpose of the Manual is to describe a system whereby the user can rapidly assess the condition of a stream, in a repeatable manner, without specialized equipment or significant training.

- *Intended use:* Intended for use by regulatory agencies and the regulated public using the Clean Water Act and Virginia Water Protection permits that use compensation in the Northern Virginia Stream Bank.
- *Ability to calculate multiresource credit:* No

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- *Sensitivity:* Unknown
- *Capability of being integrated into multiresource credit:* Yes

Subjective Evaluation of Aquatic Habitats
Kansas Department of Wildlife and Parks
2004

To provide a rapid holistic evaluation based on subjective assessments of physical, biological, and chemical parameters of the aquatic system. Descriptive, ordinal scale, and nominal scale output.

- *Intended use:* Kansas ephemeral, intermittent, or perennial streams and small impoundments or large lakes
- *Ability to calculate multiresource credit:* No
- *Sensitivity:* Unknown
- *Capability of being integrated into multiresource credit:* Unknown

Technique for the Functional Assessment of Non-Tidal Wetlands in the Coastal Plain of Virginia
Virginia Institute of Marine Science
1991

A wetland functional assessment based on WET that assesses functions of nontidal wetlands in the coastal plain of Virginia. Output is a rating system of high, medium, and low relative probability that a wetland has the opportunity to perform or be effective at performing a function.

- *Intended use:* To evaluate the relationships among vegetation structure, function, and landscape position. Has been largely phased-out by HGM models.
- *Ability to calculate multiresource credit:* No
- *Sensitivity:* Unknown
- *Capability of being integrated into multiresource credit:* Yes

Temperature Trading Platform
Oregon State University

Tool that allows landowners to draw a reach for riparian shade and estimate the temperature credits created. The tool is powered by a derivative of the Heat Source model rather than the Shade-a-Lator. Wetted width and some data still need to be collected in the field, but most runs on spatial GIS layers.

- *Intended use:* Temperature credit calculator
- *Ability to calculate multiresource credit:* No
- *Sensitivity:* Unknown
- *Capability of being integrated into multiresource credit:* Unknown

Uniform Mitigation Assessment Method (UMAM)
Florida Department of Environmental Protection

A functional assessment for wetlands and surface waters but also applicable to several terrestrial habitat types. Quantifies gains and losses by developing a multiplier applied to area. Considers landscape support, water environment, and community structure. Also applies factors for time lag for recovery and risk of project failure.

- *Intended use:* Wetland mitigation credit calculations
- *Ability to calculate multiresource credit:* Unknown
- *Sensitivity:* Unknown
- *Capability of being integrated into multiresource credit:* Unknown

Manual 10: Unified Stream Assessment: A User's Manual
Urban Subwatershed Restoration Manual Series
Center for Watershed Protection (Maryland)
2005

The Unified Stream Assessment is a rapid technique to locate and evaluate problems and restoration opportunities within an urban stream corridor in Maryland.

- *Intended use:* Maryland subwatershed restoration planning
- *Ability to calculate multiresource credit:* No
- *Sensitivity:* Unknown
- *Capability of being integrated into multiresource credit:* No

Variables for Assessing Reasonable Mitigation in New Transportation (VARMINT)
Vermont Agency of Natural Resources
2004

To provide a framework to lessen and mitigate impacts to terrestrial environments. Nominal and ordinal scale output.

- *Intended use:* Pennsylvania. Habitat not stated but implied that the framework is applicable to most habitats within a project area including, but not limited to, shrubland, forest, prairie, wetlands, and riparian areas.
- *Ability to calculate multiresource credit:* No
- *Sensitivity:* Unknown
- *Capability of being integrated into multiresource credit:* Unknown

Vermont Stream Geomorphic Assessment Protocol Handbooks
Vermont Agency of Natural Resources
2003

The Handbooks have a focus on those watershed processes and features critical to its riparian corridor management objectives.

