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Trends and Outlook: The Aquatic Ecosystem Restoration Program of the U. S. Army Corps of Engineers

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Public interest in ecological restoration has grown in response to past environmental degradation of valued ecological services. In 1996, Congress authorized the U. S. Army Corps of Engineers (Corps) to improve environmental quality (EQ), as first defined by the National Environmental Policy Act (NEPA), using aquatic ecosystem restoration and protection measures. The program grew rapidly before recently leveling off. Despite demonstrable need at global to local levels, many forces are likely to limit future success. This study assessed the trends and trend-shaping forces potentially affecting the success of the Corps aquatic ecosystem restoration program, as indicated by program objective achievements. They document widespread and profound degradation and restoration needs as well as impediments to restoration success. Since success is difficult to assess without a clear program objective, a chronic impediment is confusion over the program objective and its achievement. Corps policy guidance established an objective that focuses on restoring degraded ecosystems to a less degraded more natural condition and requires nonmonetary measurement of objective achievement. But the policy fails to clearly explain what counts as "degraded" EQ and why nonmonetary measurement is required. The explanation accepted here rests in the link between the protection of restored EQ in the 1996 authority and a NEPA goal to preserve important natural and cultural aspects of national heritage. The value of heritage is a "nonuse value" that motivates the protection of restored outputs for the benefit of future generations. The Corps forbids monetary measurement of nonuse value because the methods are unreliable. Based on this and other information, the program objective is to restore the Nation's threatened ecological heritage—expressed in its biodiversity—to a more sustainable state. Because of the unclear statement of objective in policy guidance, restoration projects often fail to align well with the Nation's biodiversity-maintenance goal indicated in various laws. Objective achievement has been subverted by diversion of scarce funding into projects that target recreational or other use improvement. Success is also limited by inadequate technical guidance. The feasibility of the ecosystem restoration approach itself is now widely doubted by ecologists, who recognize how intractable environmental change has become. Because ecosystems are constantly changing in space and time, the best that can be hoped for is to maintain national biodiversity by restoring unsustainable species elements to a sustainable state somewhere in the changing ecosystem context. Corps culture is another limitation. The Corps is not as sustainability oriented as it might be because of its emphasis on project engineering, continued focus on resource use improvements, and reliance on nonfederal partners to sustain project outputs. Budgets are tenuous and doubts in the merits of the program are growing. No new projects have been funded since 2010. The program is most likely to survive in existing regional water resources "rehabilitation" programs where success might still be compromised. Success could be enhanced by clarifying the program objective and improving benefits metrics, technical guidance, personnel skills, communication, and restoration success stories. The Corps may also be able to influence the success of programs favoring a nationally coordinated systems approach to biodiversity recovery and protection, more effective integration of resource management across agencies, and increased research and development consistent with new restoration paradigms. Other trends and forces are beyond Corps influence, but need to be recognized and managed when feasible.

Disclaimer: The contents of this report have been developed and reviewed for factual accuracy, logic and clarity but remain the author's interpretations and views, and do not necessarily reflect the views of the U. S. Army Corps of Engineers or the Institute for Water Resources.

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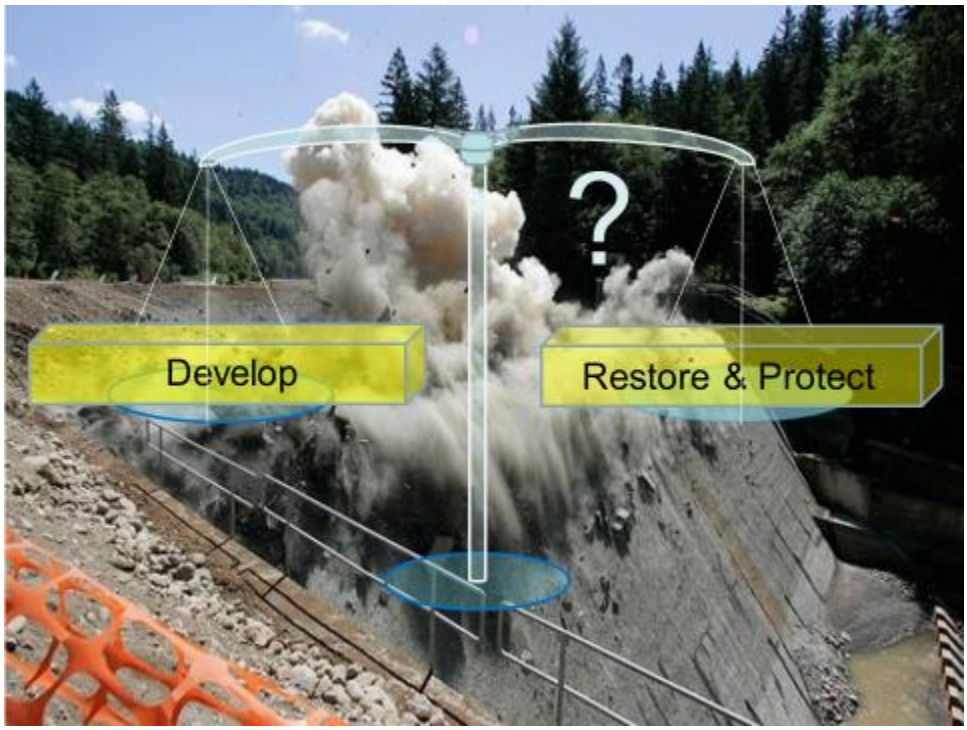

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Table of Contents

Acknowledgements ii
Table of Contents iii
List of Figures vi
Executive Summary 1
Introduction 8
  Study Purposes and Limitations 8
  Corps Aquatic Ecosystem Restoration and Protection 9
  Report Organization and Approach 11
Past Global and National Environmental Trends 11
  Overview 11
  Environmental Impact Trends 13
    Population and Environmental Impact 13
    Land Transformations 14
    Water Transformations 17
    Atmospheric Transformation 20
    Natural Environment versus Novel Ecosystems 22
  Environmental Management Trends 25
    Environmental Awakening 25
    Natural Resource Conservation 26
    Environmental Movement 26
    Ecosystem Restoration 28
Past Regional Ecosystem Trends and Implications 39
  Overview 39
  Saint Lawrence River and Great Lakes 40
  Northeastern Atlantic Coast and Rivers 42
  Chesapeake Bay and Tributary Rivers 44
  Southeastern Atlantic Coast and Rivers 45
  Florida Peninsula 46
  Eastern Gulf Coast and Rivers 48
  Lower Mississippi River and Tributaries 51
  Missouri River Basin 53
  Upper Mississippi River Basin 54
  Ohio River Basin 57
  Western Gulf Coast and Rivers 59
  Colorado River Basin 60
  Columbia River Basin 62
  Pacific Rivers and Coast of the Coterminous U. S. 63
  Alaskan Rivers and Coasts 65
  Great Basin Rivers 66
Past Trends in Federal Government 67
  Overview 67
  Natural Resource Conservation 67
  Environmental Protection 70

Environmental Regulation Authorities 70
Sustainable Development 73
Environmental Protection Progress 74
Past Trends in the Corps Program 75
Overview 75
Program Authority and Regulatory Trends 77
Policy Guidance Trends 80
Program Objectives 80
The Systems Approach 87
Environmental Sustainability and Sustainable Development 90
National Interest and Resource Significance 91
Benefits Estimation 93
Adaptive Management and Climate Change 97
Measuring Ecosystem Restoration Program Success 98
Budget Trends 99
Overall Trends 99
Project Trends 101
Program Trends 103
Competition for new ecosystem restoration projects 104
Cultural Trends 106
Corporate Division and Decentralization 107
Accountability 110
Diversification of Purposes, Responsibilities, and Personnel 113
Transitioning from Project Focus to Collaborative Systems Management 115
Future Outlook 120
Overview 120
The Big Picture 122
General Trends and Forces 122
Public Environmental Concern and the Economy 123
Growth of Human Impacts 125
Public Perceptions of Environmental Issues 125
Challenging Costs 127
The Bottom Line 127
Future Need For A Corps Ecological Restoration Program 128
Future Corps Authority and Policy Guidance 129
Authority 129
Policy Guidance 131
Future Budget Expectations 132
Total Federal Budget 132
Operation & Maintenance Budget 133
Planning and Construction Budgets 134
Reimbursable Funding Possibilities 135
Future Corps Culture 135
Corporate Division and Decentralization 135
Accountability 139
Diversification of Purpose, Responsibility, and Personnel 140

Transition from Project Development to a Systems Approach 143
Summary Outlook for the Corps Program 147
Summary Points 150
References 153

List of Figures

Figure 1. Estimated past and projected world human population growth (from UNEP/GRID-Arendal 2010 http://maps.grida.no/go/graphic/world_population_development)..... 13

Figure 2. Net loss of land to erosion over the last 10,000 years (from Wilkinson 2005)..... 15

Figure 3. Percentage of species federally listed as threatened and endangered by habitat degradation from various sources of human activity in the United States (modified from Wilcove et al. 2000). 17

Figure 4. Relative numbers and locations of U. S. dams and reservoirs in 1850, 1900, 1950 and 2000 (from Vince 2011)..... 18

Figure 5. World protein production from various sources from 1950 through 1999 (from Brown et al. 2000). 19

Figure 6. Trends for atmospheric carbon dioxide concentration, global carbon emissions from fossil fuels, world gross domestic product (GDP), and world population number (from NOAA: http://www.noaanews.noaa.gov/stories2009/20090421_carbon.html)..... 21

Figure 7. Global average land-ocean temperature index (C^o) trend at earth's surface for 1880 to 2010 (from NOAA http://data.giss.nasa.gov/gistemp/graphs/). 22

Figure 8. The past trend in humanity's ecological footprint based on the number of earths needed to support the world's population (Loh and Goldfinger 2006;(from the United Nations Environmental Program http://maps.grida.no/go/graphic/humanity-s-ecological-footprint)..... 23

Figure 9. Trends in the Living Planet Index used to indicate the change abundances of the worlds species in terrestrial, freshwater, and marine environments (Low et al. 2005) ((Courtesy of United Nations Environmental Program http://maps.grida.no/go/graphic/humanity-s-ecological-footprint). The index is being used to target biodiversity protection..... 24

Figure 10. Gross domestic product (GDP) and genuine progress indicator (GPI) for sustainability from 1950 through 2002 (from Mastny et al. 2005)..... 25

Figure 11. The number of world heritage sites identified since initiation in 1978..... 27

Figure 12. Changes in Missouri River flow following construction of dams in the river by the Corps (from Postel 2006)..... 39

Figure 13. Numbers of plant and animal species presumed to be extinct or are possibly extinct in each state of the United States (from Master et al. 2000)..... 41

Figure 14. Number of freshwater fish and mollusks considered to be at risk of extinction (imperiled) in major river basins of the United States (from Chaplin et al. 2000). 41

Figure 15. Watersheds that need to be protected and restored to protect the freshwater biodiversity of the United States (from Chaplin et al 2000). 42

Figure 16. Annual expenditures by the Corps on protection of species listed as threatened and endangered under the ESA (data from internal annual reports). 63

Figure 17. Trends for listing species as threatened and endangered under the protections of the ESA (U. S. Fish and Wildlife Service). 75

Figure 18. The Corps budget as a percentage of Gross Domestic Product and federal budget from 1930 through 2000 (from USACE 2001). The fractions remained about the same since until the recession of 2009 when it increased slightly. 100

Figure 19. The Corps Civil Works appropriations in 1995 constant dollars from 1955-2000 (from USACE 2001). The trends since 2000 have remained about the same (Congressional Research Service 2011) except for an increase in 2006-2010 of about 30 % for construction and about 10 % for the total. 101

Figure 20. Balancing National Interests 149

Executive Summary

Report Purpose and Limitations

Public interest in ecological restoration has grown in response to past environmental degradation of valued ecological services. In 1996, Congress authorized the U. S. Army Corps of Engineers (Corps) to improve environmental quality (EQ), as first defined by the National Environmental Policy Act (NEPA), using aquatic ecosystem restoration and protection measures. The program grew rapidly before recently leveling off. Despite demonstrable restoration needs, many forces may limit future success. This study assessed the trends and trend-shaping forces potentially affecting the success of the Corps aquatic ecosystem restoration program over the next three decades, as indicated by program objective achievement. The trends and forces document profound degradation and restoration needs as well as impediments to restoration success.

The report was developed primarily for use in Civil Works strategic planning. The achievement of program-area objectives is the basis for evaluating program success and ranking projects for investment priority. Consistent with that focus, this report gauges past and future trends and forces influencing success based on achievement of the program-area objectives interpreted from Corps authority and policy guidance. The main consideration is the form and amount of national benefit intended from program investment. Future program achievement depends on being aware of and managing to possible extent those trends and forces that impede objective achievement.

The report organization reflects trends and forces influencing the Corps at global, continental, and regional scales; in federal government; and the Corps itself. Except for megatrends, the analysis of trends and possibilities of future trend-shifting events relies largely on qualitative historical assessments because of data limitations. Outlook uncertainty is unavoidable. The more probable trends and forces are emphasized in the discussion, which focuses largely on aspects that the Corps may be able to change or influence, as well as those aspects it cannot influence but should consider for their effects and adaptation needs. Major points are summarized at the end.

Restoration Program Area

The objective of the Corps aquatic ecosystem restoration program area defined in its project planning guidance must be well defined to determine success by objective achievement. In this study, that definition is based on interpretations of Section 206 of the 1996 Water Resources Development Act (WRDA) and the Corps project planning guidance. Section 206 programmatically authorized the Corps to carry out aquatic ecosystem restoration and protection anywhere in the United States as long as projects cost-effectively improve environmental quality (EQ), and are in the public interest. Projects also must be cost shared with a nonfederal sponsor. The protection aspect of the authority sets it apart from other authorities. Ecosystem restoration measures can be considered for problem management in any Corps project plan, and under various authorities regardless of purpose. But Section 206 is clearly the primary authority behind the mission described in Corps project planning policy guidance.
The protection aspects of the restoration and protection authority generally identify who shall benefit from the project and how. The Corps planning guidance defines environmental protection

in terms of adverse-impact mitigation and preservation of cultural and natural heritage. Unlike economic development, which is intended to benefit the investing public, ecosystem restoration outputs are expected to benefit future generations as well. The Corps definition of environmental protection came from the National Environmental Policy Act (NEPA). It established the concept of EQ in federal law and the need for EQ protection and improvement actions to benefit Americans both immediately through provision of safe, healthful, and otherwise beneficial use of the environment and by preserving important cultural and natural aspects of national heritage for future generations. Civil works program-area authorities other than Section 206 target improvements for beneficial use of water resources. In the context of the policy and goals of NEPA, the EQ protection aspect of the new authority implied that the justification for project investment was restoration and protection of degraded national ecological heritage sustained in native biodiversity and the potential for continued diversification.

This interpretation of the authority is not universally understood and accepted, however. The National Ecosystem Restoration (NER) objective and its achievement have been sources of confusion since it and an ecosystem restoration study objective were established in a 2000 revision of the Corps Planning Guidance Notebook (PGN). One result is growing doubts about the merits of the program. The confusion seems to derive from various sources, including a historic focus on economic development and the structure of the PGN itself. The possible sources of confusion and potential outlook effects are discussed under Corps program trends. Not finding any policy-acceptable alternatives in this review of trends, national ecological heritage restoration and protection was the outcome used in this analysis to judge mission success.

The ecosystem restoration program area has had a short but complex history that will influence its outlook for the next several decades. This report describes the numerous trends and forces affecting program success. Some may not be influenced by the Corps, but are considered for strategic purposes. Other trends and forces will influence program-funding level regardless of program success as interpreted here. A few important forces that originate from within the Corps and its partnerships have the greatest potential to be influenced by the Corps.

Past Environmental Trends

Environmental “megatrends” reveal a long history of increasingly intense human impact, which became so extensive a new geologic epoch—the Anthropocene—has been seriously proposed. The condition of land, water, atmosphere, and ecosystems changed dramatically in response to the impacts of population and technology growth and are likely to continue as climate change interacts with past environmental change. The species compositions and interactions with physical environment have been changed so much by human effects that virtually all ecosystems located where the Corps works are now novel systems, different from any previous existence.

The cumulative effects of environmental change have reduced the suitability of habitats for many species to a small fraction of what they once were. As the unique attributes of species die out, ecosystem diversity and integrity erode away. Even if all refugial habitats are protected, without a major investment in restoration activities, global climate change could cause the extinction of many species. The rapid decline of freshwater species is particularly relevant to the Corps aquatic ecosystem restoration and protection authority. EQ is degraded enough to justify

restoration investments for a long time. But the old restoration paradigm is changing. While restoration of threatened species to a more natural abundance and diversity may be possible somewhere in the United States, restoration of ecosystems to a condition like that which once existed is highly unlikely because profound environmental changes are largely irreversible at the project level. Adverse impacts on national ecosystem integrity and diversification occur everywhere in the United States, but unevenly. In general, they tend to increase from north to south and in many locations where past water resources development is extensive.

Public awareness of environmental impact has grown and has increasingly acted through law and education to prevent further degradation, especially by any federally funded activity. Building on earlier conservation principles, NEPA and other environmental laws greatly elevated federal emphasis on protecting desired EQ from new development. But the limits to protection alone became much clearer in the past few decades. Habitat degradation was so far along that protection alone would not assure the viability of many species. The protection of ecological resources through restoration has a long history (treating soil erosion and flood problems, for example), but the more holistic concept of ecosystem restoration is more recent. It arose during the 1980s in federal "ecosystem management" approaches to protecting and recovering threatened and endangered species while managing specific land and water resources for sustainable use authorized by Congress. Ecosystem management and restoration investments have increased rapidly, but with mixed results. Success is much more likely when restoration objectives target broad functions (such as increased productivity and decreased erosion) than when they target desired structure, such as a particular species composition.

Public interest in more environmental legislation faded from top American concerns after the major environmental laws of the 1970s, but efforts to weaken laws have generally failed. Interest in new environmental legislation has grown as concerns about global climate change have grown, but a weakened economy, public skepticism, and resistance from vested interests have prevented any passage of new environmental legislation of outstanding significance.

Past Corps Program Trends

Civil Works Program authorities, regulations, and planning policy guidance grew increasingly complex, environmentally oriented, and often more confusing. The dramatic changes and confusion rippled through the Corps culture, which is shaped largely by its structural engineering orientation to resource-use problem solution. The rate at which new economic development purposes were first authorized peaked in the early 20th century and culminated in the 1960s when public interest and congressional attention began to swing toward environmental protection and restoration. Unprecedented passage of federal environmental legislation in the 1970s led to less Corps prominence in environmental regulation—established largely in the 1899 Refuse Act—and caused a shift in agency identity from regulator to regulated. Compared to some other agencies, however, the adjustment was relatively rapid. EQ consideration was limited to compliance with the law and EQ protection until 1986, when the Corps was first authorized to improve EQ.

The 1986 authority was limited to Corps projects and was widely viewed as a means for compensating for EQ losses at projects built before NEPA. The authority allowed any means for

repairing significant environmental damage, whether or not the value is monetizable, and was more consistent with NEPA process than with the ecosystem restoration and protection authority that followed ten years later. The evaluation latitude of the 1986 authority predisposed project planners to accept broader project investment justification criteria than was directed by the Corps project planning regulations, or Planning Guidance Notebook (PGN), after its revision in 2000.

Until 1996, when the new ecosystem restoration and protection authority was issued, all authorized Civil Works purposes promoted economic development and compensatory mitigation for significant EQ losses. Corps personnel were predisposed toward economic development and mitigation. Revision of the PGN in 2000 did not completely resolve that problem. The somewhat disarticulated and incomplete organization of the PGN and contradictions in the regulation establishing the ecosystem restoration purpose have often led to inconsistent interpretations of the ecosystem restoration program objective.

PGN deficiencies contributed to the failure of Corps planners to uniformly recognize the importance of protection in the ecosystem restoration and protection authority. Protection is defined in terms of heritage in a paragraph about National Economic Development (NED) in the section on the federal project planning objective, but neither protection, nor sustainability, or heritage are mentioned explicitly as essential aspects of the National Ecosystem Restoration (NER) aspect of the federal project planning objective. In a separate section, the PGN clearly indicates that the desired ecosystem condition is self-regulating, one which will sustain benefits for the longest possible time. In an entirely different chapter, sustainability of biologically desired species and biodiversity are emphasized in indicators of study objective achievement. Yet the PGN does not clearly state that future generations are to be served by the long-term sustainability or indicate how the authority connects to the heritage preservation goal of NEPA.

The rationale behind the nonmonetary measure of justifying benefits required from restoration projects is not clearly explained either. The PGN separately prohibits monetary measurement of nonuse value because the economic method is of questionable reliability, but it fails to link nonuse value to the nonmonetary measurement of ecosystem restoration benefits or to national ecological heritage. Confusion over the program objective delayed development of better metrics. The PGN allows any physical or index indicator of benefit for plan evaluation except money. Different metrics have proliferated doing little to clarity the objective or its achievement. In addition to many specific problems with those metrics, metric proliferation has complicated project planning quality control and communication among partners, stakeholders, and reviewers, including the Office of Management and Budget (OMB). The different metrics do not indicate relative value and cannot be compared to determine each project's relative contribution to national welfare because different indicators and habitat needs are required at different sites.

Feasibility studies have improved, but indicate continued misinterpretation of the ecosystem restoration program objective and a lingering tendency to accept broader criteria for objective achievement than policy guidance allows. This tendency is reinforced by pressures from nonfederal project sponsors, who must share project costs, and a perceived need for authorized projects to sustain Corps revenues. The required nonfederal sponsor, who is not always that concerned about the national interest, reduces the program-area success based on national ecological heritage preservation. While Corps understanding of the program objective has

improved, objective achievement measurement remains a problem. Too many different metrics are used, often with unclear connection to the objective. The Biodiversity Security Index was designed to address deficiencies and continues to be developed within the Corps. It is based on the restoration of viable populations of nationally unsustainable species that more precisely indicate a more sustainable ecological heritage held in the distinctive attributes of the species. The intent is to use unsustainable species as indicators of all ecosystem characteristics needed to sustain native biodiversity at the national level. The supporting ecosystem needs are identified through calibration of a risk management term in the metric. The BSI is comparable across plans and projects because species population scarcity and risk-management effectiveness are indicated in universally applicable terms. BSI acceptance faces resistance that originates in the diverse interpretations of the mission objective and reluctance to adopt new approaches.

Budget trends, aging infrastructure, and commitments to completing projects in progress are likely to dampen the rate of new restoration project authorizations. The inflation-corrected Civil Works budget decreased from a high in the early1970s and, with the exception of supplemental funding, has varied about 20 percent without much net change over the past three decades. The Operation and Maintenance budget has increased while General Investigations, Construction, and programmatic budgets have decreased. Restoration has remained near 10 percent since 2001. Increasing demand for infrastructure repair and rehabilitation has increased competition for scarce budget and restoration projects have accumulated in a backlog recommended for construction. An increasing number of planned projects are part of long-term multi-project regional programs with a restoration purpose or a combination of purposes including restoration. Recent emphasis on Corps infrastructure repair, rehabilitation, and other priorities has displaced some investment in new projects since 2010.

Corps cultural trends have influenced rates of acceptance of the Corps environmental mission and its restoration capabilities. They have been influenced by increasing agency decentralization, accountability demands, diversification of purpose and disciplines, and emphasis on systems management. Largely as a consequence of these trends, the Corps has become more open to collaboration, more sensitive to the broader impacts of its activities on the environment and society, and more restoration capable. Despite improvements, Corps history continues to influence suspicions of its environmental motivations. The Corps continues to identify deeply with its civil engineering past and, while improving significantly, remains better at implementing traditionally engineered measures than a broader array of management measures. Corps acceptance of the mission was slowed by concern over the need for new capabilities, given a limited budget. While the Corps emphasizes sustainability, the required transfer of restored ecosystems to nonfederal maintenance and may hamper full acceptance of restoration output sustainability and heritage preservation as a Corps responsibility.

Future Forces, Trends and Outlook

Unless there is a major change in the public resistance to increased taxes and mandated federal spending, the Corps can in general expect total program funding similar to the past three decades, largely because major infrastructural repair and rehabilitation needs are growing. Trend shifting forces depend largely on economic conditions and how Congress deals with past public intransigence over taxation and federal social security mandates.

Trends suggest that most future restoration done by the Corps will be part of regional water resources rehabilitation efforts and new individual restoration projects will be fewer. Because of established commitments, multi-project regional rehabilitation programs are increasingly likely to dominate the Corps agenda for decades. With some exceptions, new project starts outside existing regional programs are likely to give way to repair, rehabilitation and backlog-reduction needs. This seems most likely even though rehabilitation of other regions may potentially contribute more beneficially to the Nation. A possible trend shifter could occur in Congress as membership changes and demands for other projects supplant the ones now on the horizon.

The extent to which future ecosystem restoration by the Corps contributes significantly to national ecological heritage maintenance depends largely on how carefully projects and regional programs are systemically planned with heritage preservation in mind. But the effectiveness of an ecosystems approach is limited by Congressional influence and by insufficient personnel capability, planning guidance, technological support, and strategic planning. A national assessment of water resources rehabilitation priorities, including restoration, could significantly improve the ranking of investments for annual budget requests. The extent to which internal insufficiencies are addressed is likely to depend more on Corps internal funding decisions than on increased federal budget over the foreseeable future.

How much weight will be placed on heritage restoration and protection versus economic development is difficult to judge because of the subjectivity of the tradeoffs involved and changing political pressures, which right now tend to favor present welfare over future welfare. Recommendations for project inclusion in the federal budget, may favor traditional Corps purposes over ecosystem restoration investment because of the continued disposition of the Corps toward structural engineering used in traditional project purposes, the methodological uncertainties of restoration projects, and a confusing NER objective. On the other hand, restoration projects are attractive to nonfederal sponsors in part because they do not have to meet a clear benefit-cost standard and the objective can be interpreted more broadly than intended. A clear objective focused on heritage restoration and protection is likely to reduce the field of interested nonfederal sponsors while concentrating on those that are serious about the mission. While program size may decrease objective achievement may actually increase.

The positive forces and trends operating to increase program-area success over the next several decades include: a) growing public awareness of human impact on aquatic ecosystems; b) increasing scientific and public awareness of threats to native biodiversity; c) growing recognition of the insufficiency of protection strategies alone; d) a two-thirds federal contribution to the total project planning and implementation cost; e) growing Corps awareness of a need to clarify the ecosystem restoration program objective and achievement measurement; f) improved Corps bridge building with other organizations; g) increased Corps emphasis on an integrated, collaborative, systems approach to planning; h) increasing Corps effort to improve and integrate ecological, economic, and engineering knowledge; and i) increased professed commitment of the Corps to environmental quality protection and improvement.

More numerous negative forces and trends continue to operate against the long-term success of the restoration program. They include: a) growing competition for limited public funding; b)

continuing OMB, project partner, and internal confusion over ecosystem restoration program purpose, objectives, and metrics for achievement; c) possible capping of the ecosystem restoration budget; d) continuing nonfederal pressure to apply the program to problems inconsistent with the authority; e) insufficient documentation of success; f) uncertainty and risks associated with global climate change and other effects; g) growing public scrutiny and criticism of the Corps ecosystem restoration activities; h) persistent Corps predisposition for project-centered engineering and economic gain; i) possible decreases in federal contribution to project cost or conversion to a grant program; k) insufficient systems thinking and technical guidance; l) continued legal constraints on full Corps embracement of ecosystem sustainability and heritage maintenance; and m) erosion of the heritage restoration and protection focus by new law.

The outlook for the Corps ecosystem restoration program area depends on trends and forces that the Corps can control or influence, and others beyond its influence. The Corps has little or no control over the large-scale forces and changes in the economy, society, politics, and environment that could have great influence on program outlook. Those trends indicate even greater restoration needs and complications in the future, as well as economic issues that may impede restoration investment in the interest of future public welfare. But the Corps can improve program objective statements, policy guidance, benefits metrics, guidance for integrated and collaborative systems approaches, success stories, and public communication, although tough decisions may be required to redistribute funding internally. The Corps may be able to positively influence agency collaboration, systems-oriented research and development, and a new authority favoring a nationally coherent, systems approach to integrated resources management, including ecosystem restoration, if it can demonstrate greater cost effectiveness.

Even with internal improvements, successfully achieving the ecosystem restoration and protection objective, as it is interpreted here, may not guarantee program funding success because of forces outside the Corps. It is doubtful, however, that favoring those nonfederal sponsors with economic development in mind will guarantee funding either, because of the growing competition for tightening federal budgets and public oversight. The trends and forces are complex and various, and the outlook is uncertain despite the need for ecosystem restoration. But the program is young, the Corps is learning, and it has options that could improve chances for long-term success. That may not mean a larger restoration program, but, perhaps, a more effective and sustainable one. Success is likely to hinge on how well the Corps can master a regional, multi-project, systems approach that can adapt to global environmental changes.

Like all other environmental agencies, the Corps faces a difficult future, challenged by growing infrastructural problems, a public that has minimal insight into those problems, a Congress and President besieged with many pressing issues, environmental changes that grow in complexity, and never enough budget to meet all needs. Among the most difficult of its challenges is determining the proper balance to recommend between rehabilitation of resource use now versus restoration and preservation of intact ecosystems for the resource options they sustain well into the future. The Corps can only recommend, but it may have substantial influence on decisions.

Introduction

Study Purposes and Limitations

Public interest in ecological restoration has grown in response to past environmental degradation of valued ecological services. In 1996, Congress authorized the U. S. Army Corps of Engineers (Corps) to improve environmental quality (EQ), as first defined by the National Environmental Policy Act (NEPA), using aquatic ecosystem restoration and protection measures. The program grew rapidly before recently leveling off. Despite demonstrable need at global to local levels, many trend-shaping forces are likely to limit future success. This study assessed the trends and forces potentially affecting the success of the Corps aquatic ecosystem restoration program over the next 30 years, as indicated by program objective achievements. They document widespread and profound degradation and restoration needs as well as impediments to restoration success.

This report is intended for use in Civil Works strategic planning, but may of value to anyone interested in program direction, including readers from outside the Corps who may not be very familiar with the Corps Civil Works Program. Consistent with its strategic focus, past and future program-area success was gauged by achievement of the program-area objectives described in Corps authority and policy guidance. The achievement of program-area objectives serves as a basis for Corps evaluation of program success and ranking projects for relative investment priority. The form and amount of national benefit intended from program investment was a primary consideration in this assessment as was the availability of funding. Future program achievement depends on managing threats to the mission and building and maintaining stakeholder support by performing effectively.

The Future Directions Program at the Corps Institute for Water Resources funded this study and outlined its scope, which required a comprehensive review of trends and forces at global, continental, and regional scales as well as in federal government and the Corps Civil Works Program. The scope of work stipulated that all scales of past and possible change from global megatrends to regional trends in the United States and trends within federal government and the Corps be considered to an extent relevant to the outlook assessment. While megatrends and forces are not likely to be influenced much by the Corps, they can have substantial influence on the future direction, size, and effectiveness of the aquatic ecosystem restoration program area. Regional trends and forces inform the Corps about areas within its national jurisdiction with greatest potential restoration need. Trends and forces within federal government could indicate changes in the federal context of the Corps Civil Works Program, which the Corps needs to anticipate to manage the program area most effectively for success. Trends and forces within the Corps Civil Works Program are among those amenable to Corps control and were therefore especially important in this assessment of program-area outlook. This emphasis is consistent with identifying those trends and forces that the Corps ought to be aware of strategically, may be able to influence, and can definitely influence.

The report scope and analyses were limited by the quality and amount of information available for the assessment. Significant uncertainties are reflected in the discussion of past interactions between forces and trends and their effects on future outlook scenarios. Except for some

environmental megatrends, quantitative trend analysis is limited by sparse data. That limitation includes the short time frame over which restoration-program trends can be assessed. The discussion emphasizes the more likely trends, forces shaping trends, and trend-shifting events. But forecast likelihoods are unavoidably subjective and uncertain.

This problem is not unique because of the complexity of interactions among social, economic, political, technological and environmental forces operating on trends. In fact, too much reliance on quantifiable trends may miss more relevant history. For those reasons, the discussion of trend and force interactions, and future possibilities, often may be more valuable than future forecasts. Except for the most reliable projections, a scenario approach to describing different possible futures is more generally favored. The report concludes with summary observations and recommendations about how the Corps may act to shape program-area outlook. These issues and caveats were discussed with and accepted by the manager of the Future Directions Program at IWR.

Corps Aquatic Ecosystem Restoration and Protection

The aquatic ecosystem restoration program area of the Corps has had a short but complex history preceded by a much longer period focused on very different economic improvement missions. Some knowledge of that history is necessary to understand the intents of this outlook assessment (more detail is provided in the authority and policy sections of the report section that addresses Corps program trends). In 1996, Section 206 of the 1996 Water Resources and Development Act (WRDA) authorized the Corps to carry out aquatic ecosystem restoration and protection projects anywhere, as long as they cost-effectively improve environmental quality (EQ) in the public interest. Other law requires Corps project cost-sharing with a nonfederal sponsor. Section 2020 of the 2007 WRDA modified Section 206 slightly by explicitly including the elements and features of estuaries among the conditions to be restored and protected.

The protection aspect of the restoration authority was a major change for the Corps focus on beneficial use of water resources because it focused on setting aside a restored aquatic ecosystem condition from incompatible use for an indefinitely long time. The Corps definition of environmental protection in planning guidance came from the National Environmental Policy Act (NEPA). It established the concept of EQ in federal law and the need for EQ protection and improvement actions to benefit Americans, both immediately through provision of safe, healthful, and otherwise beneficial use of the environment and by preserving important cultural and natural aspects of national heritage for future generations. In the context of the policy and goals of NEPA, the EQ protection aspect of the new authority implied that the justification for project investment is restoration and protection of degraded national ecological heritage sustained in native biodiversity and the potential for continued diversification.

The signing of NEPA into law in 1970 established environmental policy and goals for all federal activities and a federal interest in restoring and maintaining EQ. Since then, all federal projects have had to be planned with NEPA policy and goals in mind. The NEPA concept of EQ protection and improvement is focused on human welfare maintenance and improvement and, through its goals, promotes safe beneficial use of the environment while preserving the diverse natural and cultural aspects of national heritage for future use options. A year after NEPA was

passed; Congress amended the Water Resources Planning Act (WRPA) to include a national EQ protection and improvement objective for all federal water resources project planning. To be consistent with NEPA goals and WRPA objectives, all Corps projects must consider protection of important natural and cultural aspects of national heritage as they improve EQ through development of beneficial resource use or through ecosystem heritage restoration and protection.

Congress requires that the benefits of all Corps civil works projects at least equal the costs. The benefits that justify ecosystem restoration investments differ from benefits expected from traditional economic development projects (e.g., navigation, flood risk management). The Corps Planning Guidance Notebook (PGN, USACE 2000) requires the value added by economic development for beneficial use of water resources to be measured in monetary units, consistent with federal guidance (WRC 1983) for water resources project planning authorized by WRPA. In contrast, ecosystem restoration and protection must not result in economic development measurable in monetary terms and must instead be quantified in physical units or indices for investment evaluation during the planning process. This requirement is consistent with a PGN prohibition on measurement of nonuse value in monetary units because the existing method is unreliable (USACE 2000). Nonuse value results from the protection of desired resources from destructive use and includes option and bequest value intended to benefit future citizens (see OMB 2003, NRC 2005a, and Cole 2014a) for discussion of use and nonuse value).

The indefinite protection of the restored ecosystem resources is the management measure that preserves the bequest value of ecological heritage restored from an unsustainable to a sustainable state. Numerous other statutes allow ecosystem restoration measures to be used at Corps projects, but only the 1996 statute explicitly limits EQ improvement to ecosystem restoration and protection measures. Corps economic development authorities allow a wide range of management measures to be considered during planning, including ecosystem restoration (such as floodplain restoration for flood risk management). In such situations, incidental heritage benefits normally do not count toward justification of the economic development purpose, but may be considered during plan selection when plans have similar economic benefits.

The Section 206 authority is the basis of the ecosystem restoration purpose as defined in Corps guidance and the NER aspect of the federal water resources project planning objective. The PGN applies broadly to Corps projects with an ecosystem restoration and protection authority—from small continuing authority projects (less than $7 million each) to individually authorized and multi-project regional programs amounting to billions of dollars in potential investment. Like navigation improvement and flood and storm risk management, ecosystem restoration and protection is a primary purpose of Civil Works, which may be carried out independently or in multipurpose projects.

Being as big a change as it was, the understanding and integration of the ecosystem restoration program area into Corps activities have been far from issue free. Past feasibility studies revealed confusion over the objective of ecosystem restoration and protection and the extent to which restoration could be justified by resource use benefits measurable in monetary terms. Many planners did not seem to understand why nonmonetary measurement was required and do not recognize the relevance of ecological heritage. The reasons are complex, but probably derive in part from planner predisposition toward economic development benefits and to poor articulation

of the restoration program-area objective. Confusion over the objective has influenced project ranking for priority in the annual budget process. Unique aspects of Corps authority and policy probably contribute to confusion outside the Corps. Most agencies other than the water resources agencies have broad restoration authorities for beneficial use and/or heritage preservation and have not been required to separate out and monetize use benefits. The report section on past Corps trends discusses factors contributing to the confusion.

Because of pent up demand and other reasons described later in the report, the ecosystem restoration and protection program area has grown rapidly in number of project starts and the federal budget allocated to feasibility study and construction. While that rapid growth suggests a bright future, numerous forces are acting even now to dampen further growth. Some forces may come from outside the Corps while others are internal.

Report Organization and Approach

The organization of this report reflects the interest expressed in the hierarchical influence of global, continental, regional, federal and Corps Civil Works Program trends and forces on the future aspects of the ecosystem restoration program area for strategic planning purposes. To accommodate more selective interests, executive summary and major conclusions are provided and each major section is summarized in a brief overview. The report 1) identifies and describes various social, technological, economic, environmental, and political "megatrends" and forces that may adversely affect ecosystems and their restoration over the next 30 years; 2) discusses the impacts and implications of the trends and forces regionally —especially with respect to the federal roles and responsibilities; 3) reviews trends and forces pertaining specifically to the evolution of the ecosystem restoration mission within the Corps; and 4) discusses the implications of trends and forces for the future of the Corps ecosystem restoration mission.

From the outset of this study, the outlook for the ecosystem restoration and protection program area appeared to depend largely on four major groups of trends and forces: 1) scientific perception of needs for sustaining public welfare, 2) public and Corps perception of a national need for ecosystem restoration and protection projects of any kind, 3) public and Corps perception of Corps program success in meeting the perceived national need, and 4) competition among agencies for a limited federal budget that must provide for many more diverse needs than those addressed by the ecosystem restoration and protection program area. These groupings largely shaped the search for and analysis of historic trends and forces at all scales of the assessment from global to organizational.

Past Global and National Environmental Trends

Overview

The environmental impact of humans is a function of population and technological growth. Human impacts were very limited, but identifiable in prehistoric evidence nearly 50,000 years old (Rule et al. 2012). Virtually all parts of the global ecosphere are now noticeably influenced by humans and most of the changes have been beneficial, judging by the rates of population growth and accumulated human wealth. However, since the organization of the United Nations

after World War II, international concern for human welfare has grown as the supply of environmental resources has failed to keep pace with needs in many areas of the world. High population growth rate and uneven distribution of material resources and educational opportunities stand out among identified causes. World-wide sustainable development that addresses these and other issues is now a priority international goal.

There is general agreement among environmental scientists that human activities physically and chemically transformed the global environment; exploitation of forests, fisheries, fresh water and other natural resources in many parts of the world is unsustainable; and species loss to extinction has accelerated (Travis and Hester 1991, Cohen 1995, Jackson et al. 2001, Brown et al. 2005, Millennium Ecosystem Assessment 2005, IPCC 2007 and 2014, Dawson et al. 2011). There is less agreement about the causes, solutions and, most recently, the implications of accelerating global climate change. Numerous ecologists and economists believe that the World's environmental or ecosystem services have been significantly compromised by human impacts. Yet the services dependent on renewable resources often can be restored to a sustainable state as long as the productive elements remain extant (Suding 2011). Species sustainability is a commonly used "canary in the mine" indicator of potentially damaging change to the productive base. The rate of net species loss is estimated to be at least 100 times what it was before the industrial revolution and accelerating climate change is expected to increase it dramatically (Cole 2009). The cumulative impacts of local land, water, and atmospheric change have reduced area of suitable habitat for many species to a fraction of what it once was. Global climate change could reduce it to the point of extinction for many species. For that reason, protection of what is left is not enough. Ecosystem restoration will be crucial for sustaining the integrity of the Nation's ecosystems.

In the United States, actions taken to reverse past environmental impact trends advanced most rapidly during the 1970s, when the federal government passed a number of comprehensive environmental laws. Those laws remain intact, but the rate of new environmental legislation output has slowed to a trickle. While the public continued to support investment in environmental improvement over economic expansion under generally good economic conditions (Greenberg 2004), more recent concerns about a faltering world economy have weakened environmental support (Gallup 2010). Sustained economic improvement appears to be the key to continued commitment to environmental improvement in the United States and elsewhere.

Ecosystem management is among the latest strategies used to achieve sustainable development in the United States where it came about in response to NEPA, the Endangered Species Act (ESA) and other law that encouraged a more holistic approach to sustaining and developing ecological resources for present and future utility. The Corps is among the few federal agencies explicitly authorized to apply ecosystem restoration and protection approaches to resource management, but many have broad management authorities that allow ecosystem restoration measures to improve human welfare. The Environmental Protection Agency (EPA) promotes ecosystem-based management, including restoration, wherever possible. Ecosystem management is now considered the conceptual but challenging core of increasingly large and collaborative regional approaches to resource management. While it shows potential, ecosystem management is

complex, frequently misunderstood, and fraught with uncertainties that require a rigorously applied adaptive approach (Grumbine 1994, Franklin 1997, Meffe et al. 2002).

Environmental Impact Trends

Population and Environmental Impact

The future of the Corps ecosystem restoration program is influenced by global and continental environmental trends that are broadly described here. The growth of human impact on the environment is reflected in the rapid growth of the human population (Figure 1). But the total impact of humans is a function of technological growth as well. The complex play of positive and negative interactions between population growth and technological growth has so far resulted in net positive growth in human welfare (although unevenly distributed), but is ultimately likely to be limited by natural resource constraints (Cohen 1995, Lee 2011).

Population numbers were nearly stable for millennia and then accelerated rapidly during the transition from foraging to agriculture from 11,500 to 3,500 years ago (Boquet-Appel 2011). The world population increased from about 6 million before the agricultural revolution to about 7 billion today. During recent history, the world population growth rate accelerated during the past half century (Bloom 2011), but more recently began to decline (Lee 2011). While population growth appears to have been beneficial overall (Bloom 2011), the beneficial trend has not been consistent among local populations (Diamond 2005).

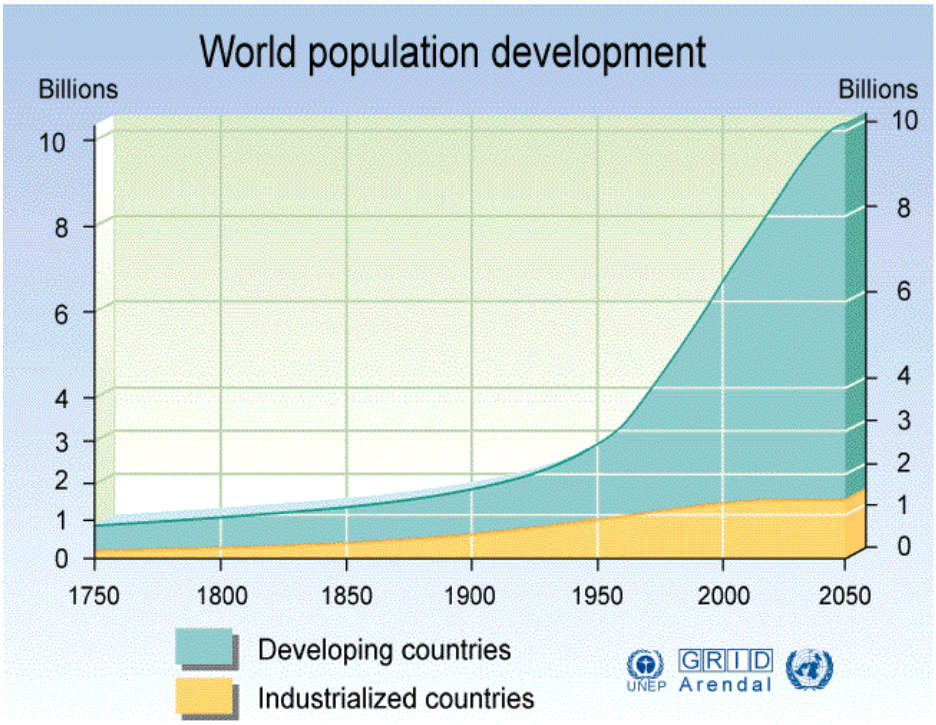

Figure 1. Estimated past and projected world human population growth (from UNEP/GRID-Arendal 2010 http://maps.grida.no/go/graphic/world_population_development).

Environmental history repeatedly reveals how different cultures left too little to sustain essential resources. The fates of these cultures may be warnings of a more universal setback for an increasingly global society (Diamond 2005). Contemporary humanity is better informed, yet lags continue to exist between environmental impact and awareness of possible consequences and effective countermeasures. Environmental impacts have grown to global dimension and intensity great enough to influence the geological record, leading some scientists to propose a new geologic epoch named the Anthropocene (Zalasiewicz et al. 2000, Vince 2011, 2014.

Slowed world population growth rate in recent decades appears to be an outcome of increased human welfare and education (Bloom 2011). In the common model for explaining 20th century population trends, medical, nutritional, and other technological improvements reduce mortality, which is quickly followed by increased population growth rate and by educational and economic improvements that later result in decreased birth rate and population growth rate. This model of the mechanisms behind high population growth rate has spurred significant investment by the developed nations in the health and other welfare improvement of less developed nations. The model's validity is a basic assumption of the United Nations pursuit of world sustainable development (United Nations 1992).

Many different social-economic trends contribute to the growing environmental impact of humanity. One of the most troubling impacts is particularly relevant to the ecosystem restoration mission of the Corps—the decline and irreversible loss of aquatic ecological heritage. An accelerated loss of ecological heritage to species extinction is a consequence of human impact on the ecosphere (e.g., Wilson 1988). The ethics behind this concern vary, but the United Nations is concerned because of the lost potential for resource development and erosion of ecosystem services (WCED 1987, Millenium Ecosystem Assessment 2005). The loss rate over the past two centuries tracks human population growth rate closely. The next sections provide short histories of environmental impact trends and are followed by more specific description of regional trends in the United States and trends and forces operating in the Corps environmental and ecosystem restoration program areas.

Land Transformations

The need for and success of a federal aquatic ecosystem restoration and protection program is profoundly influenced by the condition of the land. A short history of human population growth, dispersal, and technological, social and economic advancement illustrates the progressive impact of humans on the earth's landscapes. By the beginning of the Holocene, over 10,000 years ago, the human population had spread from Africa (Mellars 2006) to all continents except Antarctica. Evidence of direct physical impact of humans on landscapes extends back at least 10,000 years (Stanford et al. 2005, Mellars 2006). Estimated land erosion rate is a general indicator of land change (Figure 2, Wilkinson 2005) and aquatic impact. Global dispersal of humans is associated with advances in hunting, fishing, clothing, housing, transport, storage, utensil, and weapon technology. Population growth rates in hunter gatherer societies were much slower than now, however, and less than a few million people lived on earth before the agricultural revolution (Stanford et al. 2005). Until that time all technological development depended solely on human energy.

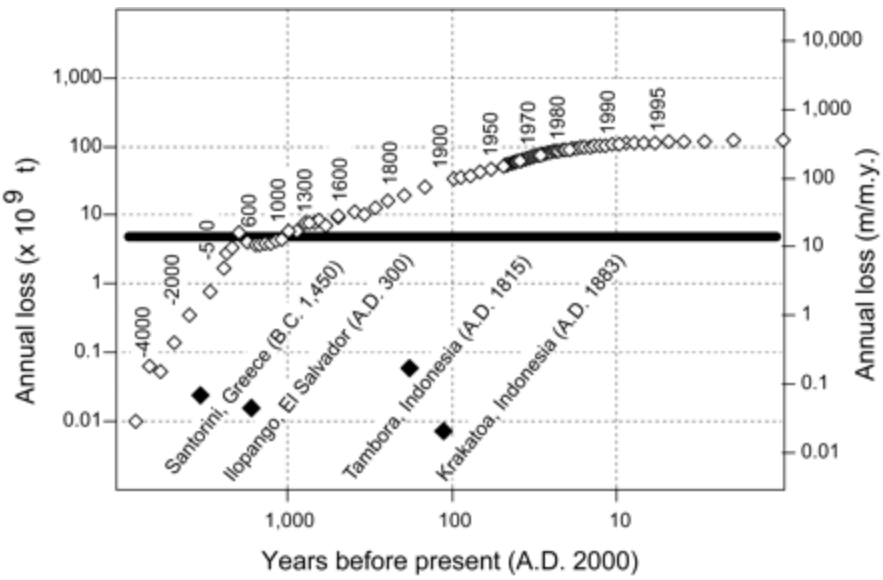

Figure 2. Net loss of land to erosion over the last 10,000 years (from Wilkinson 2005).

The history of human environmental impact may be indicated most reliably by human energy expenditure and materials use and manufacture. As the last glacial epoch passed about 10,000 years ago, humans first harnessed the energy of domesticated animals and established the foundations of modern crop culture. Animals magnified human energy expenditure by an order of magnitude. Agricultural settlement spurred many new innovations in implements, engineered structures, and animals bred to power mills, draw water, and to transport goods and people (Roberts 1993). Metals replaced many stone tools and weapons and woven cloth largely replaced hides and furs. Irrigation, water power, and large wind-powered boats were among the more important innovations.

Agriculture supported rapid population expansion of humans and work animals, which resulted in more power expended, division of labor into areas of specialization, extensive transportation systems, military and police, complex governments, elaborate trade markets, currency based economies, and increased environmental impact. Reliance on wood for fuel needed for heating, cooking, shelter, and implements led to local forest depletion and locally limited human population growth (e.g., Diamond 2005). By the time of the Roman Empire, human caused changes in the landscape were clearly evident. A view from space would have identified a small but significant percentage of altered landscapes concentrated on or near river floodplains and deltas of all of the continents except Antarctica.

Population growth continued in eastern Asia as it slowed in Europe and western Asia during the centuries following the collapse of the Roman Empire (Roberts 1993). As people moved from Asia throughout the Pacific Islands, they left species extinctions in their wake, including the Moa in New Zealand and several Hawaiian bird species. Growth and technological advance resumed in Europe during the renaissance and trade expanded into Asia, Africa, and then to the Americas. The fisheries and forests of Europe were depleted, but improved ships led to new fisheries thousands of miles distant from homelands and to exploration for new sources of natural resource wealth.

Needs for fish, quality timber for ship building and other resources were particularly strong strategic motivations for exploration, naval superiority, and colonization. Fuel wood and charcoal became scarce. By the middle of the 18th century, Europeans had established generally self-sufficient settlements around much of the world's temperate coastlines and trade routes for goods produced in the colonies. Sailors had driven at least two island bird species into extinction by hunting them for meat (the dodo and great auk). Colonial economies were largely agronomic. Industrialization had increased significantly, but was limited by dependency on human or animal labor or on water power.

The rate of fossil fuel use is a good general indicator of change in human environmental impact over the past 150 years. The invention of the steam engine in the late 1700s accelerated the industrial revolution (Oliver 1956), which relied on combustible energy, at first wood then largely fossil fuels. Steam power revolutionized industry and transportation, but also accelerated forest cutting (Holechek et al. 2002). Oil lamps replaced candles, providing more time to advance knowledge. Because lamps worked best with whale oil, whaling became a mainstay industry and whale populations were greatly depressed worldwide before whale oil was replaced by petroleum. Technological innovation led to substitution of one resource for another and established faith in the continued improvement of human welfare as the impact of humanity on the natural world accumulated.

Agricultural development advanced rapidly and, in 1890, Turner (1963) declared the end of the undeveloped American frontier. Disastrous floods, water shortages, forest depletion from cutting and fires, livestock die offs, and depressed wildlife numbers contributed to concern that natural resource use had become unsustainable. The American conservation movement became the federal government's solution to resource exploitation (Hays 1959). It promoted public natural resource ownership and management for the greatest good over the long run. The states prohibited market hunting and regulated personal take of fish and game much more stringently. But numerous species approached extinction and two very abundant bird species—the passenger pigeon and Carolina parakeet—died out by 1918. Other migratory bird species were protected by the Migratory Bird Act in 1916 and active investment in federal wildlife refuges.

Much of the remaining public lands of the United States were set aside for public use and management of their forest, range, water, wildlife and mineral resources (Hibbard 1924, Holecheck et al. 2002). Most the remaining public highlands in the West were set aside in forest reserves to protect water supply. Much of the public land was opened to livestock grazing. Exceptional sites were set aside from consumptive use as national parks. Sale of public lands in the United States ended as a general practice in the 1920s. That left a third of Nation in public trust, which retains most of the Nation's undeveloped lands.

Over 60 % of the land in the United States is privately owned (Lubowski et al. 2005) and the majority of it is at least moderately affected by agricultural and urban development (Sisk 1998). Daily (1995) calculated that about 43 % of the earth's terrestrial vegetated surface had lost some capacity to provide "natural services" to human kind because of unsustainable land use. By the end of the 20th century, most causes for listing endangered species under the ESA were associated with agricultural, urban, and water development (Figure 3).

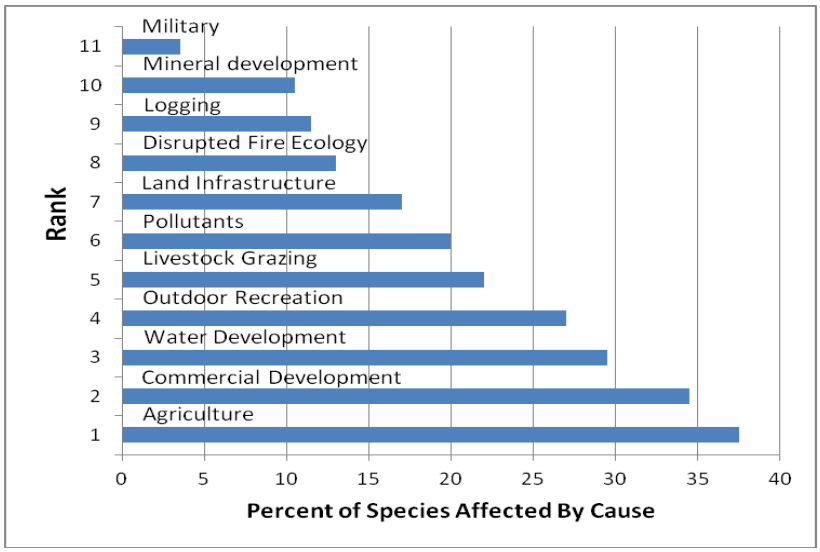

Figure 3. Percentage of species federally listed as threatened and endangered by habitat degradation from various sources of human activity in the United States (modified from Wilcove et al. 2000).

Water Transformations

Trends in the conditions of the aquatic environment are essential knowledge for determining the likelihood of aquatic ecosystem restoration success. Land transformations by forest cutting, crop production, overgrazing, and urban development contributed largely to profound freshwater and estuarine changes in the United States during the 19th century (see Cole [2009] for a review pertaining specifically to freshwater resources development). Accelerated erosion was widespread and extreme in areas of highly erosive soils. Stream sedimentation also accelerated and intolerant freshwater species began to disappear. Organic pollution by riverside cities was common place. Drought intensified the environmental impacts on many freshwater species. Many river reaches became too warm, silted and depleted of oxygen to sustain intolerant fish and shellfish. Submerged aquatic vegetation—once common in many rivers, lakes and estuaries—began to disappear. For the most part, the impacts of water resources development were minor compared to other early sources of degradation, but became increasingly significant (Cole 2009).

The Corps began to remove snags from waterways in the early 1800s then began to dredge shallow channels through shoals. By the late 19th century, the Corps had developed shallow-draft waterways in many tributaries to the Mississippi River and in other rivers that flowed to the coast. The role of water resources development in freshwater species imperilment grew more rapidly during the 20th century when other federal water resource agencies were created. The widespread construction of 9-foot waterways and large water supply and flood control reservoirs left little naturally flowing habitat in the larger rivers where many unique fish and mollusks lived. Except for salmon and a few other species, they were not valued much for food or sport and largely overlooked. Fish ladders had been pioneered in the early 20th century to sustain migratory runs of commercially and recreationally valued anadromous species. The combined

impact of dams, suspended sediment, oxygen depletion, toxic contaminants, biological contaminants, temperature alterations, hydrologic changes, and introduced invasive species reached a peak in the 1950s and 1960s (Cole 2009). Little was done to counter imperilment of many freshwater species until the ESA was passed in 1973.

State and federal governments responded to unprecedented public pressure to reform natural resource management through environmental legislation passed during the 1960s and 1970s. In general, the control of "end of the pipe", point-source pollutants rapidly reduced chemical and biological contamination, including materials causing oxygen depletion. Human health threats were greatly reduced, but significant threats to ecosystem vitality remained untreated. Dams and other hydrologic impacts continued to increase in number (Figure 4). As a consequence, the Environmental Performance Index, developed to indicate adverse national environmental impacts (Yale Center for Environmental Law and Policy 2008) ranks the United States very high for health (98.5 out of 100) and comparatively low for ecosystem vitality (63.8). The United States is ranked 39th from the top performance among nations for its record on ecosystem impacts, mostly because of contributions to global warming.

Aquatic impacts originate largely from diffuse sources, including agriculture, urban runoff, and physical alterations of hydrologic process (EPA 2008). Water resources development has continued to reduce the geographical area of undeveloped aquatic ecosystems and contributed to a decline in species (Figure 5), although at a much slower pace of conversion than during the 1930s to 1960s.

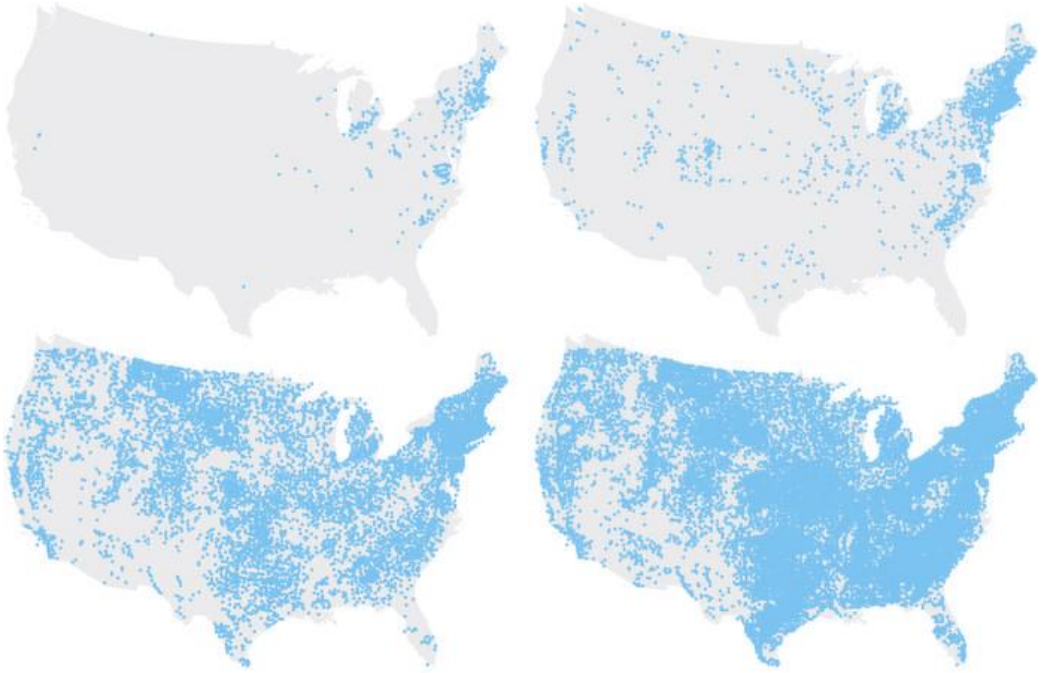

Figure 4. Relative numbers and locations of U. S. dams and reservoirs in 1850, 1900, 1950 and 2000 (from Vince 2011).

As indicated by species decline and disappearance, the impacts on freshwater ecosystems have been several times as harmful as impacts on terrestrial ecosystems (Ricciardi and Rasmussen

1999, Cole 2009). Most recently, however, significant inroads reversing past damage have begun through the planned process of aquatic ecosystem restoration, much of it by the Corps. The decades since 1950 have witnessed greatly accelerated rates of oceanic change via global marine fish harvest, coastal hypoxia expansion, marine biological invasion, and mangrove, sea grass, and coral loss (Doney et al. 2011). Exploitive fisheries have had the greatest impacts on aquatic ecosystems (e.g., Jackson et al. 2001) and indirectly on terrestrial and coastal systems. As a consequence of much reduced harvest in many marine areas, more protein is supplied by mammalian and avian meat or soybeans (Figure 5) and from aquaculture, all of which have their own significant environmental impacts. Over-fishing of the largest marine predators to small percentages of former abundance has reduced their "top-down" influences in marine ecosystems, contributing to profound changes in marine community composition (Myers and Worm 2003). Harvest reductions of estuarine shell fish, which filter prodigious amounts of water for their particulate foods, has contributed to increased water turbidity and reduced production of sea grasses, which sustain threatened species as well as the food-web support for the shell fish. On top of other changes, climate change is affecting sea level, water temperature, ocean alkalinity, oxygen concentrations, and dependent marine species (Doney et al. 2011)

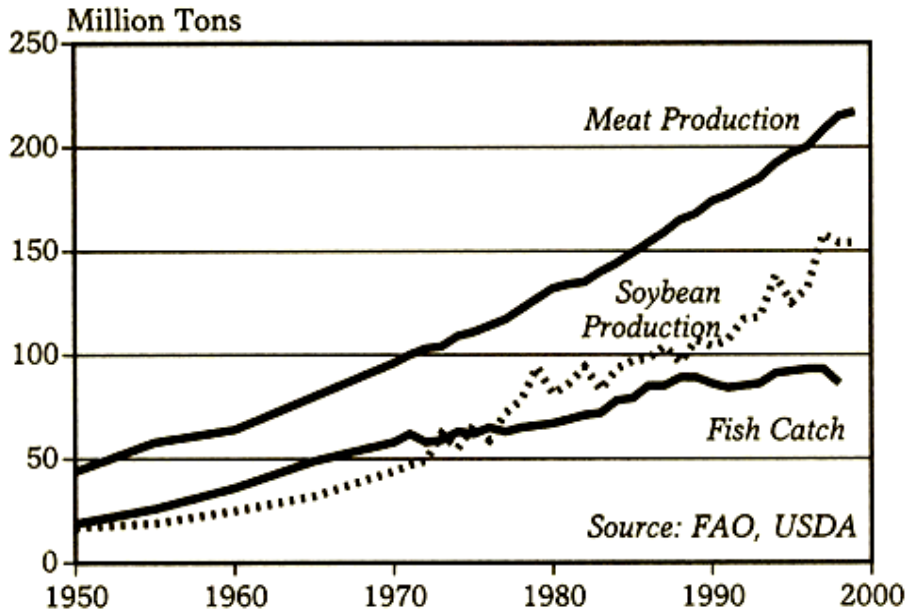

Figure 5. World protein production from various sources from 1950 through 1999 (from Brown et al. 2000).

The complexity of marine ecosystem impacts is illustrated by changes in kelp-dominated ecosystems. Reduction of whale and fin-fish biomass by fisheries in the north Pacific is believed to have caused major changes in kelp ecosystems (Estes et al. 1998). Fish reduction by human harvest probably contributed to decreased abundances of sea-lions. Whales and sea lions made up most of the diet of orcas (a large carnivorous porpoise), which have since switched more to a sea otter diet. The sea otters eat urchins, which feed on kelp and totally consume it when not controlled by predators. The kelp disappeared. Many other species depend on kelp for survival. These types of changes significantly complicate restoration based in habitat improvement alone.

Atmospheric Transformation

Air quality changes became more complicated and costly as many local improvements in recent decades were over-shadowed by global concerns (e.g., Jacobson 2002). The large majority of atmospheric scientists have concluded that human-caused emissions of green-house gasses contribute significantly to rapid global change in air quality and climate (IPCC 2007, 2014). Global warming is expected to have a major effect on the viability of the species numerous species over the next century (Jenkins 2003, Lovejoy and Hannah 2006, Botkin et al. 2007). Global climate changes could have major effects on the planning and success of ecosystem restoration projects. Future trends are extremely important considerations.

Air quality degradation of all kinds, including global changes in green-house gas concentrations, is primarily a function of technological growth fueled by wood, coal, oil, natural gas and other living and fossil hydrocarbons. Centuries ago, air quality was locally degraded largely by burning wood for cooking, home heating, and local land clearing. Impact intensity and extent increased more rapidly as manufacturing and urbanization replaced lifestyles based largely on agriculture. Air pollution increased from local concentrations around manufacturing centers (e.g., Brimblecombe 1987) to regional and global proportions during the industrial revolution, which accelerated coal, oil and other fossil fuel use.