- *Intended use:* The purpose of the assessment protocols is to provide a phased method for gathering information that can be used for watershed planning and detailed characterization of riparian and in-stream habitat, stream-related

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erosion, and flood hazards. The information will be used for basin planning; river and riparian corridor protection, management, and restoration projects; aquatic and riparian habitat assessment; and hazard assessment to reduce property loss and damage from riverine erosion during floods.
- *Ability to calculate multiresource credit:* No
- *Sensitivity:* Unknown
- *Capability of being integrated into multiresource credit:* Yes

Visual Stream Assessment Protocol
Natural Resources Conservation Service (NRCS)

NRCS has a number of protocols used by field staff to identify baseline farm conditions and design conservation plans. Most are visual assessments that provide general scores of conditions.

- *Intended Use:* Water Quality Assessment
- *Ability to calculate multiresource credit:* Unknown
- *Sensitivity:* Unknown
- *Capability of being integrated into multiresource credit:* Unknown

Wadeable Stream Assessment Field Ops
EPA
2004

Contains the field operations and bioassessment methods for evaluating the health and biological integrity of wadeable freshwater streams throughout the United States. These methods can be used to determine stream conditions or monitor the effects of impacts on aquatic organisms, particularly benthic macroinvertebrates. Descriptive, ordinal scale, nominal scale, and quantitative output.

- *Intended use:* Nationwide. Wadeable streams (generally stream orders 1–3, or higher orders in arid to semi-arid regions of the United States). Intermittent or ephemeral streams can be sampled using the WSA Field Ops protocols but only when water is present in the channel.
- *Ability to calculate multiresource credit:* No
- *Sensitivity:* Unknown
- *Capability of being integrated into multiresource credit:* Unknown

Washington Aquatic Habitat Design Guidelines
K. Saldi-Caromile, K. K. Bates, P. Skidmore, and J. Barenti
2004

To characterize the present (or historic) state of habitat and the processes that create and maintain it so that problems and appropriate restoration options and obstacles can be identified and prioritized. No output units are defined.

- *Intended use:* Washington. Primarily aquatic habitat in streams, riparian areas, and standing water bodies.
- *Ability to calculate multiresource credit:* No
- *Sensitivity:* Unknown
- *Capability of being integrated into multiresource credit:* Unknown

Washington State Wetlands Function Assessment Program (WFAP)
Washington State Department of Ecology

The Wetlands Function Assessment Project was a statewide effort to develop relatively rapid, scientifically acceptable methods of assessing how well wetlands perform functions such as improving water quality, reducing floods, and providing wildlife habitat. The methods were developed for different wetland types in Washington state.

- *Intended use:* Wetland assessment
- *Ability to calculate multiresource credit:* No
- *Sensitivity:* Unknown
- *Capability of being integrated into multiresource credit:* Yes

Washington State Wetland Rating System (Western and Eastern Versions)
Washington State Department of Ecology
1993; 2002

Washington's wetland rating system evaluates functions and special characteristics weighted heavily on the opportunity of a wetland to perform a particular function. Also evaluates sensitivity to disturbance, rarity, and inability to replace.

- *Intended use:* Wetland assessment
- *Ability to calculate multiresource credit:* No
- *Sensitivity:* Unknown
- *Capability of being integrated into multiresource credit:* Yes

Watershed Vulnerability Analysis
J. Zielinski
2002

To identify and classify subwatersheds that are vulnerable to changes in land use based on estimates of current and future impervious cover and to identify subwatersheds that warrant restoration actions. Descriptive output.

- *Intended use:* Streams within subwatersheds. The model was based on research in the Pacific Northwest and Mid-Atlantic regions. However, supporting data exist for the Northeast, Upper Midwest, and Southeast.
- *Ability to calculate multiresource credit:* No
- *Sensitivity:* Unknown
- *Capability of being integrated into multiresource credit:* Unknown

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Watershed-Based Preliminary Assessment of Wetland Functions (W-PAWF)
R. W. Tiner
2003

To provide a preliminary assessment of wetland functions based on enhanced National Wetlands Inventory digital data. The assessment uses a combination of wetland classifications, specifically the U.S. Fish and Wildlife Service's official system (see Cowardin et al. 1979, Classification of Wetlands and Deepwater Habitats of the United States) and the classification system to enhance the NWI by adding landscape position, landform, water flow path, and waterbody (LLWW) descriptors for landscape position, landform, water flow path, and water body type (see Tiner's 2003 article in *Wetlands,* Estimated extent of geographically isolated wetlands in selected areas of the United States). Descriptive and nominal scale output.