By the late 19th century, poor air quality in American manufacturing centers rivaled that in Europe. Soot sometimes turned mid-day industrial cities as dark as night in the worst places, such as Pittsburg, PA (Stradling 2002). Extremely polluted air caused debilitating and sometimes fatal illnesses. The worst examples became places of last-resort to live and persisted because tenants had little economic choice. Despite rapid growth in clean hydropower during the first half of the 20th century, most power came from fossil-fuels. Rapid growth of automobile use following invention of the internal combustion engine added greatly to fossil fuel emissions (Figure 6) and poor air quality. The greater rate of increase of fossil fuel emissions compared to population increase reflects an increasing per capita impact of energy consumption.

Mortality from air pollutants increased in the United States until the 1950s when serious regulation of emissions began, but implementation of the Clean Air Act in 1970 did more than previous legislation to improve air quality in American cities and manufacturing centers. It did nothing directly to curb green-house gas emissions, however, including, most importantly, carbon dioxide and methane gas, although the EPA has begun plans to regulate emissions. Over the last few decades much was learned about the potential impacts of various gasses and particulates emitted to the atmosphere. Recent science has documented an accelerating increase in atmospheric carbon dioxide since the beginning of the industrial revolution (Figure 6). It contributes to increased atmospheric and oceanic temperature (Figure 7) (IPCC 2007, 2014) and to lower pH of ocean water (higher acidity), which coral and other carbonate-dependent species do not tolerate well. Responses of species to past climate change have been documented for a wide variety of species (Parmesan 2006) and projected changes in green-house gas concentration interacting with past land and water development effects portend major impacts on ecosystems and species (Sala et al. 2000, Schneider et al. 2007). However, model-based forecasts are crude because they do not consider the capacity for adaptation **(**Willis and Baghwat 2009, Dawson et al. 2011).

The limiting impacts of habitat fragmentation are well documented (Ward and Stanford 1989, Collier et al. 1996, Lindenmayer and Fischer 2006)**,** and the potential complications caused by climate change are increasingly being considered (e.g. Opdam and Wascher 2004). Engineered structures—including roads, impoundments, and levees—are often barriers to species movements. Species ranges in the northern hemisphere are generally expected to migrate north and upward along elevation gradients (EPA 2008 and Janetos et al. 2008), but only as far as natural and man-caused barriers allow. Species limited to isolated springs, wetlands, lakes, and habitats isolated by engineered structures have few redistribution options. Many amphibians, for example, are limited so and some are in declines associated with climate change (Cole 2009). Up to a third of all fish species may be lost from the Ohio, Upper Mississippi, and southeastern river basins because of increased drought (EPA 2008). The stresses associated with global climate change have profound implications for ecosystem restoration planning effectiveness.

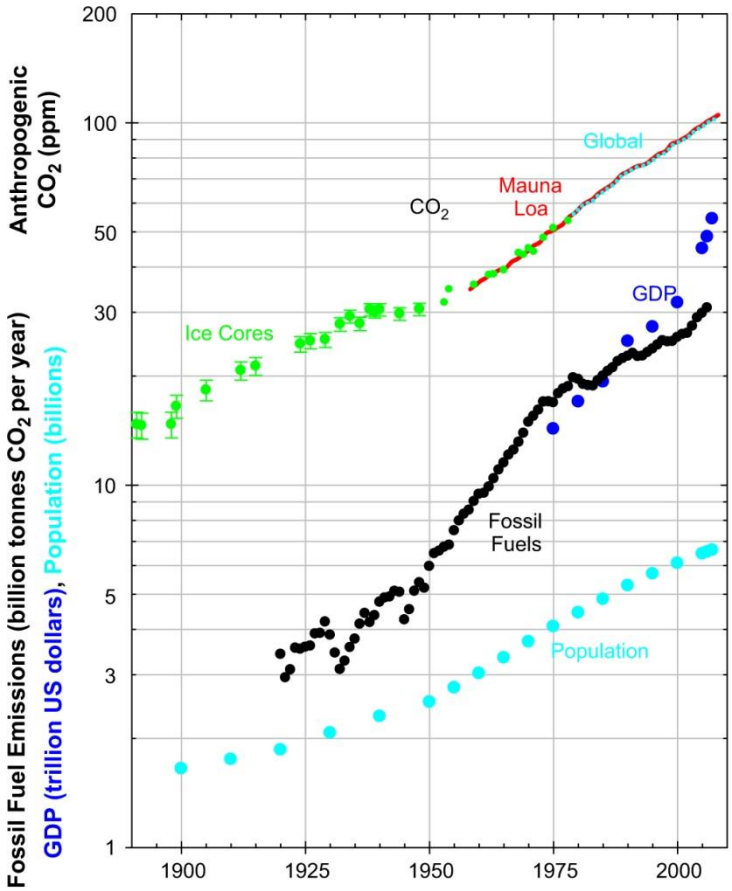

Figure 6. Trends for atmospheric carbon dioxide concentration, global carbon emissions from fossil fuels, world gross domestic product (GDP), and world population number (from NOAA: http://www.noaanews.noaa.gov/stories2009/20090421_carbon.html).

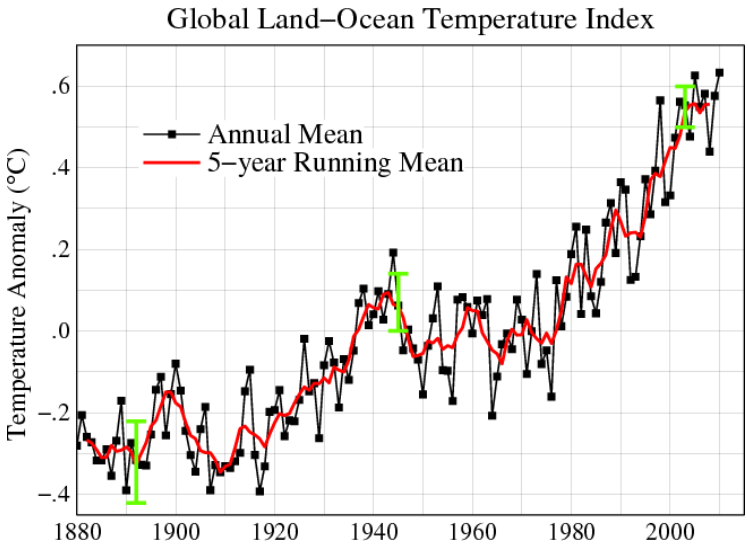

Figure 7. Global average land-ocean temperature index (C°) trend at earth's surface for 1880 to 2010 (from NOAA http://data.giss.nasa.gov/gistemp/graphs/).

Natural Environment versus Novel Ecosystems

The Corps ecosystem restoration program places significant emphasis on restoring ecosystems to a "more natural", self-regulating condition to support reestablishment of desired ecosystem resources. But exactly what a more natural system is now difficult to discern and as is the achievement of a more natural system condition from ecological restoration. Humans have profoundly transformed the natural ecosystems of the earth's biosphere into novel ecosystems that never previously existed (Turner et al. 1990, Hobbs et al. 2006, Hobbs et al. 2013). The causes are numerous, but include extensive land and water use, introduced species, human-caused changes in biogeochemical cycles and climate, widespread distributions of synthetic chemicals, and intense human predation (fishing, hunting, and trapping). The component parts may remain natural and provide natural resources for human use or potential use, but the ecosystems systems that support them are no longer natural and are constantly changing. Even so-called restoration practices contribute to ecosystem transformation by *adding* human effect to simulate a "more natural condition" or by causing new alignments of species and physical environments when human effects are locally removed. Yet many novel ecosystems are locally free of human regulation of the type the Corps makes possible and can be managed to restore a wild state by removing human regulation. The word "wild" is usually used here to indicate a self-regulating, but not necessarily more natural ecosystem state.

Trends toward even more humanly dominated and controlled environments affect the future perceived need for ecosystem restoration. The Millennium Ecosystem Assessment (2005) sponsored by the United Nations estimated that about half of the earth's land surface is now more or less wild. The fraction is likely to decrease to about 30 % over the next 30 years, a percentage already reached in the United States. Vitousek et al. (1986) calculated that over 42% of the world's terrestrial photosynthesis is consumed by humans and their livestock in the 1980s. If increased consumption since then was roughly proportional to the growth in world population,

it has surpassed 60 % since then. These trends explain a lot of the decline of many species to unsustainable numbers (Wilson 1988, Stein et al. 2000, Botkin et al. 2007).

Working for the United Nations, environmental scientists recently integrated numerous indicators of change into a comprehensive index of the human ecological footprint for the world and individual nations (Millennium Ecosystem Assessment 2005). Precisely what these interpretations of impact mean is not always easy to discern, but they do call attention to the weaknesses of past simple economic indicators of human welfare, such as the gross domestic product (GDP). Both world GDP (Figure 6) and the world ecological footprint (Figure 8) show increasing trends over the past few decades. The ecological-footprint trend indicates that world development has been unsustainable for some time and is now at least 25% unsustainable. Figure 9 shows major trends of Living Planet Indices devised to indicate changes in species abundances (Loh et al. 2005, Loh and Goldfinger 2006). Among vertebrates excluding fish, one fifth of all species are classified as threatened (Hoffman et al. 2010). Freshwater species are adversely affected significantly more than terrestrial species in the United States (Ricciardi and Rasmussen 1999, Cole 2009). A "considerable number" of species extinctions are anticipated before 2050 (Jenkins 2003).

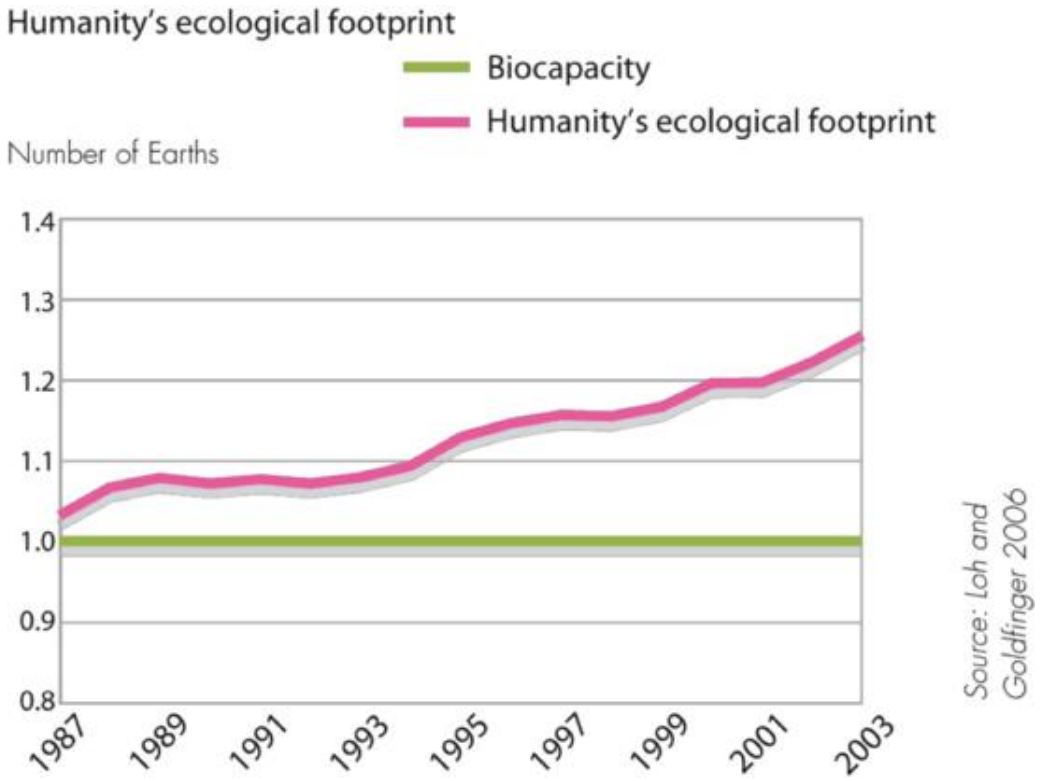

Figure 8. The past trend in humanity's ecological footprint based on the number of earths needed to support the world's population (Loh and Goldfinger 2006; (from the United Nations Environmental Program http://maps.grida.no/go/graphic/humanity-s-ecological-footprint).

Environmental groups also have developed indicators of progress that take sustainability into account, such as the Genuine Progress Indicator (GPI) shown in Figure 10 for the United States.

It indicates that past American progress toward sustainability was slower than the progress indicated by GDP. This assessment is heavily influenced by the estimated impacts of the United States on global warming and on globally unique biodiversity (especially freshwater impacts). The composition of biotic and abiotic elements of ecosystems changed significantly as the land, water and atmosphere changed. Most ecosystems have undergone compositional changes as a direct or indirect consequence of human impact, including climate change, creating many "novel" ecosystems that have never previously existed (Hobbs et al 2006, Williams and Jackson 2007, Doney et al. 2011, Hobbs et al. 2013).

These trends have profound implications for ecosystem restoration based on the notion that ecosystems previously occupying a particular site can in fact be restored as they once were at that location or even to a condition like that of a reference site selected for its more natural appearance.

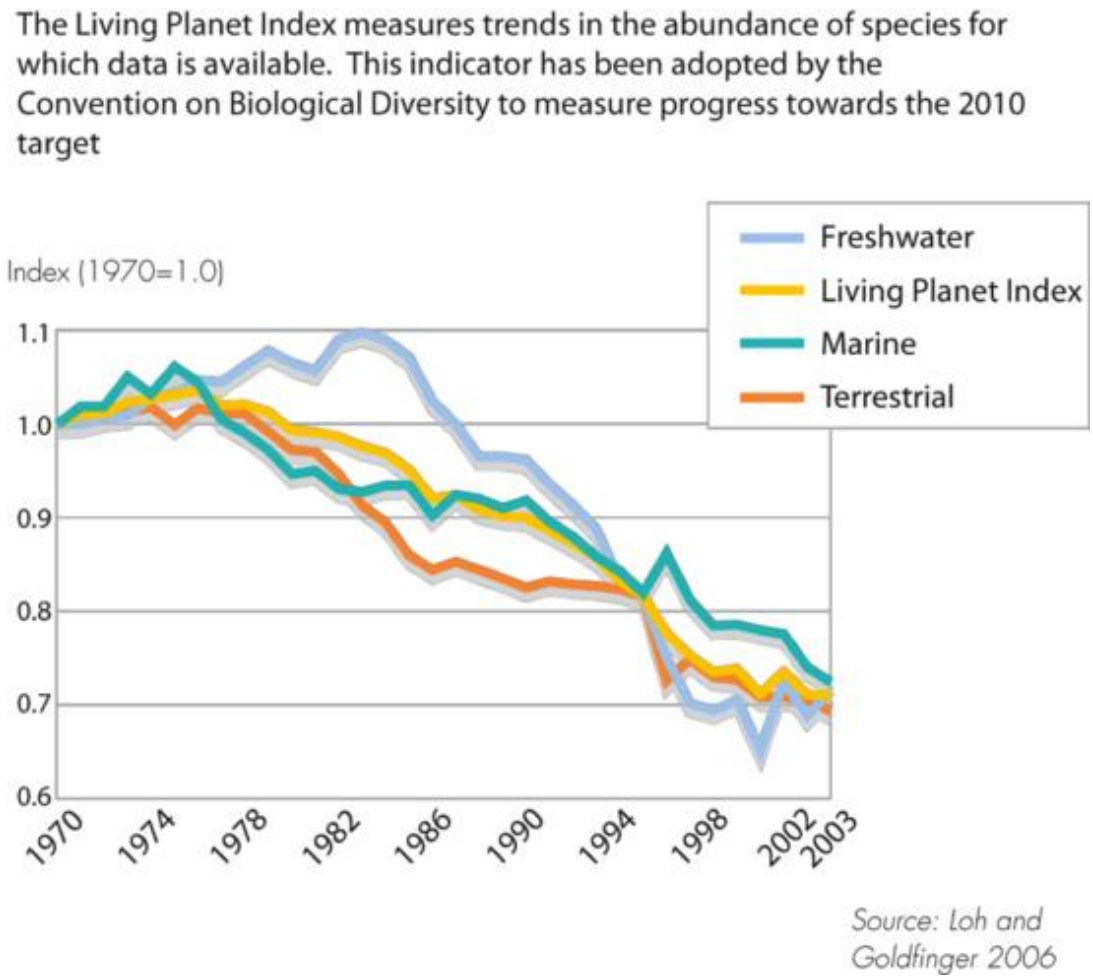

Figure 9. Trends in the Living Planet Index used to indicate the change abundances of the worlds species in terrestrial, freshwater, and marine environments (Low et al. 2005) ((Courtesy of United Nations Environmental Program http://maps.grida.no/go/graphic/humanity-s-ecological-footprint). The index is being used to target biodiversity protection.

The best that can be hoped for is restoration of unsustainable species elements to a sustainable state somewhere in the Nation, thereby sustaining the diversity of ecosystems even as they continuously change. The sustainability of many species decreased as the environmental impacts accumulated. The trends in species vulnerability and restoration science paradigms raise the bar for success and the estimated cost of sustaining an intact ecological heritage.

Environmental Management Trends

Environmental Awakening

Trends since mid-20th century shaped the present outlook for environmental policies, politics, and public concerns. The effects of a worldwide environmental movement during the three decades following World War II dominate more recent and contemporary environmental policies, politics and public attitudes. The environmental movement had deep roots in the Age of Reason during the 18th century when the foundations of contemporary approaches to science in general and natural history in particular were established. In the United States, environmental awareness was significantly influenced by the early 19th century romanticism and philosophies of American transcendentalists (Kline 1997).

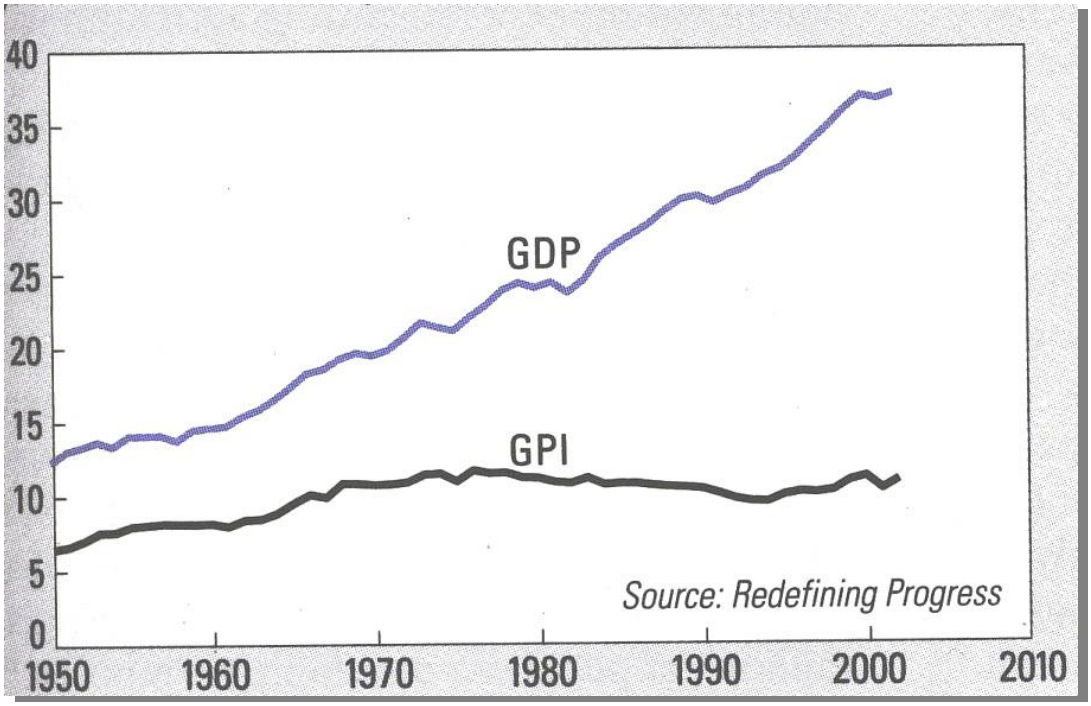

Figure 10. Gross domestic product (GDP) and genuine progress indicator (GPI) for sustainability from 1950 through 2002 (from Mastny et al. 2005).

Before transcendentalism, American relationships with nature and wilderness had been mostly antagonistic, domineering, exploitive, and unexamined in much depth philosophically. Transcendentalism originated in coastal New England where much of the landscape had been cleared for agriculture and settlements. Canals, railroads, and turnpikes were rapidly penetrating the wilderness interior. Led by Ralph Waldo Emerson, transcendentalism integrated nature into a

philosophy of life including the arts, the spiritual and the political. Influenced by transcendentalism, many of the best American landscape artists of the mid-19th century glorified nature in their paintings. The influence of these artists on the most politically influential citizens is often overlooked. Frederick Church, Albert Bierstadt, Thomas Moran and other leading landscape artists could attract thousands to the showing of a single painting (Novak 1995). Nature study, sport-hunting and sport-fishing became common pastimes of the well-to-do and tourism at the margins of the wilderness became respectable and profitable.

Natural Resource Conservation

Even as environmental awareness grew exploitation of natural resources continued to grow rapidly. The environmental destructiveness of the Civil War and accelerated exploitation of private and public natural resources ultimately awakened concern in national leaders, many of whom had been influenced by transcendental philosophy and the arts. Well-to-do sportsmen—among them George Grinnell, a politically influential editor of popular hunting and fishing magazines and founder of the Audubon Society—lobbied hard for improved wildlife, forest, and other natural resource management (Reiger 1975). One of the most influential reformers, President Theodore Roosevelt, made natural resource conservation philosophy a cornerstone of his presidency. The philosophy promoted "wise use "of public natural resources based on a principle of resource production sustainability for the good of the people over the long run (Hays 1959). The public generally welcomed conservation philosophy and the systems of public land and water management that grew from it.

Resource conservation tenets concentrated on the sustained yield of economically valued resources and dominated public resource management concepts for much of the twentieth century. Tempered by accepted conservation practices, President Franklin D. Roosevelt made natural resource development a strategy for recovery from the Great Depression and the extreme drought of middle America during the 1930s. Water resources development accelerated rapidly during that time frame, but was interrupted by World War II. After the war, the concept of resource conservation based on sustained yield of economically valued resources was gradually replaced by a more holistic concept of environment and resource management, which considered the needs of future generations as well as present-day demands.

Environmental Movement

Outdoor recreation grew very popular after World War II. By the 1960s, much of the public had experienced firsthand the good and the bad in environment—especially with respect to air and water pollution. Concerns about environmental poisons spread quickly, fueled by well-articulated assessments, such as Rachel Carson's influential book, *Silent Spring*. Televised investigative reporting was particularly influential. State and federal environmental laws grew rapidly in number and comprehensiveness, peaking during the "green decade" of the 1970s. An influential fraction of the public became more acutely aware of natural heritage degradation and loss, largely in the form of threatened and endangered species and unique landscapes. Growth in this awareness and its importance materialized in the specific wording of NEPA, ESA and other laws that established goals for local, national and world heritage preservation (Figure 11).

But, in the judgment of Hays (2000), many environmental goals established during the environmental movement remained incompletely achieved. He attributed this to resistance from entrenched interests and "general weakness in environmental advocacy from the nation's institutional leaders" who were skeptical about "the worth of natural values in society" (Hays 2000). But Hays believed that skepticism was overwhelmed by public support for "natural values" and how they played a part in consumer preferences. However, he counted a push to reduce consumption among the failures of the movement along with curbing urban sprawl, and national population growth rate. Much of the public has difficulty making hard choices between present satisfaction and future wellbeing.

Environmental concerns among international policy makers have deepened world-wide in response to broad scientific acceptance of the notion that human-caused global change is well underway. But perceptions of economic stress are displacing attention at this time. Policy makers in the United States have been more cautious about climate change, influenced by significant public skepticism. Actions of the Obama administration indicate a commitment to development of a sustainable energy policy and mitigation of impacts from global climate change. As recently as 2014, polls indicated that much of the American public had yet to catch up to most climate scientists and the administration about the potential cost of global climate change (Gallup 2014), probably because the ramifications are far off, politicized by ideologues, and inconvenient for many interests.

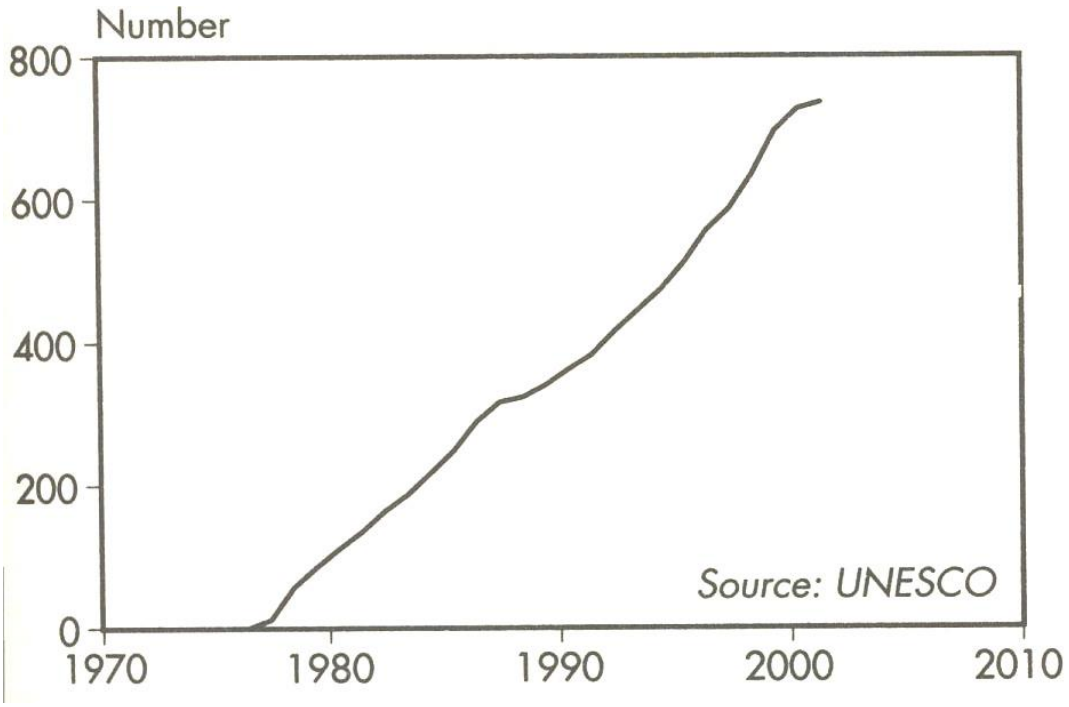

Figure 11. The number of world heritage sites identified since initiation in 1978.

More recent polls reveal increased concern, however (New York Times). Presidential plans for promoting comprehensive legislation aimed at the control of greenhouse gas emissions have been on indefinite hold and are likely to be for some time.

Environmental political action in general has approached equilibrium in the United States in recent decades. Public concerns about the environment indicated in polls over the last 25 years indicated variability depending on the economy, but the environment usually ranked higher in importance until relatively recently (Gallup 2010). Economic and social uncertainty may explain much of the recent erosion of public concern but may also reflect general satisfaction with existing environmental law. Most of the public has consistently supported the goals and execution of existing environmental law despite continuing special-interest complaints about regulatory restrictions. The transformative federal laws passed in the 1970s have stood the test of time with minor modification. Attempts to greatly weaken federal environmental laws have largely failed. Enforcement has varied in intensity with changes in administration and Congress, however, and Congress has rarely been less friendly to environmental regulation.

Ecosystem Restoration

Ecosystem restoration trends have been influenced by trends in land use degradation, environment laws, ecosystem science, ecosystem-based natural resources management, and the concerns of biodiversity conservancies. In general these trends indicate an increasing need to address environmental problems more comprehensively, systematically, and specifically if they are to be effectively managed using restoration techniques. Established paradigms of ecosystem restoration science and practice have shifted markedly over the past two decades as the extent of human impact and resistance to holistic ecosystem restoration approaches have been widely recognized among restoration professionals (Hobbs et al. 2013).

Early History

As originally conceived, ecosystem restoration is a holistic approach to recovering the structural and functional diversity of ecosystems (NRC 1992). The concept grew out of the restoration of specific ecosystem functions that controlled soil erosion and other specific services desired by those who invested in restoration practices. George Washington and Thomas Jefferson recognized soil erosion restoration possibilities, and George Perkins Marsh called attention to deteriorated watershed functions and their restorative treatments (Marsh 1864). Runoff and erosion control planting and protecting rooted vegetation became a management principle over a century ago (e.g., Holechek et al. 2002). About the same time, wetlands were created to replace natural functions in support of waterfowl hunting as wetland habitats were eliminated (Reiger 1975), but not nearly enough to nullify the losses. Starting early in the nation's history, communities acted to restore water quality by ceasing to release pollutants into local waters.

Early Federal Restoration Laws

Federal promotion of EQ restoration as well as EQ maintenance is well established in the environmental goals and policy of NEPA. The procedures for implementing NEPA and the Fish and Wildlife Coordination Act (FWCA) introduced the legal concept of compensatory mitigation, which included restoration among the categories of measures that might be taken to replace damaged environment and habitat in particular. While a systems approach is not mentioned in Corps mitigation guidance, compensatory mitigation became the practical basis for later Corps planning and implementation of ecosystem restoration and protection measures.

Some federal laws that followed in the wake of NEPA are basically restoration laws. Two of the more important ones are the Clean Water Act (CWA) and the ESA. These laws are particularly relevant to Corps activities and have influenced thinking about the Corps ecosystem restoration purpose.

The CWA emphasizes restoration of aquatic ecosystems degraded by waste "assimilation" use to a more useful environmental state. It led to significant reduction of nutrients, toxic materials, suspended particulates, and other water-borne pollutants. The nation's waters, however, are far from fully restored. Contending with non-point sources of contamination through watershed planning and the concept of Total Maximum Daily Load (TMDL) has proved much more difficult than point source controls (NRC 2001a). CWA does not substantially address physical restoration of the Nations waters either, leaving other legislation, including the Corps ecosystem restoration and protection authority, to pursue that role. The laws are complementary and, largely for that reason, Corps ecosystem restoration policy prohibits restoration of water quality that is the responsibility of others to address in compliance with CWA and other law. The Corps plays an important regulatory role in the implementation of CWA by overseeing permitting of wetland fill (Section 404) that is generally consistent with mitigation considerations described under NEPA regulations. Under CWA authority, the Corps has promoted establishment of off-site mitigation banks, the location and dimensions of which often have more potential for preserving ecological heritage than on-site mitigation.

The ESA promotes ecological sustainability through species protection and recovery in the context of supporting ecosystems. The globally unique biodiversity of the United States is in decline, especially in freshwater ecosystems (Cole 2009), and reversing this decline to a sustainable state is one of the greatest challenges for the Nation under the leadership of the federal government. The ESA declares that all federal agencies can and should act, consistent with their authorities, to sustain our national fish and wildlife heritage for future generations. Restoration of species elements to a sustainable wild state is the main strategy for achieving this national goal. The Corps ecosystem restoration program area has great potential for contributing to goal achievement (Cole 2009).

Ecosystem Management

The NEPA and the ESA imperatives to sustain the abundances of species in decline on public lands were major motivations for federal adoption of ecosystem management principles (Temple 1997). Protecting all species from decline as economically valued renewable resources are managed for sustained yields, requires a broad ecosystem approach to natural resource management, including consideration of all species habitat functions. Ecosystem-based management of natural resources (e.g., Harris 1984, Franklin 1997) is founded in ecological principles and theories (Odum 1953, Golley 1993), and in general systems theory (Bertalanffy 1968). While conceptually understandable, successful practice of the principles is challenged by scientific and social limitations.

The usual objective of ecosystem management is to sustain the full diversity of ecosystem attributes for sustainable use of resources and to sustain "diversity of choice" for future generations (Meffe et al. 2002). Principles of ecosystem management evolved with gains in

ecological knowledge and promotion of ecosystem approaches by NEPA and the ESA. The principles of ecosystem management promote more thorough consideration of the consequences of human interaction with biological and physical elements of ecosystems so as to more beneficially manage and sustain natural resources for present and future human benefit (Grumbine 1994, Yaffee et al. 1996, Franklin 1997, Meffe 2002). The concept of ecosystem services was honed during this period (e.g., Daily et al.1997). It is now a preferred means for communicating the value of sustaining biodiversity in wild ecosystem settings to maintain resources for immediate use and future options (Millennium Ecosystem Assessment 2005).

Early in its history, ecosystem management raised some expectations that it could simplify resource management designed to protect all species from decline and possible extinction. As more typically recognized now, ecosystem management, including ecosystem restoration, adds layers of complexity to species-based management. Done well, it requires careful assessment of the needs of targeted elements of ecosystems, typically scarce species at risk of extinction or species in demand for their resource use. Success depends on quality information, analysis, concept formulation, and numeric modeling at a wide range of ecological scales from population to landscape and region. The rapid expansion of computing capacity and systems science since the 1950s had a profound effect on the acceptance of ecosystem concepts and ecosystem management practice, especially in environmental contaminants analysis (Golley 1993).

Early ecosystem models were developed and used to integrate existing scientific understanding of ecosystem structure and function and to evaluate that understanding using sensitivity analysis to determine the most promising research investments (Golley 1993). International research on ecosystem productivity produced major advances in ecosystem models simulating the functions and dynamics of forests, grasslands, lakes, streams and other ecosystem types (Blair 1977). Contemporary computing capability is now a critical tool for ecosystem-based management at a wide range of scales, including ecosystem restoration. Even so, the uncertainties and risks associated with restoration of desired outputs remain high and challenging (Suding 2011, Hobbs et al. 2013). Contemporary practitioners consider adaptive management essential. Ideally applied, it integrates scientific learning into the management process and continuously improves management models and management results (Holling 1978, Walters 1986).

Nongovernment Organizations

Private entities have applied management measures that in effect have contributed to restoration of aquatic ecosystems, whether or not that was the initial intent. Dam removal is a good example. Many small dams have been removed at private expense (Panel on Economic, Environmental, and Social Outcomes of Dam Removal 2002). The usual reason for removal is to protect public safety (and reduce liability), but restoration of natural resources is often an additional benefit. More generally, the Nature Conservancy, World Wildlife Fund and other biodiversity conservancies have played important roles in advancing concepts of ecosystem-based management with intent to protect and sometimes restore ecosystems in support of threatened biodiversity (Groves 2003).

Biodiversity conservancies first emphasized the protection of terrestrial ecosystems. They focused on buying lands with diverse species compositions minimally altered by humans

(Groves 2003). The biodiversity concept matured with ecosystem management to incorporate the variety all life interacting systematically with physical environment at all levels of ecological organization from individual organisms to ecosystems. Biodiversity preservation requires a holistic concept of protection at population to regional scales. The conservancies needed to assess how much geographical area needed to be set aside and how it should be arranged to cost-effectively gain the most conservation benefit. Conservancy employees joined with academics and government employees concerned about NEPA and ESA goals to establish new sub-sciences of conservation biology and landscape ecology, which focused research attention on species populations at increased risk of extinction.

But the extensive damage to certain terrestrial and many aquatic ecosystems has nearly eliminated prospects for further protection of numerous ecosystem types. Protection alone is insufficient where ecosystems were nearly completely transformed by human impacts. In those situations, the conservancies turned more attention to ecological restoration (e.g., Yaffee et al. 1996, TNC 2011). Many of the principles of conservation biology and landscape ecology applied to ecological restoration center on biodiversity recovery to a sustainable status. Ecological restoration will become an increasing priority as global climate changes in regions where only fragments of protected ecosystems remain.

Relevance of ESA and Conservation Biology to Corps Restoration Authority

Corps ecosystem restoration policy guidance makes clear that there is far more to ecosystem restoration than water quality and quantity restoration, and has more in common with the goal of the ESA. The ecosystem restoration study objective identified in Corps project planning guidance indicates high native plant and animal diversity and restoration of "more biologically desirable species" are indicators of success when achieved by restoring supportive, self-regulating ecosystems (USACE 2000). Corps policy guidance also emphasizes restoration of scarce resources of significance to the public, which suggests that the ecosystem restoration program should at least include as an important aspect, if not focus entirely on, restoring scarce elements of biodiversity now threatened with global extinction to a self-regulating, sustainable state, consistent with the ESA heritage preservation goal.

Policy guidance does not, however, definitively limit program purposes to restoration of threatened biodiversity to a more secure status, regardless of its economic or other social values, and that has led to considerable confusion over program intents. Many questionable projects have been proposed for study and implementation, competing heavily for a limited annual budget that must be shared among other important Civil Works purposes. Perhaps worse, projects contributing most to achievement of the intended objective may not always be ranked highest for consideration in the annual budget process. These complications contribute to questions about Corps intents and competencies, and to the future of the program.

Scientific Organization Influences

Environmental scientists had documented environmental change and recommended specific changes in federal policy and practice for decades before the federal environmental laws of the 1970s were passed. NEPA and ESA emphasize the importance of understanding ecosystems and

applying ecosystem science to important management of environmental problems. But the global breadth of environmental problems threatening sustainable development of national and world human welfare was not comprehensively addressed by ecological science until after the U. N. published its first report on sustainable development (WCED 1987). In 1991, the Ecological Society of America (the leading ecological scientific organization in the United States) supported publication of a committee report about the science underlying management of natural resources and maintenance of life-support systems (Lubchenco et al. 1991). The report identified a large array of interrelated environmental issues that came together in three critical problem areas facing humanity: "global change, accelerated loss of biological diversity, and sustainability of natural and managed systems". Similar issues were independently raised by a National Research Council panel (Stern et al. 1992). The issues are articulated at the scale of the global ecosphere, but their resolution requires local action appropriate for the diversity of ecosystem attributes and their relationship to human services.

The main purpose of the Ecological Society report was to identify major research needs, but in identifying the three critical areas, it established a loose framework for approaching issues relevant to the ecosystem restoration mission of the Corps. The three areas are related in many ways. Self-regulating ecosystems cannot be sustained without the variety in form and function captured in the concept of biodiversity. By altering natural systems, human actions can act destructively or in harmony with the environment. Recent rapid changes in the global environment are major threats to future maintenance of biodiversity and to sustained harmony between man and nature. They further complicate the ecological restoration directed at maintaining the diversity in ecosystem structure and function (Hobbs et al 2013).

How well the Corps applies existing science to its ecosystem restoration and protection authority is a critical aspect of the program's success and outlook. Ecological science is much more complex and less thoroughly considered than the geophysical bases of traditional Corps project planning and construction. The geophysical scientists and engineers that dominated the Corps professional body were not ecologically well prepared for the ecosystem restoration and protection authority, and the onslaught of projects and programs proposed under its auspices. While the Corps consulted other agencies for advice, no government agency had extensive experience doing aquatic ecosystem restoration with a focus on biodiversity oriented improvements. The Corps has been in a steep learning curve since the authority was passed.

Until relatively recently in its history, the Corps had been slow to assimilate environmental and ecological science and values into project considerations, earning it the suspicion of many in the environmental community (e.g., Costenbader et al. 2004). The Corps has typically focused on "restoring" geophysical features of the environment based on an assumption that desired species will colonize the site later. This assumption, "if you build it, they will come", is characterized as restoration mythology by restoration scientists because of the many risks that remain unmanaged (Hilderbrand et al.2005). The Corps gradually came to realize that the risk of project failure often was quite high as this was confirmed by many others in the restoration community of practice (Suding 2011).

After some reluctance, the Corps has adjusted to the need for science-based adaptive management to manage the risks. Monitoring plans for potential corrective measures is now

required by law (2007 Water Resources Development Act [WRDA]) and adaptive management plans are now required by Corps policy guidance. Adaptive management is a scientifically based approach to water resources management (e.g., Holling1978, Walters 1986, NRC 2004d) that is particularly essential for managing the many risks and uncertainties associated with ecosystem restoration and protection of scarce ecological attributes. Corps policies in the past have stressed management of all significant risk and uncertainty in the engineered structures used to achieve economic development objectives. The Corps did not consider a post-construction adaptive process suitable for risk management. Its experience with adaptive management in an operating project is rudimentary and complicated by the reliance on nonfederal partners to operate and maintain ecosystem restoration and protection projects once they are implemented.

Ecosystem Restoration Concepts and Challenges

Ecosystem restoration is a particular approach to ecosystem management that in the past emphasized a return to some previous ecosystem condition; usually a more natural condition (NRC 1992). The motivations varied widely, depending on the authorities and missions of the responsible organizations, but biodiversity maintenance remains a common theme (Rana 1998, Clewell and Aronson 2007, Hobbs et al. 2013). Restored productivity, broadly defined, continues to be another motivation, such as restoring the productive capacity of strip mines, whether for agriculture or natural productivity. This limited form of functional restoration is often referred to as reclamation (NRC 1992). Another example of broadly defined restoration is found in the replacement of damaged wetland functions in support of human services carried out through wetland mitigation actions administered jointly by the EPA and Corps under the CWA. Enforcement of the Act provides one of the better examples of functional restoration—the response of aquatic ecosystems to elimination of most point-sources of water pollution.

The Corps definition of ecosystem restoration is a bit different. It emphasizes restoration to a condition that would have occurred if there had been no human effect. This takes into consideration self-regulating change, but requires some means for assessing it. But more important is the difference in the objective, which appears to be centered on restoring nationally scarce elements of native biodiversity to a sustainable state. Whereas objectives in earlier restoration activities were often functional, the Corps objective is primarily structural (environmental laws behind the objective are more clearly focused on structure than on function, such as species abundances and chemical concentrations). Reclamation is concerned about restored productivity (function), but not necessarily in the same structural form. Roadside plantings were more concerned about aesthetics and erosion control than about structural replacement. In fact nonnative species were often used in early functional restoration activities, contributing to a major challenge for the growing emphasis on restoration of both structure and function, so as to restore native biodiversity to a sustainable state (Hobbs et al. 2009, Suding 2011).

Restoration in general has met with mixed success and failure (Suding 2011). Examples of success typically involve restoration of gross functions and services, such as biomass recovery and erosion control. However, complete recovery of species compositions has rarely been demonstrated and ecologists now largely believe that the structure of communities and ecosystems is always changing (Cain et al. 2011, Ricklefs and Relyea 2014). The past success of

aquatic wetland restoration in particular is mixed when judged by functional attributes and is particularly limited when judged by the recovery of the scarcest species (NRC 2001b). Kearney et al. (2011) and Paola et al. (2011) describe some large-scale examples of mixed results that the Corps has been involved with in the Mississippi River delta. Restoration of ecosystems to previous "natural conditions", or to conditions that would have existed without human impact, is extremely difficult, if not impossible, given the widespread and virtually irreversible environmental changes that have taken place.

Restoration to some previous "natural" ecosystem condition is now recognized as impractical under most circumstances (Vitousek et al. 1997, Lockwood and Pimm 1999), largely because of the novel ecosystems that have resulted from widespread environmental change, including climate change (Hobbs et al. 2005, 2009, 2013). Restoration scientists now realize that species in ecosystems have been reassembling in novel ways more rapidly than in the past, much of it as a consequence of widespread human influence (Rosenzweig 2003, Hobbs et al. 2006, 2009, 2013). A major factor is the high past and present rate of nonnative species introduction into ecosystems composed of native species (Lockwood et al. 2007). These influences are not well understood, but indicate that restoring structure as it once was, or as it is in some "more natural" reference condition, is highly unlikely. Nonnative aquatic species contribute to the increasingly widespread distribution of novel aquatic systems in the United States and to significant economic costs incurred by their effects and management (Cole 2005). Some of the most aggressive invasive nonnative species also have been implicated with native species imperilment and extinction (Lockwood et al. 2007, Cole 2009).

Most nonnative species are so firmly established that removing them entirely is impractical, but they can be locally controlled at substantial cost. Because most nonnative species have integrated into ecosystems without much evident impact, it is imperative to develop means for identifying the particularly aggressive invaders with the greatest potential for impact on native species to focus control on them, where possible. Establishment of nonnative species is particularly frequent and noticeable in disturbed ecosystems. They are especially common in recently established ecosystems where native biodiversity is lower than in surrounding areas. The aquatic environments of peninsular Florida and the Great Lakes are two examples where proposed and existing restoration projects have to assess which invaders must be controlled and which can be accepted as part of the novel communities that now occupy those areas. One of the most cost-effective means of control is the introduction of other nonnative species—usually host-specific parasites or predators that have been carefully investigated for destructive side-effects.

Human-caused climate change is another important force behind the widespread emergence of novel ecosystems. Most climate scientists believe that global climate is warming much more rapidly than in the past, largely because of human activity (IPCC 2014). The main causes are now believed to be fossil fuel emissions and deforestation. Restoration scientists and other ecologists have recognized the profound implications of more rapid climate change for some time (Harris et al. 2005, Loarie et al. 2009). The effects of future climate change are expected to markedly reshape the species composition and character of ecosystems as they have in the past (Baron et al. 2009). Predicted future patterns of species redistribution in response to climate change are similar to past responses (Loarie et al. 2009). Based on moderate estimates of climate change rate, Loarie et al. (2009) estimated the velocity of mean atmospheric temperature shift

between 8 and 126 km/century, depending on the elevation and other features of the environment. The rates and directions of species distribution change differ widely among species and the uncertainty of effects is great.

The widespread distribution of synthetic chemicals (Travis and Hester 1991) and human caused changes in biogeochemical cycles other than the carbon cycle (Jacobson et al. 2000) also contributes to assembly of novel ecosystems. Global changes in the nitrogen, phosphorus, and sulfur cycles cause widespread nutrient enrichment of aquatic ecosystems. Increased fertility typically favors high productivity of certain species and depressed productivity of other species. It also contributes to changes in the oxygen cycle through decomposition-driven oxygen depletion, which results in more species changes.

Severe reduction of large predators in terrestrial and aquatic ecosystems has had profound top-down impact on ecosystem structure and function. In the aquatic realm, this issue is particularly widespread and well documented in marine ecosystems (Jackson et al. 2001), but occurs commonly in freshwater systems as well. Top predators play an important role in maintaining community stability in ecosystems (Sergio et al. 2008). Estes et al. (1998), for example, described the complex effects that commercial fishing had on west-coast kelp communities. An important exception is excessive human predation, which has severely reduced or entirely eliminated the biomass of most large predators in many terrestrial and aquatic ecosystems.

Regardless of the many challenges, the cumulative impact of humans on ecosystems has exceeded the capacity of ecosystem protection alone to assure that the integrity of national biodiversity is sustained. Reestablishing wild, self-regulating ecosystems is essential to sustain native biodiversity and future diversification. The need to sustain native biodiversity is accepted by the public in various environmental laws, but especially in public desire, clearly expressed in the ESA, to sustain an intact native fish and wildlife heritage. While few, if any, ecosystems can be restored to what they would have been without any previous human impact, they can be managed to become self-regulating and more suitable for native species, including many that are now deemed unsustainable by conservation biologists. Unsustainable species outnumber the small fraction of species listed for protection under the ESA by about 5 to 1 (Scott et al. 2006). This alternative to pure restoration is often referred to as rehabilitation (NRC 1992), which may be achieved by way of designed and engineered ecosystems (Mitsch and Jorgensen 2004). Most Corps “restoration” projects fall into this rehabilitation category.

The object of rehabilitation and human engineering of ecosystems is to reestablish self-regulating ecosystem conditions in support of desired structural and functional outputs that might not have occurred through a self-regulating ecosystem design and restoration process. It is particularly relevant in river and coastal ecosystems that have been so widely modified by human development that vestiges of previous ecosystems cannot be depended upon to self-restore over larger areas, especially where removal of past human effects cannot be justified economically.

The dimensions of these environmental changes and increasing awareness of biodiversity threats has reoriented many restoration scientists and practitioners from functional restoration of ecosystems, regardless of structural make up, to a much more intensive focus on the needs of the scarcest native elements of ecosystems (Hobbs et al 2009, Suding 2011). For federal agencies,

the legal justification for investing in biodiversity recovery and maintenance is based largely in the fish and wildlife heritage goal of the Endangered Species Act and related laws. Engineering novel ecosystems is quite acceptable, if it cost-effectively achieves the biodiversity objective. In this new view, the operational objective is to reestablish the diversity of conditions necessary to sustain continuing diversification of species and ecosystems, regardless of species composition or previous configurations of "more natural" ecosystems. The needs of the scarcest species indicate the conditions most likely to be limiting the diversification process. In this way the meaning of ecosystem restoration can be recast to a national scale of biodiversity maintenance.

Future planners of ecosystem restoration projects will have to be satisfied with rehabilitating ecosystems for the desired species instead of attempting restoration of the same assemblages and supporting environment. The increasingly probable effects of human-caused climate change add to that reality (IPCC 2007, 2014). While rehabilitation is a more practical concept, it demands more planning attention to the specific needs of desired species and associated functions (Hobbs et al. 2009). Water resources planners cannot rely on a worn out premise that the desired species will return if one restores a geophysical condition free of human regulation. Beyond costly ineffectiveness, that tactic can make conditions worse in some cases, because it may favor invasive nonnative species or other unforeseen interactions.

Restoring ecosystems to some former condition is not as relevant as establishing a novel but wild condition that sustains diversification and national biodiversity. In most cases, existing species and diversification will have to be maintained in novel ecosystems that did not exist before human effect (Rosenzweig 2003). Restoration planning will need to consider a need for many species to redistribute hundreds of kilometers over the next 50 to 100 years or parish. In addition to rehabilitation, recovery of system productivity may sometimes have to rely on reclamation methods or the creation of an entirely new ecosystem condition (NRC 1992), such as building wetlands where none previously existed. The restoration of previous natural function and structure may not be essential to sustain biodiversity and diversification processes as long as the productive value of the landscape, native species inhabitants, and features that contribute to diversification are sustained. The watch-word is risk management flexibility, while tightly focused on objective achievement.

Past restoration has not been as sensitive to restoration objectives and risks as restoration scientists and practitioners now recognize they need to be. The risks and uncertainties of restoration failure need to be more comprehensively assessed and managed, if the failure rate of restoration projects is to be reduced significantly (Suding 2011, Cole 2014c). Planning for and implementing adaptive management as needed is the primary means available for managing uncertain risks and usually is essential for achieving the objectives of ecosystem restoration projects (Suding 2011). Adaptive management is not a panacea; much residual risk is likely to remain and should be considered carefully in investment decisions. The Corps accepts adaptive management in principle and has some limited application experience in partnerships with nonfederal sponsors.

A more fundamental issue pertaining to the future of ecosystem restoration in general exists at the level of society, politics and possibly changing attitudes toward science, research, and the needs for long-term sustainability of options for future generations. Societal interest in

government investment in the future welfare of the Nation has steadily given way to national and social security needs. Interest in investing more in public infrastructure maintenance, research and development, and education is low and investment interest in biodiversity sustainability is very low. Much of the public is in denial over the degree to which environmental change is taking place and the degree to which if may threaten the future welfare of the Nation. Trust in government institutions may have approached a new low as well. Some of these trends have been in the making for too long and reach too far down into younger age groups to blame them entirely on the conservatism of older generations and the aging of the baby boom generation. Less that optimum economic conditions probably contribute to this trend, but the probability of trend reversal when the economy improves remains uncertain. This presents an uncertain funding environment for investments in biodiversity sustainability and a fundamental challenge for those who are concerned about the future welfare of the Nation.

Ecosystem Restoration Examples

An early example of ecosystem restoration activities that typify some restoration difficulties is the Chesapeake Bay Program, which was jointly initiated by the EPA, several states in the watershed, and the Chesapeake Bay Commission (Yaffee 1996). The Chesapeake Bay Program traces its history back to the objectives of the CWA and to an EPA study of the Bay authorized by Congress in 1975. A major motivation for bay restoration was the long-term decline in the Bay's commercial resources; especially the native oyster. The legal imperative was the CWA. The EPA had determined that poor water quality from nutrient and toxic contaminants and possibly related declines in submerged vegetation deserved priority attention. In 1980, the Chesapeake Bay Commission was formed to coordinate state legislation pertaining to the Bay. In 1983, the Chesapeake Bay Program was formed by agreement among EPA, the Commission, and states with bay boundaries. Its mission was to improve and protect water quality and living resources consistent with the CWA. Improvements have fallen short of goals and the native oyster has continued to decline to historic lows (NRC 2004a). A continuing issue is the slow adoption of the TMDL concept by some of the same states most likely to be adversely affected by resource decline in the Bay (although some recent events may spur progress). The difficulties encountered in the Chesapeake Bay Program indicate the critical importance of full commitment to goals by collaborators in regional rehabilitation programs. These difficulties tend to mount as the percentage and value of private land holdings in the regional watershed increase.

On the other hand, successful recovery of some threatened and endangered birds is most associated with cleanup of toxic materials forced by other legislation. This success story was due in large part to banning the use of DDT and other persistent pesticides (Grier 1982). These actions stopped the stress at the source and the contaminated ecosystems have gradually returned to less toxic states. Many avian predators, including bald eagles, peregrine falcons, and brown pelicans, have recovered enough to be removed from ESA listed status largely because of that legislation.

The land management agencies began major restoration projects during the 1980s. Of 105 ecosystem management activities reviewed by Yaffee et al. (1996), 40% involved federal agencies and 46% had restoration goals. Agency adoption of ecosystem restoration accompanied increasing acceptance of ecosystem management concepts. The purposes varied. Many focused

on restored ecosystem function. Few focused on restoring species composition. The demand for research directed specifically at ecological restoration also grew and a professional organization (Society for Ecological Restoration) was formed in 1988 to publish new science and convene regular conferences.

In one of the earliest examples of NGO restoration interest, The Nature Conservancy bought land in the 1970s to be managed by the University of Kansas as the Konza Prairie Research Natural Area (Yaffee et al. 1996). Basic principles for success emerged from such efforts and from lessons learned. Among the more critical principles is use of restoration agents more like the natural processes that shaped ecosystems (such as fire, grazing, and unregulated water flow) and choosing sites connected well enough to sources of colonizing species to successfully reestablish and maintain them in the restored project area. The Nature Conservancy's Sustainable Rivers program (TNC 2011) is an example of growing NGO interest in ecosystem restoration and collaboration with federal agencies, including the Corps.

In the freshwater realm, one of the earliest and most ambitious "restoration" actions was taken to mitigate for damage done to valued fish and wildlife resources along the Missouri River. The mitigation action was carried out by the Corps in collaboration with the Fish and Wildlife Service and several state agencies. It involved reconnecting the river to wetlands isolated by river channelization, dikes and other structural changes, and restoring riparian forests on floodplains converted to agriculture (Yaffee et al. 1996). It was studied under the authority of the Fish and Wildlife Coordination Act and 100% federally funded for construction in 1986—the same year that the Corps received its first environmental improvement authority. The methods used for mitigation along the Missouri were a prime example for environmental improvement actions, which did not require an ecosystem restoration approach. Creation of new habitat was allowed much as it was for mitigation efforts. Even so, the Missouri River mitigation actions influenced later ecosystem restoration projects led by the Corps once it was authorized in 1996. The Missouri River mitigation actions have had less than the desired effect because of hydrologic changes caused by dams built to sustain navigation depths (Figure 12). More recent efforts to address these issues by modifying seasonal discharge from the dams have been controversial (NRC 2002). An important lesson was learned—be sure to address the limiting factors to achieve success.

Mitigation models and the restoration emphasis along the Missouri River contributed largely to early concepts of environmental improvement planning, which often did not fully appreciate differences between value replacement through mitigation and adding value through improvement. In 1981, the Fish and Wildlife Service announced development of the Habitat Evaluation Procedure (HEP) to guide mitigation practices (FWS 1980, 1981) using Habitat Suitability Indices (HSI). Ecosystem models were considered theoretically more robust even by the developers of HEP (FWS 1980), but the HEP was thought to be easier to use and was acceptable. By the turn of the 20th century, the Corps had become a major agency participant in ecosystem restoration activities. It is now widely recognized as a lead agency in aquatic ecosystem restoration planning and implementation and strongly supports a restoration community of practice largely through biannual national conferences focused on ecosystem restoration research, practices, and policies. Recognition of the Corps as an important player was

greatly enhanced by its leadership in the Everglades regional restoration program, which, in terms of estimated cost, may be the largest ecosystem restoration program started anywhere.

Past Regional Ecosystem Trends and Implications

Overview

Environmental problems, progress, and opportunities for improvement are not equally distributed across the United States. This is equally true for environmental resources valued for use and for

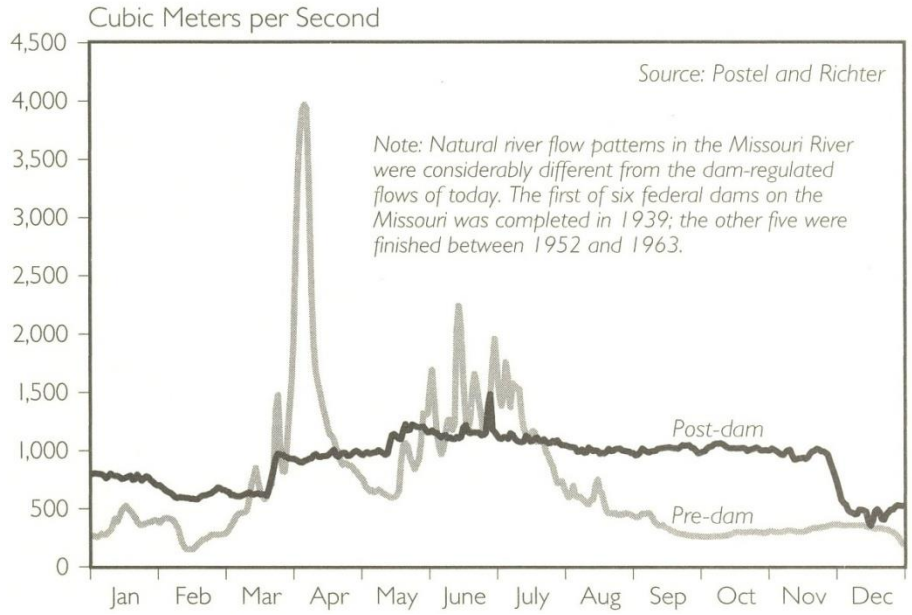

Figure 12. Changes in Missouri River flow following construction of dams in the river by the Corps (from Postel 2006).

ecological heritage, but the focus here is on the latter. The loss of ecological attributes that comprise our national ecological heritage results in losses of human service and resource-use potential before the resource value is understood. Careless land use has been a fundamental cause of past aquatic-ecosystem losses. It alters the discharge rates and timing of water and water-transported materials—including polluting levels of suspended sediment, nutrients, and toxic contaminants—and has created intolerable conditions for many species. Much of the damage originated on private lands. A major exception is damage caused by public water resources development, which occurred largely before environmental costs were recognized. Losses have occurred in many small to large and fresh to saline aquatic ecosystems.

The required partnering with nonfederal sponsors most likely reduces the potential for program-area success based on a national ecological heritage criterion. Consistent with that criterion, the return from restoration investment is likely to be greatest where the most imperiled species can be restored to a sustainable state. These may not be the areas where nonfederal interest is highest, however. Past nonfederal interest in ecosystem restoration project funding was widespread, but national ecological heritage was often not the main interest. More interest was often shown in

restoring resource use value, such as for recreation or floodplain use. Resource use interests tend to concentrate near population centers while heritage loss problems show up in a more general geographical trend from north to south (Figures 13 and 14), which reflects an increasing trend in native biodiversity. This trend also shows up in recommendations by Chaplin et al. (2000) to focus on certain watersheds to assure aquatic heritage preservation (Figure 15). Because of social and economic differences, there may be a difference between the distribution of heritage restoration need and the opportunity to address it because of limited nonfederal interest where the need is greatest.

Much of the Nation's aquatic ecosystem condition can be organized regionally by river basin boundaries, which is consistent with the Corps aquatic ecosystem restoration and protection authority. The organization used here breaks the country down by river basins into 13 regions. A brief characterization of each region is provided along with a synopsis of environmental trends and issues pertaining potentially to the Corps ecosystem restoration and protection authority.

Saint Lawrence River and Great Lakes

Much of the upper Saint Lawrence River Basin is occupied by the Great Lakes (Thorp et al. 2005). Because the precipitation and evaporation of the region are nearly equal, much of the water balance is sustained within the surface area of the Great Lakes. The ratio of watershed to lake surface area is relatively small. The geology is complex, ranging from metamorphosed rock highly resistant to chemical erosion in the north to soluble carbonates in the south. In its pristine state, the water was typically clear of suspended sediment and ranged from moderately soft with neutral pH and low nutrients in Lake Superior to increasingly higher pH, hardness, and nutrient concentration as the water moved through the lakes to the St Lawrence River. Because the watershed was totally glaciated over 10,000 years ago, its features are geologically young and complex ecosystems became established only recently. The native freshwater biodiversity of the upper lakes is low but several endemic species occur nowhere else.

The region was settled rapidly following American independence. It supported a significant commercial fishery before it collapsed from a combination of causes including overfishing, invasive species, and local habitat deterioration.

Because of iron and coal mines close by, the lakes became a valued transportation corridor for heavy industrial development in shoreline cities. Development of the Saint Lawrence Seaway opened the Great Lakes to international oceanic shipping including grain from the northern tier states. The regional economy depended largely on commodity manufacturing, which has waned since its peak after World War II. The watershed has lost population, leaving vast industrial "brownfields" in its wake.

The predominant environmental concerns in the 1960s included accelerated lake eutrophication and toxic contamination from urban, industrial, and agricultural sources. Environmental degradation concentrated in the lower lakes and in isolated harbors and bays of the upper lakes. The problems are well understood and reduced nutrient loading and industrial discharges have gone far toward restoring water quality. West-coast salmon were introduced in the 1970s and are now the basis for popular sport fisheries. Physical alterations of the Great Lakes

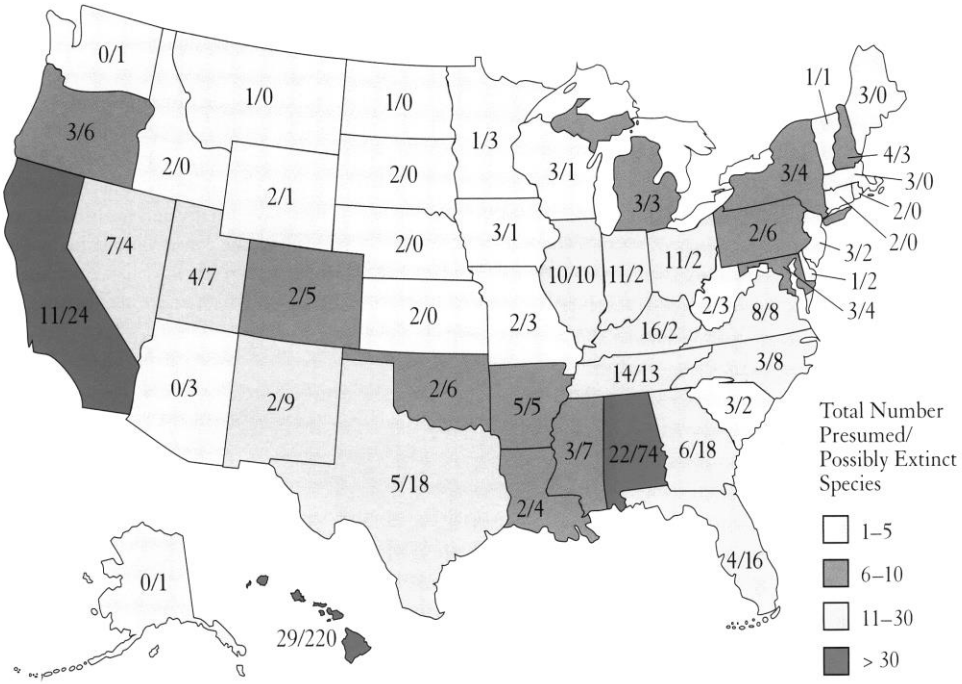

Figure 13. Numbers of plant and animal species presumed to be extinct or are possibly extinct in each state of the United States (from Master et al. 2000).

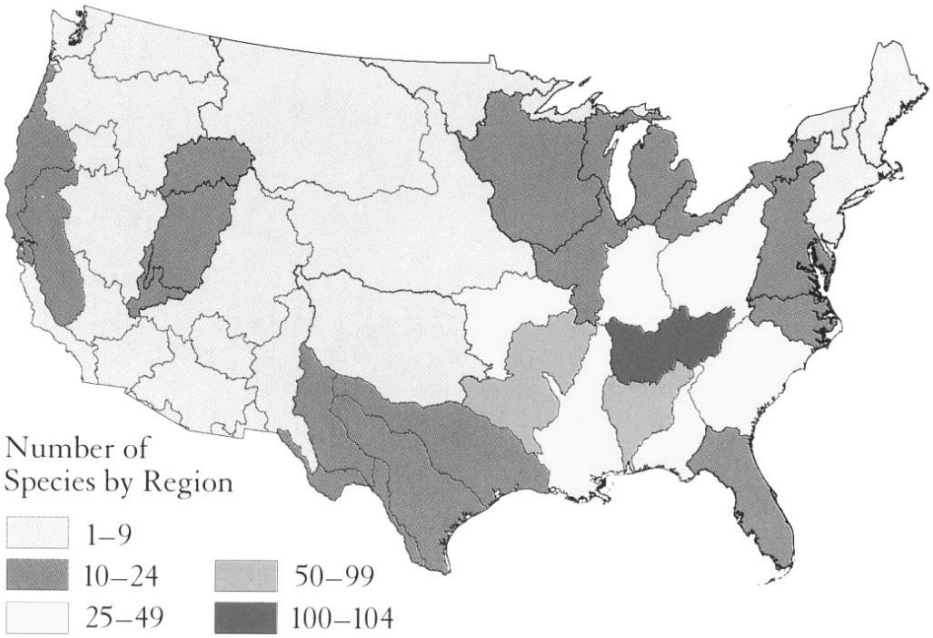

Figure 14. Number of freshwater fish and mollusks considered to be at risk of extinction (imperiled) in major river basins of the United States (from Chaplin et al. 2000).