- *Intended use:* Wetlands and deepwater habitats of the United States, but the emphasis for functional assessment is on wetlands, including shallow open water bodies such as ponds. Developed for all regions of the United States; however, the correlations focus on the Northeastern United States.
- *Ability to calculate multiresource credit:* Unknown
- *Sensitivity:* Unknown
- *Capability of being integrated into multiresource credit:* Unknown

Wetland Evaluation Technique (WET)
P. R. Adamus, E. J. Clairain, R. D. Smith, and R. E. Young
1987

WET is an initial, rapid assessment of wetland functions, designed to assess the qualitative probability that a wetland function will occur. WET has been superseded by recently developed more rigorous reference-based, regionally specific methods.

- *Intended use:* Wetland consultants.
- *Ability to calculate multiresource credit:* No
- *Sensitivity:* Unknown
- *Capability of being integrated into multiresource credit:* Yes

Wetland Value Assessment Methodology (WVA)
Environmental Work Group
2002

Estimates wetland benefits of proposed wetland restoration projects submitted for funding under the Coastal Wetlands Planning, Protection, and Restoration Act (CWPPRA). The application in the plan formulation process is described in the 2006 U.S. Geological Survey. Ordinal scale output.

- *Intended use:* Louisiana coast marshlands
- *Ability to calculate multiresource credit:* No
- *Sensitivity:* Unknown
- *Capability of being integrated into multiresource credit:* Unknown

Wildlife Habitat Appraisal Procedure (WHAP)
R. Frye
1995

To allow a qualitative holistic evaluation of wildlife habitat for particular tracts of land statewide (Texas) without imposing significant time requirements. WHAP is intended to be used for (1) evaluating impacts upon wildlife populations from development project alternatives, (2) establishing baseline conditions, (3) comparing tracts of land that are candidates for land acquisition or mitigation, and (4) evaluating general habitat quality and wildlife management potential for tracts of land over large geographical areas. Ordinal scale output.

- *Intended use:* Texas. Based on list of habitat classes; seems to represent all upland and wetland habitat in Texas (e.g., swamp, cultivated wetlands, water including ponds, and water treatment facilities, urban areas, dunes, beach).
- *Ability to calculate multiresource credit:* No
- *Sensitivity:* Unknown
- *Capability of being integrated into multiresource credit:* Unknown

Wisconsin Rapid Assessment Methodology for Evaluating Wetland Functional Values
Wisconsin Department of Natural Resources
1992

A wetland functional assessment to evaluate and provide a measure of wetland function.

- *Intended use:* For use with making routine Section 404 permit application decisions.
- *Ability to calculate multiresource credit:* No
- *Sensitivity:* Unknown
- *Capability of being integrated into multiresource credit:* Yes

Wisconsin Wetland Assessment Methodology (WIRAM)
Wisconsin Department of Natural Resources
2001

To provide a standardized process for the professional to evaluate the extent to which a specific wetland performs a given function. Descriptive output.

- *Intended use:* Wisconsin wetlands
- *Ability to calculate multiresource credit:* Unknown
- *Sensitivity:* Unknown
- *Capability of being integrated into multiresource credit:* Unknown