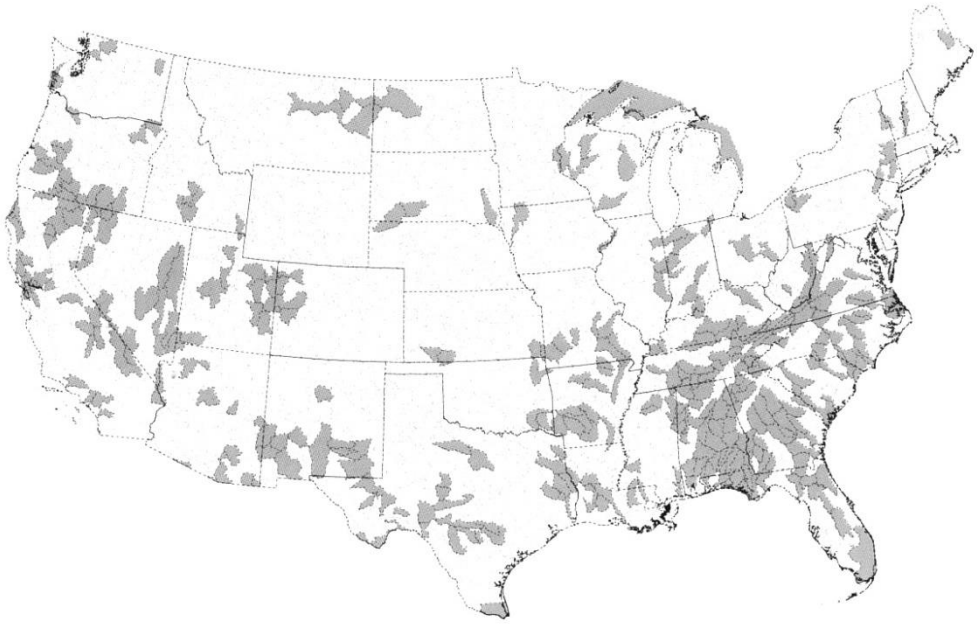

Figure 15. Watersheds that need to be protected and restored to protect the freshwater biodiversity of the United States (from Chaplin et al 2000).

have occurred as a consequence of dredging, local harbor improvements, canal and lock construction in connecting waterways, and a low-head dam at the outlet of Lake Ontario. Perhaps the greatest environmental impact in the history of the Great Lakes was the cumulative effect of many non-native aquatic species following purposeful introductions and unplanned access through canals and ship ballast water. Several species went extinct as a consequence of overfishing and nonnative species invasion by way of canals, but the number of extinctions was low compared to other regions (Figure 11). Similarly, species imperilment, while significant, is lower than regions farther south (Figure 12).

Chaplin et al. (2000) identified Lake Superior, Huron and Lake Champlain watersheds as among the 327 watersheds that would need protection and restoration to conserve all fish and freshwater mussels in the United States (Figure 14). The non-native species problems are very difficult to contend with, however, and may be the major threat to native species in the area. The most recent concern is over movement of nonnative carp species into Lake Michigan by way of the Chicago Ship Canal (built by the Corps), which links the Great Lakes with the Mississippi River. The Corp is deeply involved in actions taken to prevent movement of nonnative carp into Lake Michigan via the ship canal.

Northeastern Atlantic Coast and Rivers

The rivers of the Northeast drain generally east and south from highly weathered and recently glaciated highlands to the Atlantic Ocean (Jackson et al. 2005). The major rivers include the Penobscot, Connecticut, Hudson, and Delaware. Monthly precipitation is relatively uniform year round, much of it as cold-season snow. Annual runoff peaks during spring thaw. The basins are underlain primarily by igneous and metamorphic rock, but mixed sedimentary geology,

including limestone, is more widespread to the south, especially in the Delaware Basin. To the north, the rivers are slightly acid and soft with low nutrient concentrations and low to moderate alkalinity. They become moderately alkaline and somewhat harder and more productive with distance southward. The Delaware and Hudson estuaries are the largest and deepest in the region and provided natural harbors for early settlers. Most of the region was glaciated recently and has comparatively low freshwater biodiversity.

The watersheds of the northeastern coast were among the earliest cleared for farming and polluted with domestic and industrial waste. Land clearance and agricultural use reached a peak in the 19th century and much of the watershed has returned to a forested state. But industrial mills of diverse kinds released organic matter and toxins directly into many of the rivers, and many small mill dams were constructed. Development continued steadily in the region until after World War II when the rate of growth slowed. Much of the population dispersed into suburbs that now link the main cities into one continuous "megalopolis" from Boston to Philadelphia (and into the Chesapeake watershed). Urban industrial waste continued to degrade rivers and harbors until the 1970s when the CWA, and other federal legislation passed at that time, began to have positive effects. The northern rivers were not suitable for waterway development, but the estuaries and lower reaches of the Connecticut, Hudson and Delaware were developed for harbor and commercial water-borne transport. Numerous reservoirs were developed in the interior highlands, primarily for urban water supply.

By World War II, anadromous Atlantic salmon, shad and sturgeon runs had been reduced to a small fraction by the combined effects of pollution, dams, and fishing. Many of the anadromous species are returning in larger numbers since implementation of the CWA. Numerous dams have had fish ladders installed, some old dams have been removed, and fishing is intensively regulated. Aquatic species diversity is generally lower here than elsewhere in the United States and most species are nationally secure from extinction (Figure 12). In the year 2000, less than nine fish and mussel species were at risk of extinction, including the dwarf wedge mussel and shortnose sturgeon (Chaplin et al. 2000). Therefore, threats to biodiversity have been less of an issue here than many other locations in the Nation. Chaplin et al. (2000) indicate that protecting and restoring the upper Connecticut River, watersheds entering the St. John River in northern Maine, drainages into the lower Hudson in New York and the lower Delaware in New Jersey, and upper Delaware watersheds would contribute largely to protecting the threatened aquatic species of this region. The Nature Conservancy and the Corps cooperate on a biodiversity recovery project below dams in the Connecticut River watershed.

The total population in the region has grown slowly for several decades and probably will continue in that mode. Environmentally damaging industry was replaced by a service-based economy. Public concern for the environment in the region probably is second only to the Northwest. There is growing interest in environmental improvement, especially where economies depend on it, such as in northern New England. Much of this interest is focused on urban river and harbor clean up and private removal of small dams. Further rehabilitation of these areas would contribute relatively little to securing the nations imperiled biodiversity, however.

Chesapeake Bay and Tributary Rivers

The Chesapeake Bay serves as a common estuary for several prominent middle-Atlantic tributaries. The Bay is world renowned for its past production of oysters, crabs, shrimp, clams, and certain fin fish species. The tributaries drain watersheds underlain primarily by carbonate rocks and are naturally productive as a consequence. The Chesapeake has suffered greatly from pollution, overfishing, and physical degradation (Rothschild et al. 1994). In its pristine state, major sources of productivity were found in fringing wetlands and extensive stands of submerged vegetation. The primary requirement, clear water, was well met when the watersheds were densely forested and the Bay was densely inhabited by filter-feeding shellfish.

Watershed clearing for agriculture progressed rapidly following European colonization and the Bay became more turbid because of accelerated erosion. Shellfish yield peaked over a century ago and has declined steadily ever since (NRC 2004a). Fishing intensity gradually increased, especially for clams and oysters dredged from the bottom. Over time, the high densities of shellfish were significantly reduced by harvest. These species all feed on organic particulates by filtering the water and, collectively, they filtered the entire bay at high rates, removing algae, detritus and fine inorganic matter (Newell 1988), which helped to maintain the clarity needed by submerged vegetation.

Starting late in the 19th century, dredging for navigation into Baltimore, Norfolk and other lesser harbors contributed to greater turbidity and submerged aquatic vegetation declined locally. The cities released raw sewage, which decomposed to nutrients that stimulated algal growth and contributed to the increased turbidity. Agricultural fertilization and concentrated animal culture (especially chickens) also accelerated sharply after World War II, increasing eutrophication and turbidity. Implementation of the CWA Act has eliminated most point sources of pollution from the cities, but farm sources of eutrophying nutrients remain a chronic problem despite concerted efforts to turn pollution around. Native oysters suffer from disease that may be connected to the degraded habitat. Shellfish harvest is greatly depressed. Shellfish fishing contributed largely to reduced numbers, oyster reef destruction and, in the case of horseshoe crab fishing may contribute to decline of threatened shorebirds. One state on the Bay unsuccessfully proposed introducing nonnative oysters despite concerns about undesirable impacts (NRC 2004a). Relatively little water resources development has occurred in the Chesapeake watershed and contributes marginally to the Bay's primary problems by interrupting some anadromous fish movement.

Few of the Bay's resident aquatic species are at significant risk of global extinction. A few species of birds using the shore are vulnerable, however, largely because previous beach habitats have disappeared under development and intense use. Some freshwater and anadromous species are threatened (Chaplin et al. 2000) and one small fish species, the Maryland darter, was recently declared extinct. However, Chaplin et al. (2000) indicate that only parts of the York River watershed and the Shenandoah River (upper Potomac) need to be restored and protected to sustain fish and mussel species. The Corps dredges the lower reaches of the York River and a non-Corps dam exists on a tributary. The Shenandoah remains virtually undeveloped. The Corps also dredges at harbor locations in the upper bay where it has constructed Poplar Island to retain dredge material with positive effects on shore birds at some risk of extinction. Dredging may

contribute to turbidity, but the physical restoration of submerged plant beds and oyster beds in the bay proper is mostly untenable until other limiting factors are addressed. The major future issues for the Bay will be controlling eutrophication-caused turbidity more effectively, resolving native oyster disease problems, and managing fisheries optimally for commerce and ecosystem sustainability.

Southeastern Atlantic Coast and Rivers

Extending from the Roanoke River in southern Virginia to the Saint Johns River in northern Florida, the South Atlantic rivers arose largely in densely forested watersheds occupied by old acidic soils (Smock et al. 2005). The two rivers at the extremes are somewhat exceptional geologically. The Roanoke is slightly alkaline and comparatively steep and rocky. The Saint Johns is very alkaline. It arises on Florida limestone, has very low gradient, and is extensively influenced by tidal salt water. The remaining rivers are slightly to strongly acidic and slightly to deeply stained by dissolved organic matter. In their pristine state, river flows varied significantly and seasonally overflowed their banks into bottom land forests. Free of glaciation, and isolated by ocean water at the mouths and high elevations inland, numerous unique species evolved in the rivers. Coastal barrier beaches and estuarine lagoons are common along the coast.

Much of the watershed area along the Appalachian front underwent clearing for agriculture, some of which was later abandoned and returned to forest vegetation without human help. Cotton was a major crop on the piedmont in much of the middle elevations, which eroded badly and was depleted of nutrients. Much of the area was retired from agricultural use. Land clearing and erosion peaked in the late 19th century and early 20th century. Many of the rivers flooded more extremely and became turbid with fine sediments. Some intolerant freshwater species, particularly among mollusks, declined sharply and a few are now extinct (Cole 2009). Forest succession has slowed erosion, but suspended sediment remains significant in many locations and is the most prevalent form of pollution in recent times. Only the Savannah and Saint Johns rivers were developed for major navigation, but many of the rivers were dammed for hydropower and flood control during the mid-20th century. The extremes of the annual flood cycle have been diminished as a consequence, affecting the extent of bottomland swamps and those species particularly dependent on flow variation. Anadromous fish migration was blocked at numerous dam locations. Some of the rivers remain generally free of development.

The estuaries were once major sources of shellfish. They have declined in importance in recent decades largely because of overfishing. Barrier beaches used by shorebirds and sea turtles for nesting remain intact, but are intensively used for recreation and housing in many locations, which decreases their nesting value. The dominant water resource development in the coastal region is the Intracoastal Waterway, which extends from Norfolk to Miami. Recent population growth rate was most rapid in the highlands, especially in Georgia and North Carolina, where the greatest growth is likely to continue. However, water shortages during droughts are increasingly affecting future potential for growth. Except for the Norfolk and Jacksonville areas, population growth has been slow to moderate in the coastal regions. Smaller coastal communities depend greatly on tourism and are environmentally concerned as a consequence. The big coastal cities and inland communities are in general less concerned.

The rivers of the region have undergone substantial water resources development; some of it the work of the Corps. But much of it was constructed by nonfederal utilities for hydropower and water supply purposes. Many nonnative species were introduced by design or accidentally and contribute to impacts that threaten aquatic life. Extensive environmental damage raised the risk of extinction for at least 47 species of fish and mussels (Master et al. 2000).

Past urban population growth was significant in certain areas, but the land and water use patterns appear to be stable and are not expected to change substantially in the next several decades, except possibly along the coast and around city margins. The areas around Atlanta, Norfolk and Jacksonville are likely to grow, but are encountering expensive water supply challenges. Intense concern about water supply has increased pressure to develop new water supply reservoirs, which will most likely run afoul of the ESA if they prove feasible. More environmentally friendly alternatives exist—such as recycling, conservation, and desalinization. They may be cost competitive because the most cost-effective reservoir sites have been developed.

Hurricanes have caused significant damage here and increased insurance costs may slow growth of shore communities somewhat. Riverine sediment loading may improve with better management of agricultural lands, but will probably continue where agriculture remains important. Because of its high and threatened biodiversity, the region is targeted for attention by NGOs. Chaplin et al. (2000) identified a significant fraction of watersheds needing restoration and protection. These include parts of the Roanoke, Cape Fear, Neuse, Pee Dee, Santee, Savannah, Altamaha, Setilla, and the Saint Johns river basins. The Corps has significant development on the Savannah and Roanoke rivers and less development on the Cape Fear and Upper Pee Dee. Only short distances of the lower rivers have been developed for navigation. Navigation-related threats to endangered manatee and sea turtle populations have been a concern in harbors and the Intracoastal Waterway. The Nature Conservancy already cooperates with the Corps in biodiversity restoration projects below reservoirs on the Savannah and Roanoke Rivers.

Florida Peninsula

The Florida Peninsula is largely drained by the Kissimmee River to Lake Okeechobee and, from there south, through the Everglades “river of grass’. The region is underlain by limestone and the water is highly alkaline. The highest point in the watershed is less than 100 meters above sea level. The Everglades are nearly flat with a very gradual slope east, west and south from Lake Okeechobee. Much of the area is either temporarily or permanently flooded with shallow water where it forms extensive cypress swamps and saw grass plains dotted with hammocks (small islands a few feet higher in elevation than surroundings) occupied by semitropical forests. The peninsula has had a relatively short terrestrial history. The Everglades region emerged from the sea no more than 6,000 to 8,000 years ago**.** Being isolated by cold climate to the north and by oceans, biological diversity has not been as high as might be expected, but is greater than many areas to the north. The native fauna and flora are a mix of species with continental and Caribbean origins.

Until the late 19th century, the area remained mostly wild with scattered farms and settlements carved out of pine, oak and palmetto forests along coasts and river banks. Growth accelerated with improved railroad transportation and recognition of the agricultural and tourist advantages

of the semi-tropical climate. The region has been one of the Nation's fastest growing areas. Much of the suitable agricultural land north and east of the Everglades was cleared for citrus and various other specialty crops as well as conventional truck crops that could be grown in winter and transported north. The Everglades had a long history of thwarted attempts to drain and develop it until well into the 20th century. Even so, large areas south of Lake Okeechobee have been converted to sugar cane and other crop production.

Farther south, the unique water and landscape of the Everglades was recognized as a national treasure and much of it was established as a National Park in 1934. Flooding during hurricanes was a problem in the region, especially around Lake Okeechobee, and levees were constructed around much of it starting early in the 20th century. These levees failed in major hurricanes leading to significant loss of life and a much larger system of levees was constructed in the 1930s. Much of the water that flowed south to the Everglades was diverted east and west. Major storms and floods in the late 1940s spurred the straightening of the Kissimmee River and enlargement of the levee around Lake Okeechobee. Much of the area just south of the levee was converted to sugar cane and other crop production. The use of fertilizers and pesticides intensified causing eutrophication in many smaller lakes, rivers, Lake Okeechobee, and the northern Everglades.

Partly as a consequence of the continued economic importance of tourism, Florida has become more environmentally aware than many other locations in the United States, but only after significant damage was done. Local concern for the fate of the Everglades began to grow as the combined threats of land development, eutrophication, and less fresh water (especially during droughts) came to light. Soon after the Kissimmee River had been straightened by the Corps, the State of Florida wanted to reverse the process. The Corps objected at first, but ultimately gave way to local desires. The movement to rehabilitate water and land resources infrastructure and use in southern Florida to protect Everglades National Park grew in part from the Kissimmee experience, as well as other concerns.

The Comprehensive Everglades Restoration Plan compiled by the Corps and the State of Florida addresses the largest proposed set of ecosystem restoration projects invested in by the federal government. The plan is focused on delivery of clean water to the Everglades in appropriate amounts, frequencies and distributions to sustain characteristic ecosystems. To meet that objective, it also provides for the needs of large urban and agricultural areas. Early consideration of water delivery more like the pristine condition from the south shore of Lake Okeechobee was rejected as impractical because so much water was needed for urban and agricultural uses that the flow would never reach the Everglades when it was most needed in times of drought. A more complex replumbing of the area was then planned, one that would provide more direct and controlled delivery of water to the Park from the east side of the Peninsula. For language sticklers, the plan is more correctly depicted as a highly engineered water resources rehabilitation plan than an ecosystem restoration plan. In a relatively recent event, the owners of the biggest sugar company in the region agreed to sell their lands to the State of Florida, allowing serious consideration of alternatives to the existing plan that might address pollution and rising seawater levels more effectively.

Park restoration faces many challenges. There is the threat of continued human population growth and demand for water, although recent frequency of large hurricanes and their consequences may contribute to dampening growth. Dealing with water quality degradation from agricultural runoff has yet to be confidently resolved. The Park also faces major threats from invasion of nonnative species that become established through intentional and accidental introduction. The biodiversity of the park, while nationally unique in many ways, continues to grow with non-native species that make it to the peninsula and find open niches. Some have the potential for remaking both terrestrial and aquatic portions of the ecosystem in ways that could limit restoration goals. Over the next century, projected sea level rise over the very flat terrain could convert parts of the Park to a very different ecosystem condition.

With that and other aspects in mind, it makes sense to some to reconsider the old plan to release water more uniformly from Lake Okeechobee, thereby restoring the Everglades to the north of the Park to allow the park to be expanded northward if needed. Recent State agreements to buy sugar company lands could be a major move in this direction. Options for flexibility may close as the region continues to develop, although there are indications that the public is increasingly less accepting of future development and more tolerant of protecting what remains. Numerous species and subspecies are in a vulnerable state in the region. Not surprisingly, Chaplin et al. (2000) count the Kissimmee River and the Everglades among watersheds that need restoration and protection to preserve the Nation's biodiversity.

The Everglades restoration program is likely to dominate the environmental outlook of peninsular Florida for at least the next 30 years. However, another big issue is the filling of other wetlands in Florida for development, which is regulated by the Corps under the CWA. This issue is likely to grow more contentious as time passes. Many Florida residents may want to slow urban expansion to protect their life styles, but the real estate community is exceptionally strong. The amount of hurricane damage that occurs over the next few decades may affect this trend as well.

Eastern Gulf Coast and Rivers

The rivers of the eastern Gulf of Mexico include the Suwanee, Apalachicola, Mobile, Pearl, and several smaller rivers, which empty into moderate to large estuaries (Ward et al. 2005). The larger rivers arise in hardwood-forests on the Appalachian highlands and generally flow south to a "fall line" where the slope shifts quickly to much flatter terrain on the coastal plain. The rivers threaded through uplands of southeastern pine forest and lowland swamps, oxbow lakes, and bottomland forests. The geology is complex. Large limestone springs with alkaline water arise in some areas where underlying limestone is exposed, but the soils in much of the region are acidic and highly erosive clays and fine loams. Watersheds in the upper-most and lower-most elevations produce acidic waters while those in the intermediate ridge and valley area are alkaline. The rivers tend to increase to moderate alkalinity as they enter the coastal plain. Rivers that arise on the coastal plain tend to be more acidic and stained brown with dissolved organic matter. The geological diversity may contribute to high regional freshwater biodiversity, which is exceptionally high in the Mobile River. The rivers in the region have been isolated for a long enough period of time to allow evolution of many endemic species of snails, mussels, and crayfish that are found nowhere else.

The region began to be settled by Europeans in the early 19th century when a substantial amount of it was cleared for cotton and other farming (Ward et al. 2005). The clay soils eroded rapidly and once clear rivers became turbid and flood prone. High sediment loads and turbidity remain the most extensive water quality problem in the area despite some of the watershed reverting to forest. Interest in river navigation improvement increased because shallow-draft steam boats were the main form of cotton and other crop transport to export centers. After the Civil War, the Corps began to dredge shoals in the coastal plain rivers. In the 1920s, local interests began to build dams for hydropower production in the rivers above the fall line, especially in the upper Mobile system. By mid-century, much of the eastern tributaries had been converted to a series of impoundments (Cole 2009). Other sources of stress appeared early in the 20th century around and north of Birmingham in the central river basins, which became heavily industrialized and mined for coal. That led to wide-spread water quality degradation and Corps waterway development of much of the river system.

The major presence of the Corps in the region is in its river waterway development and the Gulf Intracoastal Waterway, which has some of the same endangered species problems as those that occur in the Atlantic Intracoastal Waterway. The Corps also built a series of lock and dam structures in the lower Mobile River early in the 20th century and enlarged them in the 1960s. Lock and dam structures were also incorporated in some of the private dams built for hydropower. Following intense efforts on the part of state Senators, the Corps built its last major navigation project in the 1970s by linking the Tennessee and Mobile rivers through the Tombigbee River. The project had questionable cost-benefit estimates and project construction had severe environmental impacts leading to probable extinction of several species (Cole 2009). It confirmed the environmental community's growing distrust of the Corps, which the Corps has had a difficult time reversing because of persistent indications that all of those old practices have not entirely faded away (NWFTCS 2004). The Corps built few reservoirs in the region. It now operates two small reservoirs in the Mobile basin and two large ones in the Apalachicola basin.

The environmental laws passed primarily in the 1970s were a bit late for the Tombigbee, but have had positive impact on point-source municipal and industrial waste, leading to substantial recovery of rivers such as the Cahaba in central Alabama. Ward et al. (2005) implied that many such waste inputs remain to be corrected, however. Non-point sources of mine acid and sediment are more widely problematic. But the ESA has had the most impact by complicating and slowing further development. Evidence of this most recently occurred with severe drought in the upper Apalachicola River Basin. This region usually is quite wet but is periodically exposed to extreme drought. Recent unsatisfied demand for water caused extreme interstate stress over water rights including the needs for sustaining endangered species populations. Continued population growth in the area could aggravate the problems.

The aquatic biodiversity in the rivers has suffered disproportionately more in this region than many other places. A large number of mussel and snail species are believed to be extinct (Master et al. 2000, Cole 2009) and most of the extant species are threatened with extinction along with numerous fish and crayfish species. Much of this loss of mollusks is now associated with water resources development, some of it caused by the Corps. Cole (2009) makes the case that at least some of the loss was probably associated with high sediment loading and other

habitat changes before water resources were developed much. But regardless of past extinction causes, extensive river impoundment now contributes largely to endangerment and is most amenable to effective management. Since 2000 alone, dozens of snail species have been declared extinct (NatureServe 2014). Drought can add largely to the stress already placed on threatened species, including the willingness of some people to sacrifice populations for other water needs.

Much effort continues to be placed on protecting what remains of the unique fauna, but only a fraction of the imperiled species are protected under the ESA. In keeping with the dimensions of the problem, Chaplin et al. (2000) estimated that virtually all of the Mobile River system, large parts of the Apalachicola, Suwannee, Pascagoula and several northern tributaries to Lake Pontchartrain need protection and restoration. Impact mitigation has progressed in the Tombigbee and elsewhere. The Corps participated in a small dam removal from the Cahaba River, partnering with The Nature Conservancy (at a cost of $200,000) with apparently excellent results for recovery of endangered mollusk populations. This project is a prototype for small projects that are strategically placed for high cost-effectiveness and is the type of project that concerned NGOs look for. No major restoration work is planned for this region. National NGOs have been more likely than local agencies to partner in ecosystem restoration projects and are more likely to take a national perspective with respect to EQ restoration needs. However, many of the problems existing in the region may be of a scale too large to address through the continuing authority program for ecosystem restoration, which is limited to $7,000,000 per project.

Except around the larger cities, past inland growth in the region was modest. Future growth is likely to be fastest in the vicinity of larger cities, such as Atlanta and Birmingham, where growth is based primarily on light industry and information-based business—a change from the heavy industry of the past. The industrial basis for much of the waterway development has leveled and is in decline in some locations. Agricultural production is relatively minor. The Tombigbee Waterway, for example, has never transported anything near projected amounts (Costenbader et al. 2004). Future projects are controversial because domestic and international trade is difficult to predict with confidence. Past predictions have typically overestimated actual traffic and benefits. Future forecasts rely heavily on anticipated expansion of international trade and on transportation system improvements, all of which were a basis for past overestimates. Coastal development has increased significantly over the last several decades of relatively low hurricane incidence. The coast is not developed much otherwise. Changing insurance policies in response to recent experiences with damaging hurricanes could slow future coastal development. Numerous reservoirs have been developed by private utilities in the Mobile basin.

This region was economically behind much of the rest of the Nation. With development foremost, the region is among the least enthusiastic about locally investing in environmental protection or ecosystem restoration. However, economic conditions have changed dramatically in areas such as Atlanta, and environmental concerns often rise with average per capita earnings. Further wealth expansion will be based primarily on light industry and information services, if past trends continue. As that occurs, there may be a growing public willingness to restore some of the developed waters to a more wild state. In the meantime, further partnering with national

NGOs, such as The Nature Conservancy, is an effective way to pursue the ecosystem restoration mission in this region.

Lower Mississippi River and Tributaries

The Lower Mississippi River, as defined here, extends southward from the Missouri River. The tributaries include the Red, Arkansas, Ouachita and White rivers draining from the west, and a number of much smaller rivers draining from the east (Brown et al. 2005). By discharge measurement, the lower Mississippi is the largest river in the United States (9th largest in the world) and only a fraction of its total flow enters from the watershed area treated here. In general, the watersheds represented here drain from very mixed topography largely overlaying limestone rock. Accordingly, most of the rivers are moderately alkaline and hard, and are quite productive. A small fraction of the largest of the river basins (the Arkansas) occurs in the Rocky Mountains; most occurs in the southern Great Plains. The smaller Ouachita and White rivers originate largely in the Ozark Mountains and surrounding highlands. The main river to the east is the Yazoo. It and several much smaller rivers originate along the margins of the very wide Mississippi River floodplain on Mississippi and Tennessee highlands and in the floodplain itself.

The waters of the Mississippi seasonally flooded and receded, creating a wide floodplain with many oxbow lakes and seasonal bottomland swamps. Long before much human impact, Spanish explorers witnessed a large flood in 1543 (Brown et al. 2005). The river transported large sediment loads from erosion in the semi-arid western watersheds. The transported sediment sustained a vast delta with numerous distributaries entering the Gulf of Mexico. Dynamic river and coastal processes (Matthews et al. 2005) joined to shape the delta into an ever-changing mosaic of freshwater wetlands, slightly higher uplands, and saltwater wetlands, mud flats, shoals, and barrier beaches. Hurricanes and river floods drove much of the channel and wetland erosion and new delta deposition.

European settlement of New Orleans began in the 1600s on natural levees, which were artificially enlarged by settlers in 1735. Establishment of shallow-draft steamboat transport in the early 1800s stimulated rapid growth of river outposts and agricultural development of the rich river floodplain. Only the lower parts of the Red and Arkansas rivers were suitable for navigation development. By 1844, levees engineered by local interests extended northward from New Orleans to the Arkansas River. Between the use of floodplain forest for fuel and clearing for agriculture, the highest parts of the floodplains were deforested by the end of the 19th century.

By the late 1800s much of the upland area in this region had been transformed to wheat and other crop production to the east and to intense livestock grazing to the west. Population density remained low. Land use accelerated erosion, causing the plains rivers to become more consistently turbid. During the 20th century, even bottomland swamps were being cleared and drained to increase agricultural land use. But some had been reserved in wildlife refuges as well, where recent reports of an ivory billed woodpecker intensified the call for better protection and restoration of forested seasonally flooded bottomlands. The Ozark highlands were a regional exception, not well suited for agriculture. Much of it remained forested and the rivers that drain it continue to run relative free of sediment. Except for local impacts mostly near cities, urban and industrial pollution is a minor problem in the area.

Flooding is a perennial problem along the Mississippi and its major tributaries. The Corps first addressed the problem with levees, which were also built to channel flood water to cut deeper river channels for navigation during low water. Then, from the 1930s through the 1960s, the Corps built multipurpose flood control and hydropower reservoirs in the Red and Arkansas River basins. The reservoirs also trapped sediment that would have gone to the Louisiana delta. Levees increasingly blocked delta distributaries and extended the river outlet into Gulf waters where most remaining sediment was dumped into deep water. Also adversely affected by channel dredging and oil and gas development, the delta equilibrium was badly upset and it began to lose barrier island and wetland acreage rapidly, especially during major hurricanes (Gosselink et al. 1998, IPET 2009).

In its pristine state, the natural biodiversity of the rivers, floodplains, and deltas in the region varied widely. The Mississippi River and its Great Plains tributaries are inhabited by species tolerant of variable flows, turbidity, and shifting shoals of sand and finer sediment. Despite proper alkalinity, the molluscan fauna is not nearly as diverse in those environments as in the more stable river basins east of the Mississippi. Numerous fish species live there though, most of which are widely distributed and common. Some unique species (mostly minnows) became scarce as engineered control of the river increased. The clear-water rivers originating in the Ozark highlands have more diverse mollusk, crayfish and fish communities than the rest of the region. Many of these species and some wetland plants are now threatened with extinction. Few aquatic species in the main-stem river or adjacent wetlands are threatened. A major exception is the pallid sturgeon. A number of delta inhabitants are threatened, including several fish, wetland plants, and bird species, and a turtle species.

Events associated with the flooding of New Orleans during Hurricane Katrina have greatly intensified previous attempts to reverse changes in the delta dynamics to help reduce future storm damage. Regardless of what ultimately happens in the region, a new respect for ecosystem services has emerged out of it along with an intensified interest in better integrating engineered and wild systems. Questions that began to be asked seriously within the Corps decades ago about the appropriate width of floodplain between levees and river channels are now gaining renewed attention with respect to solving both flooding problems and the decline of many riparian species. Katrina and other recent extreme hurricanes have also magnified growing concerns about past trends toward settlement in hurricane prone areas. Projected possible impacts of climate change add to the uncertainty faced in this region. Insurance costs are very likely to increase, perhaps dampening the urge to settle in hurricane prone areas. Recovery of the human population in the area has been slow, in part because the area was economically depressed before Hurricanes Katrina and Rita. Past regional population growth was slower than elsewhere in the United States and is forecast by the U. S. Census Bureau to grow slower than average in the future.

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Chaplin et al. (2000) indicate that significant fractions of the lower Red, Ouachita and Arkansas basins would need to be restored and protected to sustain freshwater biodiversity. A few smaller watersheds are identified for attention on the east side of the river. Corps flood control projects are a major presence in this region and the lower portions of the largest rivers are dredged by the Corps. While the sections recommended are most free of Corps projects, some Corps reservoirs

are included within them. The Nature Conservancy and the Corps have already established biodiversity restoration projects below reservoirs at several locations in the region. While the region provides many opportunities for beneficial ecosystem restoration local sponsorship of such efforts is likely to be less enthusiastic than in wealthier regions. An exception is the New Orleans area, which is undergoing study of ecosystem restoration as part of a Corps and state sponsored approach to fish and wildlife recovery, flood risk management, and tourism development. With respect to biodiversity improvements, opportunities exist for modifying operations at Corps dams, but a significant number of threatened species occur in the delta as well.

Missouri River Basin

The Missouri River flows southeastward to the Mississippi River from origins in the Rocky Mountains and Great Plains. The climate is largely semi-arid with variable precipitation. The river was prone to extreme flooding before European settlement. What is probably the largest flood in the historic record occurred in 1844 (Galat et al. 2005). The watershed geology is variable, but largely underlain by limestone; thus the basin's rivers are largely alkaline, moderately hard, and fertile. Highly erosive glacial till overlies much of the northern basin which lends to high sediment loads and turbidity. The Missouri contributed much of the sediment carried by the Mississippi River to its delta in southern Louisiana (NRC 2011a).

Human settlement in this region began slowly in the early 19th century and concentrated along the lower river in the vicinities of St. Louis, Kansas City, and Omaha. The southeastern part of the basin was intensively developed for grain production. Farther upriver, settlement was much sparser and the economy depended primarily on livestock production. Land use probably accelerated already high erosion rates. Mining started in the upper basin during the late 19th century. It contaminated sediments with toxic materials in some mountain tributaries (now superfund sites) and elevated contaminant concentrations in the main river, causing some sport fisheries consumption to be restricted (Galat et al. 2005). Major environmental alterations in lower river reaches are associated with the effects of six large impoundments and numerous smaller reservoirs constructed during the 1940s and 1950s. The sediment load of the lower Missouri River was reduced 70 to 80 % (NRC 2011a).

All but one of the six reservoirs were authorized by the Pick-Sloan Flood Control Act of 1944, which in total authorized over 50 dams in the basin. The legislation was intended to encourage development, following models established by the TVA and Columbia River development. The purposes included flood control, water supply for navigation, hydropower, irrigation for agricultural development, and recreation (including and fish and wildlife improvements). Most of the effort was led by the Corps, but irrigation aspects were managed by the Bureau of Reclamation. Most of the reservoirs authorized by the Act were small, but some of those along the main-stem Missouri are among the largest in the United States.

Events since the dams were completed bring the investment into question. By and large, the population growth the development was intended for never happened. Much of the area lost population after the dams were constructed. Plans to develop irrigation systems were finally stopped with growing realization that the benefits would not justify the costs. The 1993 flood

discharge was nearly as large as the 1844 flood discharge. Levees built by the Corps around Kansas City were the main reason it was not damaged as much as other locations. Net benefits from navigation have only been about $3 million per year (Galat et al. 2005). Because of its impacts on endangered species, the low benefit is one reason why management of reservoir water supply for low-water navigation has become controversial (NRC 2002).

While the basin hosts few species threatened with extinction (Galat et al. 2005), it has become a poster child for those few that are threatened. The Missouri River mitigation projects sponsored by the Corps (and described under ecosystem restoration history) have been oriented mainly toward recovery of those species. The dams also have affected sediment movement in deleterious ways (Harrison and Mallema 1982). In its pristine state, the Missouri River contributed largely to the sediment load in the Mississippi River and delta. The lower Missouri river is now much less turbid and has fewer sand bars and more stable flows, all conditions inconsistent with the needs of numerous native species including endangered species. On the positive side, the Missouri River reservoirs have become popular fishing sites that bring significant income to the region. The reservoirs provide nearly $90 million/year in recreational benefits (Galat et al. 2005).

The future of the region as it relates to water resources is uncertain. Recent oil and gas development has produced an economic boom in part of the basin but will eventually fade. Its long term economic future depends largely on corn and other crop prices, which are now high in part because of subsidized biofuel development. However, biofuel production from corn also incurs environmental costs that critics indicate make it the worst choice and to be avoided (Groom et al. 2008). Such emerging issues may eventually cool enthusiasm in the region. If production does become well established, biofuel may be more effectively transported by pipelines or other means than by barge. Grain export to other parts of the world will remain significant, but whether it increases or decreases depends largely on agricultural practices in other parts of the world and the extent they become more regionally self-reliant. Agriculture in the region continues to be subsidized to help sustain balanced international trade. Such subsidies have been criticized for the harmful impact they can have on developing nations. Whether the trend toward eliminating tariffs and subsidies will continue is another uncertainty affecting projections. The effects of climate change add substantially to uncertainty.

Chaplin et al (2000) have identified much of the upper Missouri River watershed as among those that need to be restored and protected if aquatic biodiversity is to be sustained. The Little Sioux, Vermillion and White Rivers are also identified for protection. However, finding cost-sharing partners for ecosystem restoration of the dimensions being considered could prove challenging in this economically insecure region where the recent development of oil and gas may not reduce future insecurity after the boom fades.

Upper Mississippi River Basin

The upper Mississippi River and many tributaries originate in and flow over glacial till plains overlying mostly limestone formations. The larger rivers are moderately alkaline, moderately hard, and fertile. The main tributaries include the Minnesota, Saint Croix, Chippewa, Wisconsin, Rock, Illinois, and Des Plaines rivers. The watersheds were covered by forests, lakes and wetlands to the north and east, grading into prairie to the south and west. The upper tributaries

were colder and less alkaline than farther south. The river meandered freely through a wide floodplain with many adjacent oxbow lakes, lateral wetlands, and riparian forests. River hydrology was less variable than the Missouri, but enough to sustain a dynamic mosaic of floodplain ecosystems. The river provides an outstanding natural service to recreational users of a major waterfowl flyway. Its floodplain wetlands host many thousands of waterfowl at migration and contribute significantly to their production.

Major settlement in the basin came with the steam-powered river boats of the early 19th century. Immigrants settled and cultivated much of the area, especially in the prairie regions to the west. The east was intensively logged and suffered many major fires as a consequence of combustible debris accumulation after logging was complete. Some of the tributaries served for log transport to sawmills and paper mills became major sources of organic pollution. In all, only a small fraction of the pristine terrestrial ecosystem condition remains, mostly in the eastern forests (Delong 2005). Once exposed to the plough, the soils become moderately erosive and the once-clear rivers become much more turbid.

As the region settled, population centers grew primarily along the major water courses where they contributed oxygen-depleting organic loads via municipal wastes and paper mills. Livestock feedlots added to the load later in the 20th century. Water quality degraded locally, but the size of the main river assimilated much of it. Like other regions, environmental laws greatly reduced point-source pollution, but agriculture remains a highly problematic source of eutrophying nutrients.

In the 1800s, the Corps began to augment shoal dredging to improve navigation by building wing-dams to concentrate flow. That was followed by construction of a series of 26 locks and dams, which created a navigation channel with a 9-foot minimum depth reaching to Saint Paul-Minneapolis. Additional lock and dam structures were built on its main tributary, the Illinois River, which eventually was linked by canal to Lake Michigan via the Chicago River. The lock and dam structures flooded wetlands and backwaters, reducing habitat suitability for some waterfowl and other species while expanding it for others. The Illinois was more dramatically transformed by lock and dams than the upper Mississippi and was more extensively affected by agricultural erosion and nutrients (DeLong 2005).

In 1924, as waterway improvement progressed, Congress created the Upper Mississippi National Fish and Wildlife Refuge along 261 miles of the upper Mississippi River, which is about half of the total reach. It occupies over 240,000 acres. The refuge was created at a time when there was concern about decline in waterfowl and the Mississippi flyway supported nearly half the total numbers. Many of the local public were avid hunters and anglers, and the refuge continues to support nearly three million recreational visits annually (from U. S. Fish and Wildlife data provided on the refuge website).

Eleven of the navigation pools are located in the wildlife refuge area. Even so, more than 80% of the river-floodplain system remains generally intact along the upper Mississippi (Delong 2005). Delong (2005) states that the lock and dam structures are “the most obvious human impact” on the river. Despite this, agricultural sources are the biggest single water quality concern, because of agriculture’s contribution to eutrophying nutrient loads, some of which ultimately contribute

to the oxygen depletion in the Gulf of Mexico (NRC 2008). Agricultural levees have also contributed to the disconnection of the rivers from their floodplain ecosystems.

Navigation improvement provided by the Corps has long been considered a mainstay of the economy. Concern about lock and dam rehabilitation needs grew as the lock and dam structures began to age beyond their planned lives (NRC 2005b). Slowed by the existing size of the locks, navigational interests lobbied strongly for longer locks, at high public expense. Meanwhile state fish and wildlife interests in the basins desired substantial improvements for fish and wildlife recreation to accompany lock enlargement. This culminated in the Upper Mississippi River System Management Act of 1986, which defined the Upper Mississippi as a sustainable, large river ecosystem with multiple uses. In it, Congress declared the Upper Mississippi system, including the Illinois River, to be "a nationally significant ecosystem" and a "nationally significant commercial navigation system". A regional management plan was developed with goals that include understanding the ecosystem, monitoring resource trends and effects, developing resource management alternatives, managing information, and developing useful products. Adaptive management is institutionalized in the authority. The NRC (2004b) complemented the progress, but also stated, "it is difficult to understand which projects are the most promising and which should be implemented first." This problem arose because restoration objectives and benefits were not clearly conveyed; a common problem in feasibility studies (e.g. Brandreth and Skaggs 2002).

One issue pertaining to ecosystem restoration justification is the relative ecosystem restoration needs compared to other regions. The rivers of the basin are rich in native freshwater biodiversity, including a moderate number of native mussel species and numerous fish species. Only two fish species and three mussel species in the area are endangered, however. Slack-water navigation impoundments are among the primary threats. Two threatened and endangered interior shore birds live and reproduce on river sandbars. Most fish species are secure from extinction, but a larger fraction of the mussel species are not. The target of much of the ecosystem rehabilitation activity, waterfowl and sport fish, are valued for recreational use, but are among the more abundant and most secure species. Compared to some other river basins, the state of the freshwater biodiversity is relatively secure (Chaplin et al. 2000) in the basin. In keeping with the limited need, Chaplin et al. (2000) identify only fractions of the Wisconsin and St. Croix rivers for restoration and protection needs. These portions have relatively little private development and are free of federal water resources development.

While global biodiversity security of species in the area is high, local losses have been great, particularly in the upper Illinois River, which lost virtually all of the 38 native species observed before 1900 by 1969 (DeLong 2005). All but two of these species had disappeared from surveys by 1912, within 12 years of the Chicago Ship Canal being opened (and flushing Chicago sewage waste down the Illinois). Fish species also were decimated. Organic pollution has much improved since the CWA was passed in 1972, but at this time only relatively common mussel species survive in the Illinois, where they remain exposed to the combined effects of navigation impoundment, fine sediment and agricultural pollutants. Numerous fish species have returned to the upper Mississippi since point-source pollutants were cleaned up. However, non-native invasive species are an uncertain player in the fate of species in the area. The Chicago Ship Canal has become a pathway for movement of potentially damaging nonnative species. The

Corps has led recent efforts to block movements of invasive fish using modern technology, but such management measures, while slowing invader progress, tend ultimately to be circumvented in some way. A common problem is fish transport in bait buckets and boat wells.

The economy in the basin is generally strong and modest population growth is expected in urban areas. However, grain production is one of the economic cornerstones and it faces the uncertainties similar to those described for the Missouri River Basin. The public in general enjoys outdoor pursuits and supports environmental protection and improvement. Prospects for local ecosystem restoration partnerships are higher than average. The future of the river ecosystems in the Upper Mississippi River basin depends largely on river management for navigation and on pollution clean-up. Nonpoint sources of sediment, nutrients and pesticides remain a chronic problem that may eventually yield to better management at the source and in the river floodplain (Hey and Philippi 1999). Navigation needs on the Mississippi and Illinois are likely to remain important for the foreseeable future, even if not as important as the more sanguine forecasts would indicate. Major rehabilitation needs, now being addressed in the Upper Mississippi Management Plan by the Corps and nonfederal partners, may be applicable elsewhere in the basin, but other locations may be a higher priority based on biodiversity threats.

Ohio River Basin

Before settlement by European Americans, the Ohio River Basin was largely covered in mixed deciduous forest grading into savannah to the west. Major tributaries include the Wabash, Green, Licking, Scioto, Allegheny, Cumberland and Tennessee (White et al. 2005). The geology is complex and was glaciated in the northwestern part of the basin. Much of the basin exists on karst limestone with many springs and cave systems, which cause complex surface hydrology in some areas. River waters are largely alkaline except in small streams of the Appalachian headlands, which are underlain by more acidic sandstones. Monthly precipitation is nearly uniform and seasonal flow variation is influenced mostly by evapotranspiration and winter freezing. The highest flows occurred in spring during snowmelt and declined through summer. Natural flows were much more stable and freer of suspended sediment than in the Missouri River because the climate was wetter, the precipitation was more uniform and the watersheds were well-forested. Erosion was minimal and the water was typically clear, naturally fertile, and underlain with sand, gravel, cobble, and bedrock generally free of fine sediment. The diversity of freshwater species was high among fish, crayfish, and mussels, with many endemic species in certain river tributaries.

Settlement began in the late 18th century but increased rapidly after steam-boat transportation was established in the early 19th century (Cole 2009, White et al. 2005). Land along the river was rapidly cleared for fire wood and farming. The highlands were only partially cleared for timber and farming. Many of the rivers were used to transport logs to mills. The Appalachian highlands to the east proved poor for farming and much of it returned to nearly full forest cover. Farther west, the rivers of Ohio, Indiana and, to lesser extent, Kentucky and Tennessee, became more constantly turbid and choked with fine sediment as the land was cleared (Troutman 1981). Stream discharge became more variable, accentuating the impacts of drought on biota. Coal was discovered to be abundant in the upper watersheds and mining for it began in earnest at the close

of the 19th century. The availability of cheap fuel and waterborne transport turned some of the river cities near coal fields into industrial towns.

Pollution from organics, toxic metals, and mine acids became a major problem. Sensitive species began to disappear (Cole 2009). A widespread species of sucker, which was especially sensitive to high sediment loads and turbidity, was last recorded alive in 1883. It may have been an indicator for other species that were sensitive to sediment, including many mussel species and some freshwater snails that also disappeared during the late 19th and early 20th century.

Water resource development began early in the 19th century with lock and dam construction in the Green and Kentucky rivers. But engineered modification of the large rivers was minimal until the late 1800s when 6-food navigation channels with locks and movable dams were built in the main channels of the Ohio and its largest tributaries. Larger lock-and-dam structures began to be built in the 1920s, at first in the Tennessee, followed quickly by the main-stem Ohio and other rivers. By mid-century, the lower reaches of the larger rivers had been transformed to much more physically monotonous waterways with larger cross-sections and reduced mean velocity. The Ohio River was almost entirely converted to a waterway to provide a minimum 9-foot navigation depth. Waterways also extend into the Tennessee, Cumberland, Green, Kanawha, Monongahela and Allegheny rivers. Numerous species became more vulnerable to extinction and some were declared extinct (Cole 2009).

The pristine river system varied naturally between flood and drought flows that were probably accentuated by widespread removal of natural forest cover. Numerous reservoirs were built on the tributaries with both flood control and drought water supply purposes from the 1920s to 1960s. Many of the larger reservoirs produce hydropower, causing unnatural fluctuating flows downstream. The combination of pollution from sediment, organic load, various metal and synthetic contaminants, and mine-acid combined with impounded water surface area and tail-water impacts to reach a peak total impact in the 1960s. At that time, river waters often were declared a public health hazard and many freshwater species were in steep decline.

Implementation of the CWA and the ESA began to reverse environmental degradation, especially from point sources of pollution. However, non-point sources of pollution remain significant in many locations, especially in the western agricultural areas and the eastern coal fields. The information age gradually displaced the industrial age in the region, contributing significantly to reduced industrial effluents. Iron and coal transportation needs began to decline. However, coal transport for fossil fuel power plants is a mainstay for barge transportation. Mine acid and coal sediment continues to be a problem in the east and high nitrogen, phosphorus and sediment loading remains prevalent in the western farming regions. However, many fish species are recovering to more uniformly high abundance in response to reduced oxygen demand and toxic contaminants.

Earlier events in the basin exacted high environmental costs. Numerous mussel, snail and small fish species that are adapted to moderately high water velocity and clean gravel and cobble bottoms are now extinct, imperiled, or increasingly vulnerable to extinction. Many persist in small fragments of suitable habitat where they are particularly vulnerable to intolerable natural and man-caused events. The Ohio Basin has one of the richest endemic fish and mussel fauna in

the United States. As a consequence, Chaplin et al. (2000) identify extensive parts of the Tennessee, Cumberland, Wabash, Green, Licking, Scioto, Muskingum, Cheat, Green Briar and Allegheny watersheds as needing restoration and protection. The Nature Conservancy established a prototype project with the Corps for biodiversity restoration on the Green River. The areas targeted for more protection and restoration have had significant water resources development, especially in the Tennessee and Cumberland Rivers. The Corps has reservoir projects in much of this area, but most prominently in the Cumberland River Basin.

The economic security of this region remains uneven and many people, once dependent on mining and manufacturing, have not fully adapted to more of a service-based economy. Thus commitment to environmental improvement is mixed as is interest in ecosystem restoration. There is continuing interest in rehabilitating the lock and dam system of the Ohio and, with it, incorporating some environmental quality improvements through restoration methods. But in recent decades, the major item transported by barge has been the coal used to fuel power plants in the lower basin. Growing emphasis on replacing bulk coal with piped natural gas, as well as renewable energy resources, may portend decreased need for barge transport and lock-and-dam structures. The benefits of major lock and dam rehabilitation are becoming much less certain in many parts of the Ohio system. Even if coal remains an important energy source, other transportation methods may prove more environmentally compatible and Ohio River restoration more feasible.

Western Gulf Coast and Rivers

The largest of the western gulf-coast rivers include the Sabine, Brazos, Colorado, and Rio Grande (Dahm et al. 2005). The natural vegetation of the basin grades from pine forests in the Rocky Mountains through short-grass prairie at intermediate elevations, then oak savannas and pine forests to the east. The underlying geology in the western highlands is complex, but limestone is predominant at lower elevations and the water is naturally alkaline, hard, and rich in inorganic nutrients. The climate is largely hot and dry, and discharge per square mile is naturally low. Even in their precolonial state, river flows in the region tended to be variable and often turbid with eroded sediment except where they are sustained by large springs on the Edwards Plateau. Sections of some rivers ceased to flow on the surface during severe droughts. Hurricanes occasionally cause intense and prolonged precipitation and extensive local flooding. A number of small tributaries of the Rio Grande originate in freshwater and brackish springs of south-central and west Texas and its main tributaries are the Pecos River and Rio Conchos.

European settlement started in the highest elevations of New Mexico in the 16th century, but progressed slowly until the 20th century. Coastal and river-valley agriculture became well established during the 19th century and much of the upland was heavily grazed. Later agricultural development of groundwater sources occurred after World War II. Oil was discovered and rapidly developed in the early 20th century in west-central Texas and eastern New Mexico. Land use impacts increased river flow variability and raised turbidity to consistently high levels in some rivers. The rivers were never very suitable for commercial navigation. Many reservoirs were constructed primarily for flood control and water supply purposes starting in the late 19th century. The reservoirs are prone to fill with sediment and alter the river chemistry, sediment movement and flow variability. Because of reservoir and irrigation evaporation,

estuaries have become more saline and less supportive of pristine ecosystem conditions (e.g., Palmer et al. 2002).

The biodiversity of the rivers is moderately high. Over 160 species of fish, 50 species of freshwater mussels, and 38 species of crayfish occur in the rivers (Dahm et al. 2005). Some species are now extinct and numerous species are vulnerable. Reservoir management, including a few Corps reservoirs, is linked to the vulnerability of some species. Irrigation diversion for agriculture is a threat in the upper Rio Grande. The Edwards Aquifer harbors an exceptional diversity of freshwater cave and spring fauna, some of which are imperiled by groundwater withdrawal and contamination (Bowles and Arsuffi 1993). A number of the spring tributaries entering the Rio Grande as well as the river itself, harbor threatened endemic species.

Regional population growth has been high since World War II, especially around Dallas, Houston, Austin, San Antonio, El Paso, and Albuquerque. Growth is likely to continue for some time in this generally well-off region (except some rural areas), but it will come at some increased cost for freshwater and electricity provision. Freshwater supply for all needs, including environmental needs, is an intensifying issue. The Edwards Aquifer is a major source of water for the San Antonio and Austin area where concerns for its unique aquatic ecosystems are growing. But much of this pro-growth region is less enthusiastic. Many multi-purpose reservoirs, including water supply, have been built by the state and the Corps, and more are being considered for water supply purposes. However, like elsewhere, costs are high and alternatives, such as increased water use efficiency and desalinization, are likely to become more attractive (Dziegielewski and Keifer 2006).

Chaplin et al. (2000) identified major parts of the Sabine, Colorado, Pecos and lesser portions of the upper Brazos, and upper, middle, and lower Rio Grande basins for protection and restoration needs. Except for the upper Rio Grande, existing Corps reservoirs play little role in these watersheds. The Sabine and Colorado watersheds also include several authorized reservoirs that were never constructed. The Corps also maintains the Gulf Intracoastal Waterway where threatened sea turtles are a continuing issue.

Colorado River Basin

The topography of the Colorado River Basin is rugged and geologically diverse. Much of the intermediate length of the main-stem river runs through steep-walled canyons. Semi-arid to mesic high lands are interspersed among more arid lowlands. Runoff at high elevations is moderately alkaline, but becomes progressively more alkaline and hard as the river moves toward its estuary on the Gulf of California. Because much of the tributary runoff originates from snow, discharge is greatest in the spring and early summer. Low seasonal flows in the larger tributaries are sustained by valley aquifers. Because of the arid landscapes, natural erosion rates are high and the largest tributaries and main stem were persistently turbid with high suspended sediment loads even before livestock grazing became widespread in the basin. River temperature fluctuated between extremes caused by cold snowmelt and very hot summers. The unique aquatic life inhabiting the lower basin evolved under those conditions.

The Colorado River Basin was among the last in the contiguous United States to be settled. Its remote setting and hot, dry environments were hostile to agriculture and other human endeavor. Livestock grazing, mining, and limited timber production were the major sources of livelihood in the 19th and early 20th centuries. Following a survey by John Wesley Powell, interest in developing more reliable sources of water for agriculture culminated in the federal authorization of major irrigation projects and construction of some of the largest impoundments in the world by the Bureau of Reclamation. The earliest development occurred on the Salt River, which established an agricultural basis for growth of Phoenix, Arizona. Major development on the main-stem and northern tributaries continued from the early 1930s through the 1960s. Large fractions of the Colorado River are now either inundated by impoundments or dramatically altered by downstream impoundment effects. Some of these reservoirs need repair, major rehabilitation, or possible decommissioning, depending on economic and environmental benefits.

The Colorado River Basin remains among the least densely populated basins in the Nation, but growth has been rapid over the last half century. Nearly three fourths of the basin is under federal land management authority (Blinn and Poff 2005). Agriculture and grazing have contributed to increased runoff of sediment and river turbidity locally, but the primary impacts on river life are from impoundment and dam operation. Large impoundment releases of water are consistently cool (9° to 14° C) and much clearer than the original flows (Blinn and Poff 2005). High evaporation from the reservoirs has increased salinity in the lower reaches and decreased discharge to Mexico and the Colorado estuary. Many nonnative fish species and several nonnative invertebrates have been introduced. The net effect on native fishes was dramatic, with 40 of 42 endemic native species now threatened or endangered (Blinn and Poff 2005). Several once abundant species are now extinct.

Localized population growth in the area soared as electricity and air conditioning became widely available. Past rapid population growth in southern Nevada and Arizona is expected to continue, but probably more slowly based in part on limited water supply. The critical habitat needs of endangered species could increasingly play a role in limiting further river development and water use. Water rights could be purchased from agricultural owners for conservation purposes, but the price of water has increased in response to growing demand for domestic water, making that option less tenable. However, conservation through waste water recycling is a reality in certain communities and is gaining more attention as it proves more practical. Desalinization of ocean water and saline groundwater is also an increasingly attractive alternative, but could be dampened by rising power costs.

The Colorado drains a relatively wealthy but generally conservative region. Environmental concern tends not to be as strong as it is in basins farther north. Many opportunities for ecosystem restoration exist; however, most of them are not associated with Corps projects. The Bureau of Reclamation has used its NEPA process creatively to apply restoration actions in the operation of some of its projects, most notably at Glen Canyon Dam (Webb et al. 1999). Chaplin et al (2000) indicate a need to protect and restore major portions of the upper Colorado and lesser portions of the lower Colorado, especially in the Gila River Basin. The Corps has a small presence in these regions and cooperates with the Nature Conservancy in a biodiversity restoration project (operations modification) on the Bill Williams River in western Arizona.

Columbia River Basin

The Columbia River is the largest river entering the Pacific Ocean on the west coast of the United States, including Alaska. Its basin extends into much of the northern Rocky Mountains of the United States and southern Canada. The topography, climate, and landscapes are rugged and geologically diverse. Much of the annual discharge originates from mountain runoff, primarily from snowmelt. Seasonal flow variation is naturally large and flooding can be extreme (Stanford et al. 2005), but most of the pristine watersheds eroded moderately because of dense forest cover. River waters tended to be highly turbid only during flood. Water quality varies widely among the tributaries and alkalinity, hardness and fertility are lower in the main river than in many of the other river basins in the contiguous United States. The Columbia was known for its tremendously large runs of west coast salmon. The cultures of native people along the river profoundly depended on salmon runs.

The basin is one of the more sparsely developed in the contiguous United States. Settlement began mid-century in the 1800s and concentrated near the coast, mostly in the Willamette River Valley, which was cleared of forest and largely developed for agriculture. Urban and agricultural development established gradually, mostly in the valleys of the larger rivers and rich prairie regions typified by the Palouse Prairie in eastern Washington and western Idaho. Much of the basin was too dry to farm and is grazed instead. The forests at higher elevations largely supported the early regional economy and remain significant economically while substantially less dominant. While there have been local impacts from urban-industrial pollution, including significant pollution with radioactive materials, the biggest changes to the river system result from water resource development. Most of the main-stem and significant portions of main tributaries have been greatly modified by impoundments built primarily for navigation, flood damage reduction, and hydropower. The Corps has a major presence in the basin.

The salmon runs of the Columbia have been decimated by the impacts of fishing, river impoundment, stream sedimentation and other pollutants. Over 50 species of nonnative fish have been introduced including species that prey on native salmon. The once high mortality of young salmon passing through penstocks is now greatly reduced, but predation, enhanced by the effects of large impoundments, continues to exact a toll (Stanford et al. 2005). A substantial number of native fish populations are now listed as threatened and endangered, although the numbers do not rank as high as most basins in the southern United States. The public inhabiting the western part of this basin is among the most committed to environmental improvement of any in the United States.

Population growth is moderate to rapid in the few large urban areas in the watershed, but the Columbia Basin remains largely rural. Water resources development has peaked in the Columbia and its tributaries. Removal of certain dams on the Snake River continues to be advocated by environmental organizations, although the costs, especially in lost hydropower production, would be high. The Corps of Engineers has spent several hundred million dollars to reduce salmon impacts (Figure 16). Salmon and other native fish will continue to dominate the environmental concerns in the Columbia River basin for the foreseeable future because of the complex mix of economic, cultural, and endangered species interests associated with the fish fauna. Chaplin et al. (2000) identified small portions of the Columbia Basin for restoration and

protection especially in the upper Willamette, Grande Ronde, and upper Snake watersheds. In cooperation with the Corps, The Nature Conservancy has a biodiversity restoration project (operations modifications) on the Willamette River. The Corps operates a number of small reservoirs in the upper Willamette River Basin.

Pacific Rivers and Coast of the Coterminous U. S.

The Pacific coastal rivers of the coterminous United States other than the Columbia River drain from mountain ranges generally west of the Rocky Mountains, including the Coastal ranges, Cascades, and Sierra Nevada. The rivers with the most significant discharges range from Puget Sound to the Santa Margarita, south of Los Angeles. Important rivers in between include the Umpqua, Rogue, Klamath, Eel, Russian, Sacramento-San Joaquin, Salinas, and Santa Ana. The Sacramento-San Joaquin dominates the total basin area. In response to climatic and topographic variation, the rivers vary greatly in physical appearance, hydrodynamics, chemistry and biology (Carter and Resh 2005). Precipitation rate is greatest on the Olympic Peninsula (the highest rate in the coterminous U. S.) and diminishes to the south. Accordingly, the natural vegetation varies from dense temperate rainforest to chaparral shrub and desert grasslands. The rivers undergo large seasonal flow variation. In general, salinity, alkalinity, and mean annual water temperature increase from North to South. Regional uplift is geologically recent and ongoing, which has contributed to the relatively low but often unique diversity of fish and other species. Many of the non-flying aquatic species in the Central Valley are endemic and unique, a consequence of geological separation from other freshwater fauna by mountain uplift.

The rapid population growth of California started with gold discovery in 1848. Settlers soon discovered that the rich land of the Central Valley and southern coastal areas was agriculturally valuable, once supplied with irrigation water, and has been extensively developed since the late 1800s. To the North, the major impact on basins was from timber cutting and isolated valley farming.

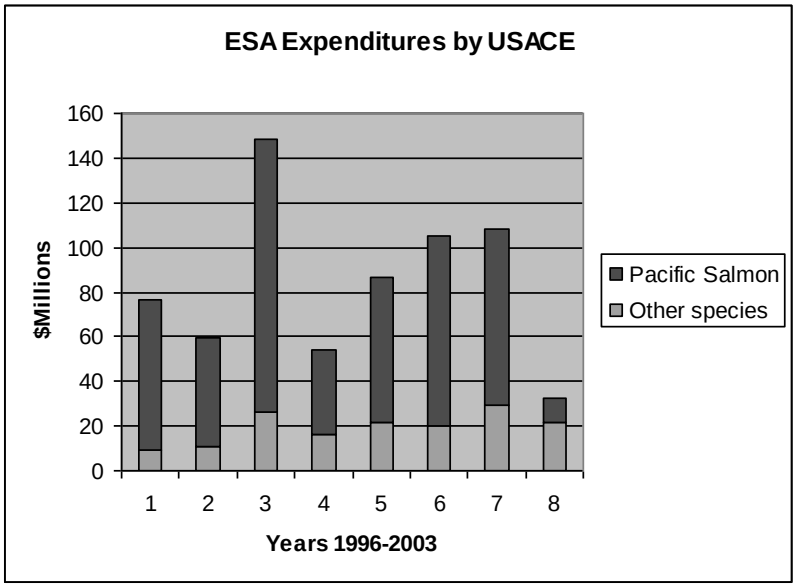

Figure 16. Annual expenditures by the Corps on protection of species listed as threatened and endangered under the ESA (data from internal annual reports).

Dams were built on most of the rivers for flood control and water supply. Regional population growth has been faster than most other areas in the Nation, and growth continues despite severe water shortages during droughts.

The combined effects of water resources and agricultural development have endangered a large fraction of the native fish species and extinction of at least two aquatic species (Carter and Resh 2005). The river ecosystems including and north of the Sacramento and San Joaquin rivers are inhabited by west-coast salmon species. These rivers are at the south end of west coast salmon range and projected climate change threatens salmon survival this far south. Many species of fish and some invertebrate species have been introduced, complicating potential for restoration. Otherwise, the coastal regions for the most part remain environmentally healthy except locally in the San Francisco Bay, Puget Sound and other harbor regions. San Francisco Bay was profoundly altered by wetland filling for urban development and massive construction of salt evaporation ponds along the margin. There is much local interest in mitigating for the aesthetic and recreational impacts of the salt ponds, but potential contributions to restoration of threatened biodiversity may be more modest than some other regions (e.g., Master et al. 2000).

The public in this region is more committed to environmental improvement than most other regions of the Nation. However, past urban, water and land development have produced changes that will be expensive to relieve as the public wrestles with increasingly obvious water conflicts over continued growth of urban water demand, degrading levees and other engineered infrastructure, the protection and recovery needs of endangered species, and a well-established and politically influential agricultural community with existing rights to much of the water. Recent extended drought is pressing the limits and the potential for serious conflicts.

The CalFed Bay-Delta Program is committed to simultaneous improvement of California water supply, water quality, flood damage reduction, and ecosystem health in the Sacramento-San Joaquin basin and the estuary in northeastern San Francisco Bay. The Program is led by the Bureau of Reclamation and California with the Corps as a participant. The Corps plays a larger role in restoration planning in the southern part of San Francisco Bay. Other smaller programs exist across the region where conflicts between established water uses and species populations listed as threatened and endangered have become increasingly common. Satisfactory resolution probably will require extensive regional rehabilitation of the land and water resource infrastructure and operations.

By comparison, settlement around Puget Sound to the North in the greater Seattle area is faced with comparatively straightforward water quality and endangered species population problems, which they hope will be resolved through collaborative rehabilitation of water and land resources infrastructure in the Puget Sound region (e.g., Schauman and Salisbury 1998). The Corps has been involved in Puget Sound restoration planning.

Chaplin et al. (2000) identify a significant portion of this region for protection and restoration need. Most is concentrated in the river basins of southern Oregon and northern California where the Corps does not have much of a presence. However, a significant area exists in the mountain watersheds of the San Joaquin River where there are numerous Corps flood control reservoirs. Other areas concentrate around San Francisco Bay where numerous imperiled species live.

Because they are so few and harbor unique fauna, most of the rivers of Southern California are also identified for restoration and protection. The restoration investment potential in this area is higher than in many other regions because of local interest and wealth.

Alaskan Rivers and Coasts

Alaskan rivers and coastlines remain physically pristine and modified relatively little biologically. The major basin is the Yukon and its tributaries (Baily 2005). Other rivers, important largely for their salmon fisheries, have much smaller basins, but some, such as the Kuskokwim, rank among the top 40 rivers in the world based on annual discharge. Other large rivers include the Alsek, Copper, Susitana, and Nushagak (Richardson and Milner 2005). The rivers of highest discharge per square mile drain to the Pacific Ocean from regions of high average precipitation in southern Alaska. Rivers draining to the Arctic Ocean have low annual discharge per square mile because of generally low annual precipitation. The region is exposed to long winters and was extensively glaciated, except for the Yukon and Kuskokwim valleys. The freshwater species diversity is low. Because of glacial scour, river valleys typically have little alluvium to store ground water and the river discharge fluctuates widely. There is relatively little carbonate rock in the region. The water tends to be soft with low to moderate alkalinity and low fertility. Turbidity varies naturally from lows in winter to highs during periods of accelerated glacial melt. Coastal regions are generally pristine.