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Table E.1. Summary Overview

Method	Intended Use	Multiresource Credit	Integrate into Multiresource
Applied River Morphology Method	River classification	No	Unknown
Artificial Intelligence for Ecosystem Services (AIRES)	Decision support system	Unknown	Unknown
Basinwide Visual Estimation Technique (BVET)	Fish abundance and habitat estimation	No	Unknown
Beneficial Use Reconnaissance Program (BURP) Field Manual for Streams	Stream assessment	Unknown	Unknown
BushBroker	Native vegetation offset credit trading	No	Unknown
BushTender Program	Native vegetation credit trading	Possible	Unknown
Business and Biodiversity Offset Program (BBOP)	Development of offset best management practices (BMPs)	No	Unknown
California Carbon Project Protocols	Carbon credit calculator	Unknown	Unknown
California Rapid Assessment Method (CRAM)	Wetland assessment	No	Yes
Casco Bay Watershed Wetlands Characterization Method	Wetland assessment	No	Unknown
City Green	Integrated ecosystem services assessment	Unknown	Unknown
Combined Habitat Assessment Procedure (CHAP)	Integrated ecosystem services accounting	Yes	Yes
Connecticut Method	Wetland assessment	No	Unknown
Delaware Rapid Assessment	Wetland assessment	No	Unknown
Descriptive Approach (Highway Methodology)	Wetland assessment	No	Unknown
Developing Rapid Methods for Analyzing Upland Riparian Functions and Values	Riparian (upland) assessment	No	Yes
Development of a Floristic Quality Assessment Methodology for Wisconsin	Floristic quality assessment	No	Yes
Eastern Kentucky Stream Assessment Protocol (eKY)	Stream assessment	Yes	Unknown
Ecological Site Inventory	Qualitative tool	No	Unknown
EcoMetrix	Integrated ecosystem services accounting	Yes	Yes
Ecosystem Diagnosis and Treatment Model	Stream assessment	No	Yes
Ecosystem Valuation Methods	Integrated ecosystem services accounting	Unlikely	Unknown
Environmental Monitoring and Assessment Protocols (EMAP)	Assessment tools	Unknown	Unknown
Envision	Water quality assessment	Unknown	Unknown
EPA Oregon Stream Methodology	Water quality assessment	No	No
EPA Region 10 In-stream Biological Monitoring Handbook	Stream assessment	Unknown	Unknown
Evaluation for Planned Wetlands (EPW)	Wetland assessment	No	Unknown
Fairfax County Stream Physical Assessment Protocols	Stream assessment	No	Unknown
Field Manual for Ohio's Headwater Habitat Streams	Water quality assessment	No	Unknown
Fire Regime Condition Class	Vegetation assessment	No	Unknown
Florida Wetland Quality Index	Wetland assessment	No	Yes
Florida Wetland Rapid Assessment Procedure	Wetland assessment	No	Yes

(continued on next page)

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Table E.1 Summary Overview (continued)

Method	Intended Use	Multiresource Credit	Integrate into Multiresource
Floristic Quality Assessment Index (FQAI)	Vegetation assessment	No	Unknown
Freshwater Wetland Mitigation Quality Assessment Procedure	Wetland assessment	No	Yes
Gravel Bed Instream Flows	Stream assessment	No	Unknown
Guidance for Rating the Values of Wetlands in North Carolina	Wetland assessment	No	Yes
Guidebook for Hydrogeomorphic (HGM)-based Assessment of Oregon Wetland and Riparian Sites: Willamette Valley Riverine Impounding and Slopes/Flats Subclasses	Wetland assessment	No	Yes
Guidelines for Evaluating Fish Habitat in Wisconsin	Stream habitat assessment	No	Unknown
Habitat Assessment Model	Terrestrial habitat assessment	No	Unknown
Habitat Equivalency Analysis (HEA)	Integrated ecosystem services accounting	No credits	Unknown
Habitat Evaluation Procedure (HEP)	Habitat assessment	No	Unknown
Hawaii Stream Bioassessment	Stream assessment	No	Unknown
Heat Source Model	Water quality assessment	Yes	Unknown
Hydrogeomorphic Method (HGM)	Wetland assessment	No	Yes
Idaho Small Stream Ecological Assessment Framework	Stream assessment	No	Unknown
Index of Biological Integrity (IBI): Birds, Fish, Invertebrates, and Plants	Habitat assessment	Yes	Unknown
Index of Marsh Bird Community Integrity	Habitat and wetland assessment	No	Unknown
Instream Flow Incremental Methodology (IFIM)	Stream assessment	No	Unknown
Interim Guidelines to Avoid and Minimize Wildlife Impacts from Wind Turbines—Potential Impact Index (PII)	Site evaluation	Yes	Unknown
InVEST	Integrated ecosystem services accounting	Yes	Unknown
King County Functional Equivalency Evaluation System (KC-FEES)	Wetland and aquatic assessment and credit calculator	Yes	Yes
Maryland Green Infrastructure Assessment	Habitat assessment	No	Unknown
MDT Montana Wetland Assessment Method	Wetland assessment	No	Unknown
Methods for Assessing Wetland Functions: Volume I: Riverine and Depressional Wetlands in the Lowlands of Western Washington	Wetland assessment	No	Yes
Methods for Assessing Wetland Functions: Volume II: Depressional Wetlands in the Columbia Basin of Eastern Washington	Wetland assessment	No	Yes
Methods for Characterizing Stream Habitat in the Natural Water-Quality Assessment Program (NAWQA)	Stream assessment	No	Unknown
Methods for Evaluating Stream Conditions	Stream assessment	No	Unknown
Methods for Stream Habitat Surveys, Aquatic Inventories Project, ODFW	Stream assessment	No	Yes
Michigan Valley Segment Ecological Classification—Inventory	Stream assessment	No	Unknown
Minnesota Habitat and Water Chemistry Protocol	Water quality assessment	No	Unknown
Minnesota Routine Assessment Method (MnRAM)	Wetland assessment	Unknown	Unknown
Montana Stream Mitigation Process	Water quality assessment	Unknown	Unknown
Montana Wetland Rapid Assessment Method	Wetland assessment	No	Yes
Multi-scale Assessment of Watershed Integrity (MAWI)	Ecosystem integrity	No	Unknown
New Hampshire Method	Wetland assessment	No	Unknown