The region has the lowest population density in the United States and depends largely on tourism, oil and other mineral extraction, fisheries, and timber harvest. Much of the northern part of Alaska has been set aside as national wildlife refuge and much of the southern part is managed by the U. S. Forest Service and National Park Service. Other than subsistence hunting, the most widely dispersed land use is timber harvest. Agriculture, urban development and water resource development are highly localized in range and impact. Most water resources development is linked to coastal harbor improvements. The greatest environmental impact is associated with the oil industry. The spill of the Exxon Valdez in Prince William Sound is still regarded as one of the Nation's worst ecological disasters. Fear of oil spills has limited further development of oil on the North Slope because of its unique wildlife status and high natural heritage value. In general though, the unique biodiversity of the region remains secure.

Future development of Alaska is likely to be based on the past pillars of its economy. Oil, forest products, tourism and commercial fisheries will continue to play major roles in that development. The public is exceptionally aware of environmental issues, but many are pro-development. Global climate change is predicted to have exceptionally costly infrastructural impacts in Alaska because of accelerated melting of permafrost. Peak river runoff is expected to be more extreme because of more rapid snowmelt. However, water resources development is likely to remain minor and continue to be focused locally on coastal needs and the few urban areas adjacent to rivers. This region has the lowest potential for ecosystem restoration because so little of it was physically altered by humans.

Great Basin Rivers

The rivers of the Great Basin drain primarily from numerous mountain ranges in and surrounding the basin to inland lakes and sinks, isolated from the ocean, where the water recharges groundwater aquifers or evaporates. Runoff derives primarily from snowmelt. Most of the lowland areas are extremely arid. The lakes are relicts of much wetter times during the last ice age when very large freshwater lakes occupied the lower elevations of the Basin. The main rivers in the basin are small compared to other rivers in the United States, including the Humboldt, Bear, Weber, Sevier, Walker and Truckee. The geology is complex, as is the water quality. High elevation runoff tends to gain in hardness, salinity, and alkalinity as it moves down-slope. The Sevier and Humboldt have higher concentrations because they originate at lower elevations underlain by limestone (Shiazawa and Rader 2005).

The region is one of the least populated in the United States and the population is highly concentrated near dependable sources of freshwater. The most widespread land use is grazing linked with irrigated hay farming in higher elevation valleys. Other crops are grown with ground and surface irrigation water at lower elevations. Urban development continues mostly in the regions around Salt Lake City and Reno. Water resources have been developed primarily for irrigation. Diversions have reduced natural discharge and river extent in some locations and blocked fish migrations between lakes and stream reproductive sites. Groundwater development for irrigation has locally reduced water tables and natural spring flows.

Most of the aquatic species in the Great Basin are endemic because of the basin's isolation by mountain ranges and aridity. While diversity is low compared to other parts of the United States, numerous distinct populations of fish and mollusks have evolved in isolated springs and lakes. A large fraction of these species are thought to be imperiled largely by introduced fish species, small water resource developments, and groundwater depletion. Urban-industrial impacts, including mines, contribute to imperilment locally. A few endemic species have been declared extinct.

Population growth rate has been high just outside the region in Las Vegas, where the demand for water is reaching into the Great Basin. Water resource use and protection will be an increasingly controversial issue, especially where unique species located in isolated springs are threatened by draw-down of ground water aquifers. The problems are not likely to be solved by traditional reservoir storage. Other approaches are being investigated, such as desalinization of groundwater too salty to be used directly, recycled use of water, and more conservative irrigation techniques. The public in this region is protective of property rights and historically resentful of federal intrusion in regional affairs. There is local interest in ecosystem restoration, such as in the Truckee River (where the Corps is involved with the Bureau of Reclamation), but enthusiastic nonfederal sponsorship is less likely here than along the coast. Even so, Chaplin et al. (2000) have identified significant fractions of the Great Basin for protection and restoration need. The Corps has not had much of a historical presence here (the Truckee River restoration project is an exception), but there is some potential for aquatic ecosystem restoration at sites not previously managed by the Corps.

Past Trends in Federal Government

Overview

Federal Government has assumed an increasingly large and pivotal role in environmental protection and rehabilitation as problems emerged on a scale that could not be addressed locally. The trend was most rapid before 1980, when the most influential of federal agency authorities and environmental laws were passed, but has continued at slower pace. Federal agencies had proliferated and grown more bureaucratically focused, isolated, and territorially defensive. NEPA dampened that trend by opening the federal establishment to public review and potential law suit. Creation of the Environmental Protection Agency at the same time consolidated dispersed authority and opened agencies to unprecedented environmental review and enforcement by a single outside agency. Project oversight encouraged more collaboration among agencies whenever a significant environmental impact was anticipated.

Environmental agency sensibilities have depended largely on whether they are authorized to manage natural resources or to regulate the actions of other agencies and the public. This has created significant tension at times, which was particularly strong in the decade after EPA was created. Agencies authorized to manage ecological resources (forests, range, fish and wildlife) have had a different relationship with the environment and a different interagency dynamic than agencies authorized primarily to manage the geophysical environment, including the water resources development agencies. In general, the agencies comprised largely of engineers and geophysical scientists had little preparation for recognizing ecological resource needs before regulations were imposed on them, and were sometimes less ready to comply quickly. The agencies managing for living renewable resources were more likely to understand and to accept such regulations. EPA personnel became dominated by professionals who zealously accepted their regulatory authority from a somewhat polarizing legal perspective, one which disturbed many resource agencies regardless of disciplinary orientation. Most agencies now embrace a more collaborative posture more consistent with the spirit of the NEPA process. The organization of resource management and environmental agencies, and the dynamic among them and environmental NGOs, has remained generally stable over the past three decades.

Natural Resource Conservation

The history of federal policy trends and agency authorities to address them is addressed in overviews by Hibbard (1924), Hays (1959, 2000), Coggins (1993), Kline (1997), and USACE (1998). Federal and state influence on local environmental behavior was minimal in the earliest years of the Nation (Clepper 1966, Kline 1997). Nearly all influence was local, variable, and uncoordinated. Municipalities diversely regulated forest harvest and burning, waste emission, fisheries and game exploitation, and use of the commons for grazing and other activities. Early in its history, the federal interest in the environment was limited primarily to interstate and territorial transportation improvement.

As the national population grew, food needs and food production also grew and became the major source of early environmental problems during the second half of the 19th century. Unregulated market hunting and subsistence hunting and fishing contributed largely to rapid

depletion of game fish and wildlife. Many States were politically pressured by wealthy sportsmen and journalists to regulate hunting and fishing harvests more effectively (Reiger 1975). Market hunting and fishing for inland game species was largely prohibited and limits were placed on individual take by sportsmen and subsistence consumers.

The federal government got involved mostly in territorial lands and waters. The Corps is the oldest natural resource development agency in federal government, starting with its first planning authorities in 1802 (Schubert 1988, USACE 1998). An underlying concern was increased national security gained through territorial settlement. The Corps remained the major "hands-on" natural resource management agency in federal government for the rest of the 19th century. The upper Yellowstone River area was set aside in 1872 as the Nation's first national park. The U. S. Fishery Commission was created to monitor marine fisheries and to recommend management measures. Congress also set aside public domain in the first federal forest preserves in the western United States with watershed protection as well as harvest control in mind (Cole et al. 2005). Late in the century, it authorized investigation of the causes of livestock range deterioration on public domain lands and possible development of the western "deserts" for agricultural purposes through the departments of Agriculture and Interior.

The first significant federal pollution legislation, passed in 1899, authorized the Corps to regulate dumping of "refuse" into navigable waters. The Corps authority was later expanded by the CWA (1972, 1977) to regulation of discharges into the Nation's navigable waters and connected waters and wetlands. Newly established federal resource agencies and programs began to diversify quickly early in the 20th century, when the administration of Theodore Roosevelt espoused a new conservation philosophy for public natural resource management and significantly expanded federal authority (Hays 1959). The agency to become the Bureau of Reclamation was created in 1902, the first federal wildlife refuge in 1904, and the Forest Service in 1905. Actions were taken to set in motion establishment of the National Park Service in 1916. Large fractions of federal lands were set aside from sale for private development to be held in the National Park system in trust for the Nation and efficiently managed *in perpetuity* to sustain natural and cultural heritage. Interest in natural resources conservation followed a period of growing scientific awareness of the complex relationships that exist among land use, resource production, watershed process, river dynamics, and watershed-based regional planning (Cole et al. 2005). Watershed planning has waxed and waned among federal agencies as it has grown more complicated by the mix of private, State, federal, and other public-land ownerships.

Emphasis on federal natural resource conservation surged again in the 1930s partly in response to the effects of extreme drought, jobs creation, and growth in NGO influence. The new National Wildlife Federation was particularly influential. Major federal fish and wildlife laws were passed, including taxation on hunting licenses, which provided funding for developing wetlands for migratory waterfowl managed under the Migratory Bird Treaty Act. This reinforced federal interest in wetland creation and restoration.

Much reorganization occurred during this time, including creation of new agencies. The Soil Conservation Service was created in the Department of Agriculture in 1933 to positively influence private agricultural land development and use, including water resources development for water and sediment management (it was later renamed the Natural Resources Conservation

Service). The Tennessee Valley Authority was created soon after that to develop and manage the Tennessee River and its tributaries. In 1946, routine federal land sales came to an end and the Bureau of Land Management was formed in the Department of Interior to manage all federal lands that were not under another federal agency's management authority. The Bureau of Biological Survey and the Bureau of Fisheries were combined in 1940.

The last period of major reorganization occurred in 1970. In addition to EPA creation, the Bureau of Biological Survey and Fisheries was transformed into the Fish and Wildlife Service in the Department of Interior and the National Marine Fishery Service in the new National Oceanographic and Atmospheric Administration of the Department of Commerce. With the creation of EPA in particular, a balance was established between regulatory programs and resource development programs and organization of the agencies has remained stable for the past four decades. Another possible reason for the stability may have been the decreasing importance of natural resources in the federal budget since it peaked in the 1930s. The stability has allowed the agencies to adjust to the large number of environmental laws passed during the 1970s more effectively than might otherwise have occurred with frequent reorganization.

The authorities of the land and ocean management agencies were fundamentally based in programmatic authorities to manage renewable forest, forage, fisheries, and other resources for sustained public use. Each agency manages its lands and waters primarily for one or two categories of renewable resources and the agencies as a whole complement each other. Many of the resources originate in ecosystem production. The emphasis of management was on cultivating resource production and yield based on principles of applied ecology. By 1970, most of the agencies were expected to continue emphasis on certain resources, but to take a holistic, multi-purpose approach to resource management in pursuit of optimally beneficial resource use. When ecosystem management concepts began to take hold in federal resource management, the ecologically oriented resource agencies were more prepared to make the transition than the agencies authorized to manage the physical properties of water and adjacent land areas.

The authority of the water resources agencies is more fragmented than the authorities of land management agencies, being based primarily in individual project planning and construction authorities and project management authorities on or near public waters. The emphasis of the authorities was on development of physical resources for improved use based on engineering principles. While all resource agencies focused on improving resource use, the ecological principles and sustainability were much less important concepts in earlier water resource management. When NEPA and other environmental protection considerations increased in importance, the ecologically-oriented agencies assimilated new concepts and regulations quickly. The water resource agencies had a more difficult time adjusting to the new management paradigm, including new concepts of ecosystem management and ecosystem restoration.

The Corps became a major exception among agencies that develop and manage water resources when it was authorized to restore and protect ecosystem qualities of interest to the American public. It had to make major adjustments to its new ecological mission, having been previously focused by its authorities on developing geophysical resources. The adjustment continues. The geophysical orientation of the Corps still contributes to residual confusion over the ecosystem

restoration and protection goal and objective and to a number of assumptions about ecosystem restoration and protection measures (more will be said about this under Corps culture).

Like other agencies, the Corps has embraced collaboration consistent with NEPA guidance, but so far has not been very successful coordinating with other agencies and conservancy NGOs in a national context. Much the same can be said for other natural resource management and environment agencies, each limited and fragmented in purpose, perspective, restrictions, and budget. Yet the project-focused authorities of the Corps leave even less latitude for big-picture planning than programmatically funded agencies. The Nature Conservancy (TNC) has moved into this vacuum to support nationwide coordination and collaboration as it relates to biodiversity preservation. Progress has been modest, but collaboration with the Corps was established through partnerships in small restoration projects and operations modifications that TNC can afford to sponsor. More recently, the Landscape Conservation Cooperatives set up by the U. S. Department of the Interior have hoped to make progress through inter-organizational cooperation adapting to climate and other environmental change, but Corps participation is spotty (Cole et al. 2014c).

Environmental Protection

Environmental Regulation Authorities

The National Environmental Policy Act

The rise of the environmental movement was a precursor to unprecedented environmental protection legislation during the 1970s. NEPA was not only the first in a series of strong federal environmental laws, but in many respects, the law that most changed the way that federal natural resource management agencies planned projects and programs that adversely affected the environment. With respect to the future of ecosystem restoration in the Corps, continued federal commitment to its national environmental policy will be an important force largely because future restoration activity is likely to be associated with rehabilitation of existing projects, which requires application of the NEPA process.

NEPA promoted federal restoration and maintenance of EQ, a new concept in federal law. In doing so, it provided the federal policy foundation for the EQ improvement authority of the Corps. NEPA defined the diverse aspects of EQ and the responsibility of the federal government in goals that emphasize beneficial use of the environment (leading to economic improvements); provision of a safe, healthy and pleasant environment for all; and preservation of an intact cultural and natural heritage for future generations. In many respects, these form the cornerstones for the planning framework used by the Corps and other federal water resources agencies, as well as international principles of sustainable development (WCED 1987). Unlike federal water resources project planning, however, NEPA implementation guidance does not require monetization of value when acceptable methods exist (WRC 1983).

Caldwell (1998) has pointed out the profound importance of NEPA policy and goals as an ethical foundation for federal behavior and its diminishment by bureaucratic processing of NEPA implementation regulations. He also has indicated how little the policy and goals of the law have

directly influenced federal behavior. Despite the NEPA emphasis on what is essentially a sustainable development principle, the Corps (and many other agencies) did not explicitly accept the sustainability principle for two decades thereafter. They viewed NEPA primarily as a constraint placed on beneficial development and operations imposed by the implementation rules established by the Council of Environmental Quality as authorized by NEPA.

The implementation rules largely eclipsed the policy and goals of the law itself. They emphasize careful consideration of EQ maintenance during any federal action upon the environment, through avoidance of adverse environmental impact and compensatory replacement of damaged environment whenever avoidance is impractical. Agencies formed branches dedicated to evaluating the need for environmental impact statements, writing them, and assuring that each step of the process was well documented to avoid law suits. The "NEPA process" became bureaucratic routine, more effective than protections before the law was passed, but less philosophically influential than was probably intended.

The important influence of NEPA on federal planning process is made possible largely by the public access to federal process granted by NEPA and the public right to sue when agencies are not in NEPA compliance. A number of NGOs in particular have assumed a disproportionately large role. Federal agency effort in the interest of EQ protection is sustained by a balance established among agencies, NGOs and Congress. That same dynamic overlaps and influences interests in federal restoration actions.

Environmental Regulatory Agencies

The EPA was created to bring greater coherency to the Federal environmental protection mission. Before 1970, federal environmental protection programs designed to curb air and water quality degradation were generally small and scattered about numerous agencies. The authorities of the EPA are largely regulatory, including regulation of federal agency activities. It also administers grants consistent with its mission. EPA was formed at the onset of unprecedented expansion in federal environmental law during the 1970s. Much-expanded versions of the Clean Air Act (CAA) and the CWA formed a nucleus for the EPA program. Other federal environmental laws and subsequent amendments have been passed since then and added to EPA administrative and enforcement responsibilities. Significant tension existed between EPA and the natural resource management agencies at first. The Corps apparently adapted more quickly than many of the agencies (Clarke and McCool 1996), but the change from being a primary federal environmental regulator (through the 1899 Refuse Act) to one of the regulated agencies was a big one, which was more difficult for the districts to adapt to than headquarters policy positions may have indicated.

Interagency tension grew largely out of a need to divert agency resources to "collaborate" by fiat. Communication and collaboration requirements associated with environmental regulations have increased agency operations costs in general without proportional increase in federal funding. The Flood Control Act of 1936, for example, recognized that a comprehensive flood control program required not only structural solutions administered by the Corps, but watershed improvements as well, guided by the Soil Conservation Service (Arnold 1988). While comprehensive interagency watershed planning might have been expected, little materialized

(Cole et al. 2005), in large part because of the way environmental management authorities are fragmented among agencies and the lack of agency accountability. EPA, NEPA and other environmental laws changed all of that. While some tension among the agencies continues, usually over specific competency and authority issues, interagency coordination and cooperation have become more routine and widely accepted.

Through its limited authority, the EPA has tried to improve integration of private and public activities to achieve environmental goals. They have promoted watershed-based regional planning, environmental management systems, and most recently the concept of ecosystem services. Watershed-based regional planning as a basis for collaborative efforts in environmental management has a long history in the United States. Cole et al. (2005) contended that the most influential integrative force in recent decades is the need to meet water-based environmental standards for human health protection and to sustain ecosystem vitality for human benefit. Because of the fragmentation of authority and cost limitations among Federal, state and local agencies and NGOs, the integration of activities in the planning process is often slow and inefficient, but the watershed approach provides a common platform that most environmental agencies consider appropriate.

EPA is a strong proponent of and federal government is gradually adopting the ecosystem services concept (Daily et al. 1997, Millennium Ecosystem Assessment 2005) to improve environmental impact assessment, mitigation of adverse effects, and ecosystem restoration wherever practical. The Corps is exploring the concept and its applicability in Corps practices (Tazik et al. 2013, Murray et al. 2013). Many ecosystem services have demonstrable use value measurable in monetary terms, but the nonuse value that motivates intergenerational protection of biodiversity is not acceptably measured in monetary units by many economists and agencies (NRC 2005a), including the Corps (Cole 2014a). Many applied ecologists generally accept the view that the functional capacity of ecosystems to *sustain* diverse human services far into the future is the most fundamental renewable natural resource requiring management stewardship (Odum 1993). Biodiversity maintenance is a fundamental service provided to future generations.

EPA did not retain complete control over all federal environmental regulations. The Fish and Wildlife Service (FWS) and the National Marine Fishery Service (in the Department of Commerce) received a critically important environmental protection authority through the ESA, which authorized federal agencies to assume jurisdiction over species listed by those agencies for protection and recovery wherever they occurred. The ESA goal is basically a national biodiversity maintenance goal, most explicitly to sustain a national fish and wildlife heritage. Much as EPA did, the two Services went through an awkward period of interaction with other agencies before settling into a more routine collaboration. But tensions still occur at times. The FWS also administers the Fish and Wildlife Coordination Act, which requires water resources agencies to involve the FWS, and other state and federal agencies as needed to consider mitigation of adverse project effects fish and wildlife with use or nonuse value. These actions are now integrated with the NEPA process in new project planning.

The Corps has retained its long established permitting authority for physical modification of navigable waters. As part of the CWA, the Corps also was authorized to manage the discharge of fill into the Nation's waters and wetlands through permit application, evaluation and issuance

when appropriate. The Corps emphasizes facilitation of beneficial development by processing permit applications as quickly as possible while assuring significant environmental damage is mitigated. EPA and the Corps jointly develop rules for the program. EPA oversees Corps activities and can veto specific Corps actions it views as inconsistent with environmental protection needs. Corps regulatory program interactions with federal agencies are relatively few compared with private developers.

Other regulatory authorities exist outside these agencies, but these are among the most relevant to the Corps ecosystem restoration program.

Sustainable Development

After years of conceptual brewing in academic halls and government agencies, the contemporary concept of sustainable development emerged in widely circulated and highly influential report of the United Nations World Commission on Environment and Development (WCED 1987)**.** In subsequent resolutions, the United Nations accepted a need to sustain resource options for future generations in the international concept of sustainable development. The policy and goals of NEPA had significant influence on the U. N. concept. The U. N. has convened several world conferences on the environment and development to promote sustainable development through various venues, prominently including global climate change and biodiversity losses. The globalization of principles embraced by the U. N. is indicative of increasing global awareness and commitment to social improvement that includes environmental improvement.

American agreement with the U. N. commitment to sustainable development had an indirect influence on the Corps of Engineers and other federal agencies through a report prepared for the President in 1996 (TPCSD). The 1987 U. N. report determined that the principle of sustainable development is to satisfy the needs of present generations without compromising the needs of future generations by limiting their development options (WCED 1987). It also determined that long-term beneficial development of human welfare required environmental, economic and social constraints that assure what has since been called economic, social and environmental sustainability (e.g., Martin and Stakhiv 1999). Cole et al. (2014a) reviewed the history of concepts related to the principles of sustainable development and their application by the federal government.

In the early 1990s, a presidential committee was convened to advise the president on the relevance of sustainable development to the United States and established goals for its ultimate achievement (TPCSD 1996). It established broad goals for the Nation which reflected the WCED (1987) report and principles developed by the U. N. in follow-up actions (e.g., United Nations 1992). World Bank scholars published a series of papers (e.g., Goodland 1995, 1996; Goodland and Daly 1996; Furtado et al. 2000) about how to integrate the principles of sustainable development into international lending practices. These and other concept papers had a major influence on federal agency acceptance of sustainable development principles about the same time the Corps received its authority to carry out ecosystem restoration and protection to improve EQ.

The United Nations principle of sustainable development was accepted for implementation of the Corps initial version of Environmental Operating Principles (EOP, USACE 2002). The EOP established the achievement of environmental sustainability as a corporate principal and goal. Corps regulations require assimilation of the EOP into all aspects of Corps activities, including the ecosystem restoration mission. But implementation of the EOP in Corps activities had stalled until the aftermath of Hurricane Katrina and a recent executive order on sustainable energy use reinvigorated Corps interest in sustainability. The EOP were revised in 2012 to reenergize interest in the principles, but the connection to the U. N. sustainable development concept remains.

Environmental Protection Progress

Federal environmental protection progressed rapidly after the very significant laws of the 1970s and 1980s were passed. New legislation since then has had more limited effect. The big environmental issues facing the globe have remained incompletely addressed by federal law. Among the most important examples are the three interrelated issues identified by the Ecological Society of America nearly 20 years ago (Lubchenco et al.1991)—global climate change, decreasing biodiversity, and environmental sustainability. These big-picture issues have yet to be effectively addressed in legislation, national planning, or closely coordinated inter-organization action. Interagency cooperation may be inadequate for the environmental challenges that lie ahead.

While NEPA, ESA, and other environmental laws provide a basis for further improvement, the federal establishment has largely settled into a routine designed to address local environmental issues. NEPA provides a strong foundation for environmental policy and goals, but it and other existing law applies in practice largely to individual actions. Biodiversity loss is addressed primarily through the ESA and related laws and treaties, which do not prevent losses of biodiversity before they become so extreme as to require ESA protection and recovery effort (Figure 17). These and other laws do not provide a comprehensive national framework for integrating local, state and federal action into common cause. Global climate change is addressed piecemeal and minimally through Executive Order, Cabinet-level orders, and other Executive Branch action.

Success depends on a clearer vision of agency and NGO collaboration in achieving a national vision of sustainable development that includes mitigation of climate change, biodiversity loss, and other erosion of human welfare improvement. While programs such as the Landscape Conservation Cooperatives provide a model of possibilities, they are vulnerable to changes in Administration. Chronic concern over the economy and political ideologies has contributed largely to legislative resistance.

Because of limited budgets, significant costs and competition for funding, what agencies can do typically is less than needed. The Corps is no exception. With respect to biodiversity maintenance, the Corps has an exceptional opportunity in its ecosystem restoration program to contribute meaningfully to a biodiversity maintenance goal (Cole 2009), but has yet to explicitly recognize it as the major point of its restoration program. While the Corps has adopted its EOP, which focuses on fostering sustainability, implementation of the principles is uneven. With

respect to global climate change, the Corps is implementing principles of "green construction" and energy use, and is developing strategies for climate change adaptation. However, these strategies have yet to have much influence on civil works project planning, implementation, and management.

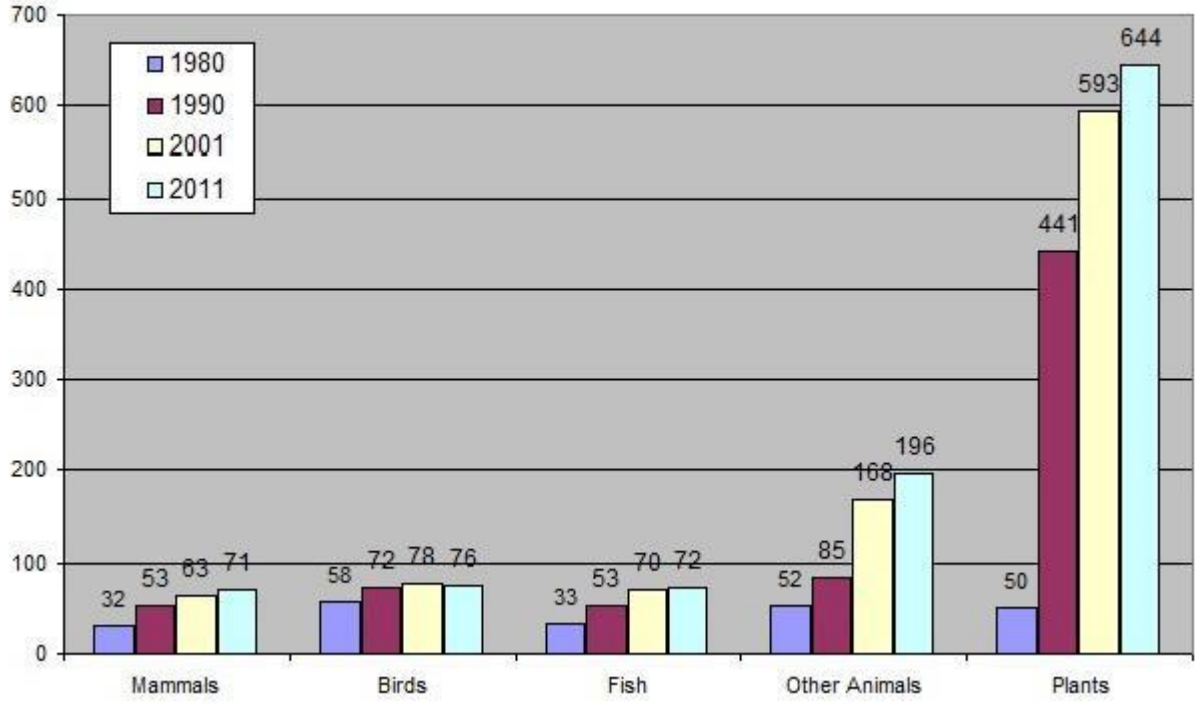

Figure 17. Trends for listing species as threatened and endangered under the protections of the ESA (U. S. Fish and Wildlife Service).

Past Trends in the Corps Program

Overview

Between 1970 and 2000, Corps civil works project planning and management changed dramatically and grew more complex in response to new project planning and environmental laws, environmental quality (EQ) improvement authorities, and several versions of civil works project planning policy guidance. NEPA introduced the concept of EQ to federal law and related it to human welfare by declaring "the importance of restoring and maintaining environmental quality to the overall welfare and development of man". Influenced by NEPA, the Water Resources Planning Act (WRPA) was amended to include congressional objectives that incorporated EQ protection and improvement along with three other objectives. WRPA also authorized creation of federal water resources planning guidance (WRC 1973), which established EQ and National Economic Development (NED) as the national objectives for which federal water resources project plans could be formulated. The guidance was modified twice in the late

1970s, largely to improve the section on EQ. Because EQ improvement had never been authorized by Congress the EQ guidance was limited to protection. Also consistent with that situation, a major rewriting of the federal guidance in the early 1980s (WRC 1983) eliminated the EQ objective and established a single NED objective constrained by EQ protection consistent with law. Congress had required the benefits from all Corps projects to at least equal the costs. The guidance directed project effects that could be measured in monetary units to be monetized for cost-benefit analysis of NED objective achievement, including all environmental impacts that could be acceptably monetized. Recreational use impacts, for example, fell into this category. Since the remaining EQ effects were not acceptably monetized, they were to be indicated in nonmonetary terms. All significant and adverse environmental effects, whether monetizable or not, were to be mitigated by avoidance and minimization of the significant effects or by compensating for the effects through replacement of the lost environmental quality.

Then Congress authorized the Corps to improve EQ in 1986 and again in 1996. That caused a conundrum since the Corps had a new objective that was not recognized by the federal guidance and there was no interest in the Executive Branch or Congress in rewriting the guidance. After more than a decade of waiting, the Corps rewrote its own project planning guidance in 2000 (the Planning Guidance Notebook, or PGN; USACE 2000). The revised PGN introduced the Corps to a new federal objective composed of NED and National Ecosystem Restoration (NER). It also established a new ecosystem restoration mission tailored for the 1996 statute, which authorized EQ improvement limited to ecosystem restoration and protection measures. The PGN declares that the outputs justifying investment in NER must not be NED outputs with use value, but fails to explain why. Nor does the guidance explain that ecosystem restoration cannot be justified by a gain in intrinsic value, since NER outputs must be tradable against NED outputs to maximize benefits from projects with both NED and NER purposes. But most importantly, while a careful analytical reader can deduce that the justifying outputs from ecosystem restoration must have nonuse value in the form of ecological heritage, that objective is not clear either. Further description of the ecosystem restoration planning objective emphasizes restoration to “a less degraded more natural condition” leading some to believe that the naturalness of the result is what adds value to ecosystem restoration outputs. The complex history of the Corps environmental program and unclear guidance has caused much confusion. As a consequence, many projects were, in effect, planned for NED outputs instead of EQ outputs in the form of ecological heritage and questions about program merits have been growing.

The Corps ecosystem restoration program is funded through the Corps annual budget, which has fluctuated without identifiable trend around 5 billion inflation-adjusted dollars for three decades. During that time, the annual budget for Operation and Maintenance increased while budgets for General Investigation (project planning) and Construction decreased. The proportion spent on ecosystem restoration projects increased dramatically in its first decade and has since leveled. The number of restoration feasibility studies probably grew more rapidly than it would have if the objective of the program had more clearly targeted heritage restoration and protection. Restoration projects were attractive to some nonfederal sponsors because Corps policy allowed more subjective analysis of the benefits needed to justify investment than economic development projects and program objectives could be finessed to allow economic improvement investments for urban renewal, recreation, flood risk management or other NED purposes. This created

concern among Corps personnel responsible for other primary missions, which declined in budget importance as restoration increased in importance.

Since the disastrous levee failures during Hurricane Katrina, Congress has paid more attention to the rapidly growing need to repair and rehabilitate infrastructure. That attention increased internal competition for annual budget allocations and reduced investment in new civil works projects of any kind. The other big source of internal competition for individual projects is the huge, multi-project, regional "restoration" programs in southern Florida, southern Louisiana, the upper Mississippi River area and a few other locations. These are more aptly called regional rehabilitation programs. Because regional programs line up projects for decades to come, they may have a competitive advantage over new individual project proposals for many years. Large regional programs also tend to be favored in Presidential priorities.

Trends within the Corps culture have a significant influence on the way the ecosystem restoration and protection authority is perceived and carried out. Corps culture has become increasingly complicated by geographical and programmatic division, and by greater decentralization through time. Decentralization complicates the development of a uniform approach to policy interpretation and execution of ecosystem restoration projects. Like other federal agencies, the Corps has become increasingly accountable as a consequence of the many legal constraints placed upon it and NGO pressure enabled by NEPA. So far, however, the restoration program has avoided much of the pressure applied to other purposes. But that latitude shows signs of change, depending on program performance and public preferences. While the Corps has professionally diversified over the last several decades, and its role as environmental steward has greatly increased in importance, the agency's Civil engineering identity remains strong and influential in its approach to ecosystem restoration and protection. Transition from project orientation to systems management has waxed and waned over the entire history of the Corps. While the ecosystem restoration authority may have contributed to a recent increase in a systems management emphasis, Corps culture is not well prepared for the many challenges before it.