(continued on next page)

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Table E.1. Summary Overview (continued)

Method	Intended Use	Multiresource Credit	Integrate into Multiresource
New Jersey Watershed Method	Wetland assessment	Unknown	Unknown
North Carolina Coastal Region Evaluation of Wetland Significance (NC CREWS)	Wetland assessment	Unknown	Unknown
Numerical Method for Evaluation of Maine Peatlands	Peatland assessment	Unknown	Unknown
Nutrient Trading Tool (NTT)	Water quality assessment	Yes	Yes
NutrientNet	Water quality assessment	Yes	Unknown
Ohio Rapid Assessment Method for Wetlands, Version 5.0	Wetland assessment	No	Yes
Oregon Rapid Wetlands Assessment Protocol (ORWAP)	Wetland assessment	No	Yes
Oregon Vernal Pool Method	Wetland assessment	No	Unknown
Pfankuch Channel Stability	Stream assessment	No	Unknown
Physical Habitat Simulation System (PHABSIM)	Discharge and habitat assessment	No	Yes
Proper Functioning Condition	Riparian assessment	No	Unknown
Qualitative Habitat Evaluation Index (QHEI)	Habitat assessment	No	Yes
Rapid Assessment Method for Oregon Tidal Fringe Wetlands (RAM)	Wetland assessment	No	Yes
Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates, and Fish	Stream and river Assessment	No	Yes
Rapid Stream Assessment Technique Field Methods (RSAT)	Stream assessment	No	Unknown
Remote Functional Wetland Assessment Model (RFWAM)	Wetland assessment	Unknown	Unknown
Remotely Sensed Indicators for Monitoring Condition of Natural Habitat in Watersheds	Habitat assessment	No	Unknown
Riparian Community Type Classification of Utah and Southeastern Idaho—Inventory	Riparian community classification	No	Unknown
Rouge River Project Rapid Assessment Method	Wetland assessment	No	Unknown
Savannah's Standard Operating Procedure—Mitigation	Wetlands and water assessment	Unknown	Unknown
Soil Management Assessment Framework	Soil assessment	No	Unknown
South Australian Biodiversity Assessment Tool (SABAT)	Habitat assessment	Yes	Unknown
Southern California Riparian Ecosystem Assessment (SCREAM)	Riparian habitat assessment	Unknown	Unknown
Spatial Wetland Assessment for Management and Planning (SWAMP)	Water quality, habitat, and hydrologic function assessment	No	Unknown
Stream and Riparian Habitats Rapid Assessment Protocol	Stream and riparian habitat assessment	No	Unknown
Stream Assessment in the Virginia Coastal Zone: Development of a Significant New Database and Interactive Assessment Application	Stream assessment	No	Yes
Stream Channel Reference Sites	Stream assessment	No	Unknown
Stream Corridor Assessment Survey Protocols (SCA)	Stream assessment	Unknown	Unknown
Stream Impact Assessment Manual for the Northern Virginia Stream Bank	Stream assessment	No	Yes
Subjective Evaluation of Aquatic Habitats	Aquatic habitat assessment	No	Unknown
Technique for the Functional Assessment of Non-Tidal Wetlands in the Coastal Plain of Virginia	Wetland assessment	No	Yes

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Table E.1. Summary Overview (continued)

Method	Intended Use	Multiresource Credit	Integrate into Multiresource
Temperature Trading Platform	Temperature credit calculator	No	Unknown
Unified Stream Assessment: A User's Manual (No. 10)	Subwatershed restoration planning	Unknown	Unknown
Uniform Mitigation Assessment Method (UMAM)	Wetland and surface water assessment	No	No
Variables for Assessing Reasonable Mitigation in New Transportation (VARMINT)	Habitat assessment	No	Unknown
Vermont Stream Geomorphic Assessment Protocol Handbooks	Stream assessment	No	Yes
Visual Stream Assessment Protocol	Water quality assessment	Unknown	Unknown
Wadeable Stream Assessment Field Ops	Stream assessment	No	Unknown
Washington Aquatic Habitat Design Guidelines	Aquatic habitat assessment	No	Unknown
Washington State Wetlands Function Assessment Program (WFAP)	Wetland assessment	No	Yes
Washington State Wetland Rating System (Western and Eastern versions)	Wetland assessment	No	Yes
Watershed Vulnerability Analysis	Stream assessment	No	Unknown
Watershed-Based Preliminary Assessment of Wetland Functions (W-PAWF)	Wetland assessment	Unknown	Unknown
Wetland Evaluation Technique (WET)	Wetland assessment	No	Yes
Wetland Value Assessment Methodology (WVA)	Wetland assessment	No	Unknown
Wildlife Habitat Appraisal Procedure (WHAP)	Upland and wetland habitat assessment	No	Unknown
Wisconsin Rapid Assessment Methodology for Evaluating Wetland Functional Values	Wetland assessment	No	Yes
Wisconsin Wetland Assessment Methodology (WIRAM)	Wetland assessment	Unknown	Unknown

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APPENDIX F

Glossary

assign/cross-walk the land uses. Matching equivalent land-cover categories between two or more classification systems.

baseline map. A map depicting background reference information, such as landforms, roads, landmarks, and political boundaries, onto which other thematic information is placed. A basemap is used for locational reference.

biodiversity. Refers to the variety and variability among living organisms and the ecological complexes in which they occur. Diversity can be defined as the number of different items and their relative frequencies. For biological diversity, these items are organized at many levels, ranging from complete ecosystems to the biochemical structures that are the molecular basis of heredity. Thus, the term encompasses different ecosystems, species, and genes.

biological assessment. A document prepared for the Section 7 process to determine whether a proposed major construction activity under the authority of a federal action agency is likely to adversely affect listed species, proposed species, or designated critical habitat.

categorical scale. A numeric scale based on discrete categories versus a gradient of values (e.g., 1–5, low to high).

coarse filter. The general conservation activities that conserve the common elements of the landscape matrix, as opposed to "fine filter" conservation activities, which are aimed at special cases, such as rare elements.

connectivity. The degree to which a landscape facilitates or impedes movement. Linkages at multiple spatial and temporal scales.

conservation. Preserving and renewing, when possible, human and natural resources. The use, protection, and improvement of natural resources according to principles that will ensure their highest economic or social benefits.

Eco-logical. *Eco-Logical: An Ecosystem Approach to Developing Infrastructure Projects* is a guidance document developed in a partnership among the Bureau of Land Management, Environmental Protection Agency, Federal Highway Administration, National Oceanic and Atmospheric Association, National Park Service, U.S. Army Corps of Engineers, USDA Forest Service, and the U.S. Fish and Wildlife Service to encourage federal, state, tribal, and local partners involved in infrastructure planning, design, review, and construction to use flexibility in regulatory processes. Specifically, *Eco-Logical* puts forth the conceptual groundwork for integrating plans across agency boundaries, and endorses ecosystem-based mitigation—an innovative method of mitigating infrastructure impacts that cannot be avoided.

ecoregion. A large region, usually spanning several million hectares, characterized by having similar biota, climate, and physiography (e.g., topography, hydrology).

ecosystem. A biological community (ranging in scale from a single cave to millions of hectares), its physical environment, and the processes through which matter and energy are transferred among the components.

ecosystem approach. Protecting or restoring the function, structure, and species composition of an ecosystem, recognizing that all components are interrelated.

endangered. The classification provided to an animal or plant in danger of extinction within the near future throughout all or a significant portion of its range.

Endangered Species Act of 1973, as amended. Federal legislation intended to provide a means whereby the ecosystems upon which endangered and threatened species depend may be conserved, and to provide programs for the conservation of those species, thus preventing extinction of native plants and animals.

endangered species. Animals, birds, fish, plants, or other living organisms threatened with extinction by anthropogenic (man-caused) or other natural changes in their environment. Requirements for declaring a species endangered are contained in the Endangered Species Act.

fine filter. See *coarse filter.*

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gap analysis. A comparison of the distribution of elements of biodiversity with that of areas managed for their long-term viability to identify elements with inadequate representation.

geographic information systems (GIS). Computer hardware and software for storing, retrieving, manipulating, and analyzing spatial data.

geospatial overlays. A spatial operation in which two or more maps or layers registered to a common coordinate system are superimposed, either digitally or on a transparent material, for the purpose of showing the relationships between features that occupy the same geographic space.

habitat. The physical structure, vegetational composition, and physiognomy of an area, the characteristics of which determine its suitability for particular animal or plant species.

landscape. The traits, patterns, and structure of a specific geographic area, including its biological composition, physical environment, and anthropogenic or social patterns. An area where interacting ecosystems are grouped and repeated in similar form.

mitigation. Measures taken to reduce adverse impacts on the environment.

natural habitat range. The geographic area a species is known or believed to occupy.

restoration. Measures taken to return a site to previolation conditions.

Section 7. The section of the Endangered Species Act that requires all federal agencies, in "consultation" with the U.S. Fish and Wildlife Service, to ensure that their actions are not likely to jeopardize the continued existence of listed species or result in destruction or adverse modification of critical habitat.

spatial analysis. The process of examining the locations, attributes, and relationships of features in spatial data through overlay and other analytical techniques to address a question or gain useful knowledge. Spatial analysis extracts or creates new information from spatial data.

spatial queries. A statement or logical expression that selects geographic features based on location or spatial relationship. For example, a spatial query might find which points are contained within a polygon or set of polygons; find features within a specified distance of a feature; or find features that are adjacent to each other.

special area management plans (SAMPs). The National Oceanic Atmospheric Administration defines SAMPs as "plans which provide for increased specificity in protecting significant natural resources, reasonable coastal-dependent economic growth, improved protection of life and property in hazardous areas, including those areas likely to be affected by land subsidence, sea level rise, or fluctuating water levels of the Great Lakes, and improved predictability in governmental decision making."

stakeholder. Any organization, governmental entity, or individual that has a stake in or may be affected by a given approach to environmental regulation, pollution prevention, energy conservation, and so forth.

watershed. The land area that drains into a stream; the watershed for a major river may encompass a number of smaller watersheds that ultimately combine at a common point.

wetlands. An area that is saturated by surface water or groundwater with vegetation adapted for life under those soil conditions, such as swamps, bogs, fens, marshes, and estuaries.

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Related SHRP 2 Research

A Framework for Collaborative Decision Making on Additions to Highway Capacity (C01)

A Systems-Based Performance Measurement Framework for Highway Capacity Decision Making (C02)

An Ecological Approach to Integrating Conservation and Highway Planning, Volume 1 (C06)

Synthesis Report on C18 and C21 Pilot Projects Results (C41)

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