Program Authority and Regulatory Trends

Between 1970 and 1996, the number, complexity and influence of Corps environmental regulations and programmatic authorities increased more rapidly than at any other time in its history. Unprecedented output of federal environmental legislation required the Corps and other agencies to protect significant environmental resources from destructive use. The Corps was also authorized to improve EQ and to regulate the discharge of materials into wetlands and other waters. Although the Corps had been required to consider protection of fish and wildlife resources under the Fish and Wildlife Coordination Act (FWCA) since 1935, it was not authorized to improve EQ until 1986. For over 160 years before then, congressional authorities had consistently directed the Corps to improve water resources for use. Then in 1986, Congress authorized the Corps to improve EQ where existing Corps projects had caused unmitigated damage. In 1996, Congress authorized the Corps to improve EQ anywhere nationally, but limited to aquatic ecosystem restoration and protection measures. The 1996 authority required major changes in the way Corps projects were typically engineered and evaluated for investment decisions. These changes caused considerable confusion about the new mission.

In addition to regulatory and emergency response authorities, the Corps is authorized to plan and implement civil works projects in what the Corps recognizes as seven nationally applicable purposes (USACE 2000). In addition to ecosystem restoration, they include navigation, flood risk management, hydropower, storm risk management, water supply, and recreation. Navigation improvement of the upper Mississippi River was first authorized in 1824 (USACE 1998) and was expanded to national scale in 1852 (Maass 1951). Flood damage reduction was first authorized along the Mississippi River late in the 19th century and expanded to national scale by the Flood Control Act of 1936. Shore area protection from storms was also first authorized in 1936. These three became known as stand-alone, primary purposes. Three "secondary" purposes had to be linked to a primary-purpose project. They include hydropower development at Corps primary-purpose projects, which was first authorized in 1909, followed by water supply development in 1958 and recreational development in 1965. All six of these purposes are intended to improve water and floodplain resource use and serve a NED objective.

Over two decades passed before the Congress authorized limited EQ improvement to compensate for past damage caused by Corps projects. But the seventh purpose —aquatic ecosystem restoration—was not established until Section 206 of the 1996 WRDA authorized EQ improvement nationally using ecosystem restoration and protection measures. It differed greatly from the previous national purposes and was difficult for the Corps to assimilate into policy guidance and interpretation by Corps planners. It too became a primary purpose.

Environmental laws constraining Corps actions also increased in number, strength and influence. Before the 1960s, most environmental protection at Corps projects was conditional. FWCA required the Corps and other water resource agencies to consider mitigation of project impacts on fish and wildlife value, particularly for commercially valued resources, such as salmon fisheries. Pressure to more broadly consider fish and wildlife and other environmental protections grew during the 1950s, particularly in an amendment to FWCA and an interagency agreement on federal water resources development known as Senate Document 97 (Caulfield 2000). Signed into law in 1970, NEPA also was conditional, but it opened the environmental impact evaluation process to public scrutiny and law suit when agencies did not follow procedures carefully. That probably increased EQ protection effectiveness, as well as project costs, more than if the agencies had been left on their own.

NEPA established the concept of EQ improvement and protection for the sake of human welfare improvement and maintenance (EQ is equivalent to environmental value). It also established environmental policy goals that apply to all federal activities affecting the environment. The goals clearly focused on federal responsibility to provide for the environmental needs of both present and future generations of Americans. They promoted beneficial use in safe, healthful and pleasing surroundings while assuring preservation of nationally important cultural and natural heritage. NEPA implementation guidance focuses mostly on procedures for assessing EQ impacts and considering mitigation of significantly adverse impacts on beneficial use of the environment and on important natural and cultural heritage. Monetization of EQ effects, even when acceptable, is not required, which contributed to confusion over benefits measurement in the restoration program. NEPA also influenced the congressional objectives of WRPA which were added by amendment about a year after NEPA was passed. The objectives included NED,

Regional Economic Development (RED), social wellbeing and EQ protection and improvement. WRPA also authorized development of federal implementation guidance for WRPA, which required a more formal analysis of benefits and costs than NEPA.

Numerous other federal environmental laws constrained Corps actions. New Federal legislation set aside many remaining wild reaches of river and shoreline from water resources development during the 1960s. The CWA, ESA and subsequent environmental laws placed further constraints on the Corps and impact mitigation became more routinely expected. State environmental laws also grew in number and comprehensiveness. By the 1980s, few acceptable sites remained for project development. Most were already developed, protected by law, occupied by threatened and endangered species, or were otherwise nationally significant in their undeveloped state.

Corps regulatory authority for navigable waters reaches back to 1899, but was significantly expanded in Section 404 of the CWA, which authorizes the Corps to regulate discharges of material into wetlands through permit application and review. Both private and public developers are regulated, including Corps project impacts. Applications may be rejected, but discharge is more frequently permitted contingent upon impact minimization and compensatory mitigation consistent with NEPA implementation guidance. While restoration of degraded wetland is the preferred form of compensatory mitigation, new wetland may be created. Use of the ecosystem restoration program area for mitigation is prohibited because the actions causing the impact must bear the costs.

Section 1135 of the 1986 WRDA authorized EQ improvement at existing Corps projects. It was treated like a post-construction mitigation authority for projects built before NEPA became law. Unlike the later EQ improvement authority, it did not limit EQ improvement actions to ecosystem restoration nor did it authorize protection of the restored resources for an indefinitely long time. The authority allowed small project improvements (less than $7 million) of environmental use value as well as nonuse value. The most usual improvements were for past impacts on Fish and wildlife based recreation and commodities (e.g., commercial fisheries). With some exceptions, the 1986 WRDA required the costs of new project planning and construction, including EQ improvement projects, to be shared with a nonfederal sponsor who assumed project operation and maintenance duties and costs. These requirements still apply. The Corps is responsible for assuring that completed projects are operated and maintained as planned.

The EQ improvement authority of Section 206 of the 1996 WRDA differed markedly from Section 1135. It restricted the management measures to aquatic ecosystem restoration, stipulated indefinitely long protection of the improved EQ, and allowed projects of any size anywhere nationally and independent of or in combination with other Corps purposes. The EQ protection aspect of the authority narrowed the EQ improvement objective to nationally important ecological heritage with nonuse value. However, the Section 1135 authority may have helped to predispose planners to accept resource use value as well as nonuse value as a justification for investment.

Ecosystem restoration and protection projects also required a nonfederal project sponsor to share the costs. Sponsors were limited to government agencies until NGOs with the necessary financial

backing were accepted in 1999. The Nature Conservancy is the most active NGO partner with the Corps. However, NGOs are not as fiscally able as some state agencies to partner in the largest projects and program areas that have been more attractive to the Corps and to federal Administrations.

The Corps ecosystem restoration and protection authority came near the end of a chain of significant federal environmental laws. More recent environmental legislation has been comparatively minor. For example, Section 2020 of the 2007 WRDA modified the 1996 ecosystem restoration and protection authority slightly by explicitly including estuarine elements and features consistent with Section 103 of the Estuaries and Clean Waters Act of 2000. The public majority generally accepts existing environmental laws, but is less enthusiastic about new legislation. The strong environmental laws of the green decade have generally held up to numerous attempts to weaken them. Recent interest in new law has circled around the issue of climate change and what to do about it. But resistance to development of any nationally comprehensive environmental law remains strong. However, the last three presidents issued a number of significant Executive Orders pertaining to sustainable development and climate change adaptation for the federal agencies.

Policy Guidance Trends

Program Objectives

Past trends in Corps project planning policy guidance became more complex and difficult to interpret, culminating in revised agency guidance (the PGN) that has served the Corps for the past 16 years (USACE 2000). The ecosystem restoration program objectives have also been difficult to interpret for numerous planners and this section is relatively long as a consequence. Despite chronic problems with interpretation, modifications of the ecosystem restoration part of the PGN have been minor.

The PGN is built around the pursuit of a federal project planning objective and project "study" objectives for each of the civil works purposes. The federal objective is a broad programmatic goal and the study objective for the ecosystem restoration and protection authority is a more specific application of the federal goal to maximize public benefit. The clarity and understanding of the objectives is fundamental to any discussion of future program outlook since the objectives are the standard by which program area success must be judged in the predicted and realized performance of each ecosystem restoration project and the entire program area.

The history of the federal objective originated in the Congressional objectives for federal water resources planning in WRPA and WRPA authorization of an interagency Water Resources Council (WRC) to write federal water resources planning guidance. The first version of the federal project planning guidance established NED and EQ objectives to be achieved incrementally in federal water resources project outcomes (WRC 1973). The focus of the guidance was on maximizing public benefit from contributions to the two objectives. The interagency authors of the guidance sought objectivity in rigorous cost-benefit analysis for NED objective achievement, with project benefits and costs measured in monetary units. They required monetization of all project value that could be monetized acceptably and counted

toward achievement of the NED objective (WRC 1973). This included the outputs justifying investment from the projects authorized for the six traditional Corps purposes as well as any adverse or beneficial impacts on various recreational, commercial and other uses of the environment. The NED objective is consistent with the beneficial use goal of NEPA.

The EQ improvement and protection objective was more subjectively conceived and its achievement less clearly measured. It is consistent with the natural and cultural heritage preservation goal of NEPA and is compatible with nondestructive enjoyment of the environment. The enjoyment aspect is a beneficial use with value that contributes to NED objective achievement. That left national heritage value—a form of nonuse bequest value (see NRC 2005)—to be the contribution to EQ objective achievement. There was no widely accepted way to measure nonuse value in monetary units and the Corps still does not accept monetary measurement in its policy guidance (USACE 2000). It is measured in nonmonetary units, but no single measure has been accepted. Many different units of measurement are permitted and have been used, complicating planning process and annual budget priorities for project investment.

Changes in the EQ aspects of the federal guidance over the decade between 1973 and 1983 kept Corps planners in a state of continuous adaptation. Since no water resources agency had been authorized to improve EQ, the federal project planning guidance was inconsistent with water resources improvement authorities. It was revised in the late 1970s largely to limit the EQ objective to mitigation of EQ impacts consistent with NEPA implementation guidance. Since EQ protection was viewed as an economic development constraint, the EQ objective was totally eliminated when federal project planning guidance was rewritten (WRC 1983) and EQ became a constraint based in environmental protection law and other official actions. Consistent with NEPA implementation guidance, the last revision did not clearly separate the beneficial use and nonuse values of EQ protection, relying instead on the NEPA implementation guidance concepts of significant effects on significant resources. This may have contributed to later confusion over the ecosystem restoration purpose, once it was authorized. However, the 1983 federal planning guidance continued to emphasize acceptable monetization of any environmental effects and accounted for as contributions to NED objective achievement. In that way, the monetary costs of mitigation for degraded recreational and other use was incorporated into NED cost-benefit analysis required by the Federal guidance (WRC 1983). While that left the remaining EQ in categories protected from consumptive use and contributing to cultural and natural heritage, the connection to heritage was no longer explicit, as it had been in the earliest version of the federal project planning guidance (WRC 1973).

The WRC was dissolved in 1983 immediately upon completion of the new federal guidance. Three years later, the Corps received its first EQ improvement authority, which was limited to replacing value lost at Corps projects during construction and operation. Corps policy guidance continued to accept NED as the objective of EQ improvement consistent with the federal guidance. The small projects planned under this authority were largely for fish and wildlife recreational and commodity improvements with monetizable use value generally consistent with the assessed value lost during Corps project construction. But this approach was awkward since the EQ objective was originally intended for improvement of heritage value. Despite the issue being raised, there was no interest in the White House or Congress in reforming the WRC to redo the federal water resources project guidance. The Corps made do.

The EQ improvement authority of 1996 raised the question of EQ benefits to a new level of concern because it was no longer limited to Corps projects and it was more obviously intended for national natural heritage preservation because of the explicit protection aspect of the authority. But in a mystifying development, the Corps continued to direct EQ improvement through ecosystem restoration and protection to NED benefits in its new agency guidance on the ecosystem restoration purpose (USACE 1999). Why it did this only a year before the Corps project planning guidance was revised to include a new federal objective for ecosystem restoration is uncertain. Why it remains unchanged today is yet a bigger mystery. It still contributes to the confusion among Corps planners and potential nonfederal project sponsors.

The PGN (USACE 2000) was revised in large part to interpret the new EQ improvement authority into project planning guidance. The PGN established a new federal objective specifically for the Corps; one with separate NED and NER aspects that are, in effect, sub-objectives. The single NED objective of the federal project planning guidance continued to apply to the other federal water resources agencies. Contributions of NED and NER to achievement of the federal objective are clearly separate. NED sub-objective achievement is expected to produce net national economic benefit measurable in monetary units. Contributions to NER sub-objective achievement are expected to benefit from restoration of "desired ecosystem resources" measured in nonmonetary units. Measurement of NER benefit should reflect improvement in ecological resource quality as a function of habitat improvement and should be quantified in physical units or indices. Cost effectiveness analysis is required instead of cost-benefit analysis. In multipurpose projects, the combination of NED and NER outputs are to be optimally combined through tradeoff analysis for greatest improvement in national welfare.

Considered in its entirety, the statement of the federal project planning objective determines that investment in projects planned under the new ecosystem restoration and protection authority should not be justified by increased use value measureable in monetary units. But the statement is complex and nowhere states explicitly that the protection aspect of the Corps EQ restoration authority points toward a national ecological heritage preservation objective. The NER sub-objective statement does not mention the protection of the desired ecosystem resources once they are restored, nor does it mention the relationship of NER to EQ improvement. It is therefore not clear how the NER objective relates to the EQ improvement objective of the ecosystem restoration and protection authority. Environmental protection is defined instead under the NED sub-objective statement, where it states that protection results from avoiding and repairing damage to the environment and maintaining cultural and natural aspects of national heritage. For ecosystem restoration projects, protection means repairing damage that threatens maintenance of ecological heritage using an ecosystem restoration approach and assuring long-term protection of the restored heritage. This has either not been clear to many planners or has been purposefully misinterpreted to allow for recreational and other use value to justify the investment without doing the cost-benefit analysis.

The Corps study objective for ecosystem restoration indicates that the desired resources contributing to NER objective achievement are living organisms. But that conclusion is not clear in what is usually perceived as the study objective statement, which is to restore ecosystem structure, function, and process to a less degraded more natural condition. However, the next

sentence allows "restored" ecosystems to mimic or simulate a more natural condition, which usually implies some form of artificially engineered regulation of the ecosystem. The important question about the objective statement is what qualifies as degradation, since the answer tells us what the objective really is. The objective statement takes a backdoor approach to answering this question by providing indicators of objective achievement—i.e., the desired resources of the federal objective.

The indicators of objective achievement include sustained output of high native plant and animal diversity, more indicator species, more "biologically desirable species", and project area support of the desired outputs. The desired *outputs* indicated are obviously living organisms. Project area (ecosystem) support for the desired outputs is a necessary *input* (habitat is not mentioned explicitly but is included in project area support). The clearest indicator of achievement mentioned is high native species diversity supported by the restored project area. But the two indicators of increased resource outputs, which are expected from a restoration investment, are more "indicator species" and more "biologically desirable species". The indicator species are a confusing red herring since they have no meaning independent of the outputs they are supposed to indicate and offer nothing insightful about the nature of the NER objective.

That seems to leave restoration and sustained output of more biologically desirable species as the study objective. Presumably the biologically desirable species are species that can contribute to high native biodiversity and are desired for the biological attributes that make them significant additions to our national ecological heritage. But that is not explained and may not be intended. Many planners have interpreted the objective as the restoration of the "more natural condition" of the geophysical properties of the project, or its simulation. The PGN does not preclude the possibility that all suitable indicators of objective achievement have been identified, leaving the door open for potentially unacceptable possibilities.

Nonfederal sponsors may have contributed to consideration of such unacceptable possibilities. The difference between NED and NER investment evaluations made ecosystem restoration projects attractive to nonfederal sponsors who were not necessarily interested in restoring national ecological heritage as cost effectively as possible. Evaluation of NED investments using cost-benefit analysis provides a clear and precise threshold for screening out bad public investments in NED. Cost-effectiveness analysis is more subjective, having unclear thresholds for screening out bad projects. It is easier to get a bad NED project funded when presented as an NER project because the cost-benefit analysis is not required. Flood risk management, recreation, and even property value improvement (urban rivers restoration) could be and were approached through some semblance of ecosystem restoration because the NER and study objectives are not clearly enough stated.

Past internal and external confusion over the ecosystem restoration objective did nothing to prevent numerous feasibility studies from favoring improved resource use over preserving ecological heritage. A number of past project studies mention the benefits that might be associated with some threatened or endangered species, but typically without convincing evidence that those species would in fact have some reasonable chance of increasing their abundance as a consequence of the project. Still other studies recommended for construction

clearly focus on habitat support for fish and wildlife desired for their monetizable recreational value rather than their heritage value. Some are urban development studies.

Without more explicit emphasis on ecosystem protection, the connection between NER and national heritage is easy to overlook. Ecological heritage is not mentioned anywhere else in the PGN, which later in the document emphasizes the importance of long-term sustainability and self-regulating ecosystem outputs, but without reference to why sustainability is so important to federal provision of national welfare. For those who think comprehensively about EQ protection law, the answer is the national heritage goal of the Nation's environmental policy (NEPA), regardless of its present utility. Nonmonetary metrics are required for NER benefits without explicit explanation. The PGN later prohibits use of economic technique for monetizing nonuse value, but fails to connect the value of nonuse to the heritage value that results from nonuse. Because the connection to heritage preservation is obscure, the NER sub-objective statement does little to clearly distinguish between use value, measurable in monetary terms, and heritage bequest value, for which the Corps prohibits monetization. The essential elements of the mission are all there, but the elements are not well integrated into a coherent whole.

The PGN probably contributed significantly to planner confusion over the program objectives that were identified in a review of restoration project feasibility studies (Brandreth and Skaggs 2002). Some confusion over the federal objective is understandable given the rapid change from previous policy guidance, focused solely on NED constrained by EQ protection, to guidance that incorporates EQ improvement in the form of NER objective achievements protected for an indefinitely long time. But that confusion is not effectively resolved by the PGN because of its incomplete explanation of the NER sub-objective and fragmented organization. The confusion has complicated ecosystem restoration planning from the onset by confounding communication internally among project planners, reviewers and program managers, and among nonfederal sponsors and project stakeholders. The confusion complicates determination of national benefit from restoration projects, which in turn has complicated interactions between the Corps and the Office of Management and Budget (OMB) over the entire life of the program. The confusion has implications for project planning efficiency and project construction effectiveness. The merits of the program are increasingly questioned.

Confusion may have led the Corps Environmental Advisory Board (EAB) to recommended changes in the NER objective in 2006, which would substantially broaden the array of benefits that might justify ecosystem restoration investment. In addition to being limited to geophysical attributes (hydrology and geomorphology) rather than the broader range of ecosystem attributes required by the authority, the objective they promoted indicated an incomplete understanding of the limits of the EQ improvement and protection authority. The implications of the proposed objective would most likely require an entirely new and much expanded programmatic authority to include social and economic benefits as well as heritage benefits as justifications for ecosystem restoration investment. Virtually any economic or social improvement could justify ecosystem restoration investments including, for example, improvements in commercial fishing, timber production, flood risk management, and human community improvements. It would in effect elevate recreation improvement from a secondary purpose to a primary purpose of the Corps. If used with the same constraints on monetization, it would eliminate any requirement for cost-benefit analysis whenever geophysical "restoration" measures were used.

The EAB recommendation may have been welcomed by some Corps planners, where a tendency to allow any value motivating nonfederal sponsor interest in the ecosystem restoration program to be included among benefits justifying federal investment in ecosystem restoration. Recreation, commerce, and floodplain use improvements are common motivations for nonfederal interest in restoration funding. Policy guidance has abetted this tendency toward growing the mission beyond existing authority by failing to link its objective statements clearly to the preservation of national natural heritage.

Some recent feasibility studies indicate that some of the confusion has been resolved. More planners are targeting improvements in the condition of unsustainable species that would contribute to preservation of national ecological heritage in the form of native biodiversity. But confusion continues to exist over how the Corps interprets its mission from its foundations in NEPA, the national objectives of the WRPA, and in Section 206 of the 1996 WRDA. NEPA, for example, is known to most planners through the implementation guidance only, which focuses on impact evaluation and mitigation. NEPA policy and goals are not that well known. Many planners are not familiar with the differences between the 1986 EQ improvement authority and the 1996 authority. The PGN does little to make these important foundations known to planners. In addition, the valuable concepts of use and nonuse value are not known to many Corps planners and are not explained for them in Corps policy guidance.

Continued confusion over the goal and objective of the program abets a tendency on the part of some Corps planners to accept the interest of nonfederal sponsors as the national interest required to justify a federal investment in ecosystem restoration. However, restoration projects can be attractive to nonfederal sponsors interested primarily in local resource use improvements of questionable national net benefit because the evaluation requirements for NER are less onerous and more subjective than NED. These feasibility studies not only compete with projects more properly focused on improved heritage value, but also divert from more deserving NED considerations. Program cost effectiveness is eroded by them making the program less successful. Corps headquarters culture is continually resisting these tendencies in district sub-cultures, but also has resisted improvement in the PGN, which contributes to the problem.

After 30 years, the federal water resources project planning policy guidance has been rewritten (now the Principles, Requirements and Guidelines) and signed by President Obama. It establishes an objective that seeks to maximize *sustainable* welfare improvement by encouraging development that restores and protects the functions of natural systems as well as mitigating adverse impacts on existing ecosystems. Federal investments should seek to maximize national welfare through optimal provision of environmental, economic and social benefits measured in monetary and nonmonetary terms. The guidance applies to many more agencies than earlier guidance and to programs as well as projects. It emphasizes investment in ecosystem restoration whenever possible and introduces the concepts of ecosystem services and environmental justice. It is quite brief and eliminates much of the previous guidance on EQ (in fact, it no longer refers to EQ). Each of the agencies it applies to must update their own guidance to accommodate the new policies. There is some question at this time whether the existing guidance or this new guidance will apply to the Corps. This leaves the Corps temporarily uncertain about the need for future changes in its own planning guidance.

Development of thorough technical guidance would probably reveal that ecosystem restoration to a more natural condition is now doubted by much of the restoration community and is not likely to be a viable objective. So many human-caused environmental changes have come about as a consequence of human impact—including climate change, nonnative invasive species, thousands of synthetic chemicals, severe reduction of top predators, and major changes in biogeochemical cycles—few ecosystems are not in some way composed of "novel" species communities in significantly different physical settings (Hobbs et al. 2006, Hobbs et al. 2013). Human effect is so thoroughly registered in the makeup of ecosystems, which are continuously changing, that certain separation of the natural from the unnatural in system structure and function is now virtually impossible. Thus the policy emphasis on restoring more natural systems appears misdirected, if not quixotic. For the Corps restoration objectives, the more appropriate focus needs to be on providing the needs of the scarcest ecosystem elements contributing most to the heritage value of ecosystem output held in the Nation's biodiversity.

Yet the program focus on restoring and protecting "more natural" systems has existed since 2000 without change in the PGN and was recently reinforced in the Corps revised Environmental Operating Principles (Bostick 2012). The PGN recognizes that the best result most projects can expect is restoration of a condition that "mimics" a more natural condition. Yet even that intent appears to be frustrated by the unknown extent to which ecosystems are now affected by humans. Corps ecosystem restoration projects in general are more properly regarded as ecosystem rehabilitation projects. Rather than less human effect, these simulated ecosystems are novel ecosystems, often with human effect added to simulate a "more natural condition". If done well, they can be habitable for desired species, but they remain novel systems that have never previously existed. The desired elements of ecosystems may be restorable to a condition of sustainability more like the natural condition, but not the ecosystems themselves.

This approach to national ecosystem rehabilitation may be the best way forward, however, as long as the desired species can be sustained by novel systems. The restoration community of scientists and practitioners is moving away from its past focus on natural systems, indicated by so-called natural reference conditions; to any type of self-regulating ecosystem condition that will achieve carefully defined objectives (Hobbs et al. 2013). This approach relies less on nature for guidance than on better understanding and modeling of system behaviors, regardless of how natural they may be. The restoration community is turning from the past to guide management and focuses more on the human services to be provided, the specific objectives to be achieved, and a systems assessment of appropriate measures at all scales of ecological influence on the sustainability of the desired species in the novel system.

Based on the paradigm shifts that have occurred in restoration science, the Corps needs to reexamine its focus on naturalness in its objectives and turn it more to restoring and sustaining scarce ecological heritage held in the Nation's biodiversity through whatever system condition works. The Corps program has yet to develop policy and technical guidance that takes recent restoration paradigm shifts and the required breadth of spatial and temporal scales of systems thinking into consideration. The critical concern is that the right parts and processes of ecosystems are established and sustained somewhere in the Nation, if not precisely where they once were, to assure that sustainable diversity results from the investment. Determining which

parts and processes are essential to establish in a project area requires knowledge of which elements of the Nation's ecological heritage are nationally unsustainable so that their needs may be targeted for reestablishment at more sustainable levels. Recognition that ecosystems are always changing and nonstationary has forced rethinking about the scale and specific attributes of the systems support needed to restore and sustain the scarcest species elements (Harris et al. 2005, Hobbs et al 2006, Suding 201l, Hobbs et al. 2013). The uncertainties involved make adaptive management planning and continuous adaptation essential aspects of any ecosystem restoration program.

The Systems Approach

The PGN directs a systems approach to all civil works project planning, but does not explain it. For the management of ecological resources discussed here, a system is presumed to be a group of elements interacting with each other and external forces to form a unified whole with generally consistent behaviors (functions) stabilized by feedback controls and cycles (Bertalanffy 1968). For the Corps ecosystem restoration program area, the most relevant resource systems are semiaquatic to aquatic ecosystems defined largely by the solar and gravitational forces that drive or influence organic synthesis, hydrologic and nutrient cycles, atmospheric dynamics, and interactions of water with the landforms in rivers and coastal zones. Underlying the systems concept is the notion of resilience—equilibration mechanisms that resist system disturbance and return a system to its dynamic equilibrium with its environment following overwhelming disturbances. The assumption that system resilience involves predictable responses to environmental disturbances, including management actions, underlies systems management, systems modeling, and forecasting future system structure and function (e.g., Grant et al. 1997).

Ecosystem stability is regulated by a combination of external forces and internal responses, including, perhaps most importantly, the diversification of system structure and function. The conditions that regulate equilibration of ecological systems change at variable rates through time, causing the systems structure and function to change as well, frequently at rates that could influence the outcomes of Corps project planning and implementation. Many studies in recent decades confirm rapid and often unpredictable shifts of system stability to quite different system conditions when exposed to enough stress **(**Gunderson et al. 2010). Ecological systems are open and hierarchically organized; smaller systems are enveloped by and influence the structure and functions of larger systems which in turn influence the smaller systems (O'Neill et al. 1986). Federal water resources management systems are subsystems of a national social-economic system in which resource managers plan management actions and impose them on ecosystems to achieve desired social-economic effects. They are driven by the guidance provided in authorities, regulations, and funding.

The systems perspective of the Corps gradually grew as it gained greater appreciation of hydrologic and economic interactions among projects and its reach extended nationally to many rivers and coastal areas. A rudimentary systems approach was used during the 1920s to address multi-purpose, multi-project planning in the context of watershed-based hydrologic systems. Yet Congress and the Corps remained generally focused on planning for individual projects without much in-depth consideration of cumulative effects on the hydrologic and economic performance of other projects. Emphasis on what would later be called Integrated Water Resources

Management (IWRM) grew, but was limited mainly to the integration of different purposes into a project-focused system designed for maximum public benefit (Muckleston 1990). The concept has more recently broadened beyond a project focus and incorporates a sustainable development goal for public civil works projects (e.g., Cardwell et al. 2006). The processes and goal of IWRM parallel the processes and sustainability goal of the ecosystem management concept developed largely in the 1990s for public land management (Meffe et al. 2002).

The science and application of systems analysis has grown rapidly since a general systems theory was published in 1945 (Bertalanffy 1968). Growth of systems science and modeling accompanied the rapid growth of computing capability. The Corps ecosystem restoration and protection authority of 1996 probably reinforced Corps emphasis on a systems approach in its planning policy guidance, but the approach is intended to apply to all Corps civil works activities. Also in 1996, Corps policy guidance directed an ecosystem approach to management of its project lands and waters (USACE 1996).

Since 2004, Civil Works Strategic Plans (e.g., USACE 2014) have consistently identified the systems approach, IWRM, and adaptive management (NRC 2004d) as major strategies for Civil Works strategic planning. Precisely what this means is difficult to glean from internal policy statements, however. The systems approach is briefly affirmed as appropriate in the PGN (USACE 2000). Operations policy has remained mostly moot about the systems approach with the exception of Corps lands and waters management under its stewardship program, which has adopted an ecosystem sustainability goal, but with little explanation for the ecosystem approach to management. Corps leadership has also promoted more of a systems approach to sediment management (ERDC 2008). But, despite the expressed dedication to and expressed need for it, the Corps has been slow to explicitly develop thorough guidance for a systems approach to project planning and operations. Other than adding some particulars for ecosystem restoration, the Corps planning guidance has changed little since the 1980s.

The ecosystem restoration program area has now existed for 15 years without sufficient technical guidance. It stands out as the exception to the rule. Technical manuals for planning most other Corps purposes have been rewritten during that time frame. The research and guidance on ecosystem restoration and protection measures is oriented toward geophysical restoration. Very little of it addresses management of ecological interactions using advances developed in conservation biology, applied landscape ecology, and restoration science. It is not entirely clear why this has happened, but uncertainty over rapid changes in the science, the Corps ecosystem restoration objectives (Cole 2014c), and the unsettling emergence of new views on restoration practicalities (e.g., Harris et al. 2005, Hobbs et al. 2006, Suding 2011, Hobbs et al. 2013) may have contributed to delay. As the ecosystem restoration authority approaches two decades, the lack of clear, scientifically consistent objectives and state of the art technical guidance, as well as outdated policy guidance, calls into question Corps capability and presumed leadership status.

A particular important aspect is the frequently insufficient scale at which ecosystem restoration projects have been planned. Corps planners have often failed to consider the systems scale necessary to sustain gross ecosystem functions, let alone the more specific needs of nationally unsustainable species. Some better examples occurred in remnant floodplain wetlands and riparian areas that are no longer sustained by river dynamics. Wetlands and riparian areas

"restored" in isolation from their rivers rarely resemble what previously existed and are less likely to contribute much to restoring and sustaining populations of nationally unsustainable species. Much larger systems perspectives and rehabilitation measures are required to achieve the floodplain and river dynamics needed to sustain scarce species elements. Similar perspectives are required in coastal environments where a systems approach to sediment management is making some progress.

With respect to the appropriate systems scale of project planning considerations, some Corps planners have confused the limits placed on planning with the limits placed on implementation. A common response to why more complete consideration of management measures for watershed-scale sources of project risk is that the Corps is not authorized to restore upland terrestrial ecosystems. While policy guidance frowns on Corps implementation activity in terrestrial areas outside the river channel or coastal zone, it emphasizes the need for a (systemically) complete planning process, which includes watershed management measures implemented by other organizations. Yet district pressures to win construction projects continue to bias the consideration of management measures toward those that can be implemented by the Corps.

One trend that is favoring more of a systems approach is the growing number of regional restoration program authorities, such as those established for the Florida Everglades and the Upper Mississippi River Basin. This trend is consistent with the NRC (2004c) recommendation for more of a regional systems approach to water resources management, with a heavy emphasis on rehabilitating the existing infrastructure of the Corps (the Corps "footprint"). Since the ecosystem restoration program area of the Corps has more in common with the concept of ecosystem rehabilitation, it integrates well with the broader concept of regional water resources rehabilitation planning.

The trend toward more regional programs composed of numerous projects provides much more opportunity for a more complete scale of planning than is typically achieved in individual project authorities. In the context of the changes in restoration paradigms, these regional rehabilitation programs are more likely to approach integration of engineered and "natural" infrastructure for improved overall water resources project performance than individual projects. There is a tradeoff, however. The trend concentrates a large fraction of the Corps restoration budget to rehabilitating a small geographical fraction of the national water resources environmental footprint in need of attention over the next several decades and it may not add the greatest use value (including safety) or heritage value to the nation. This issue has not been nationally assessed. What is ideally needed for the Corps national ecosystem restoration program is a national-scale systems assessment of future river basin and coastal zone sustainability trends to indicate prime prospects for restoration and protection investments (Cole 2014c). The possible contributions of isolated project proposals to NER could then be quite quickly judged by planners and reviewers against that background information.

Following the flooding of New Orleans during Hurricane Katrina, and a detailed analysis of causal factors and events, the Chief of Engineers declared 12 "Actions for Change", which emphasized the need for Corps transition to a more comprehensive systems approach to Civil Works project planning and implementation focused more on sustainability and adaptation to

change. The Corps has since funded research and development to serve the actions for change. But, despite expressed needs, the Corps has not developed much nationally applicable technical guidance and other support for a multidimensional systems approach to ecosystem restoration planning and operations.

Even a limited systems approach requires the Corps to overcome conceptual, technical, cultural and practical impediments. Inadequate planning guidance is a fundamental limitation. The Corps has yet to fully work out what a systems approach entails in planning and operations. Much more emphasis has been placed on cost cutting by reducing the time and resources dedicated to I individual project plans. Development of the technical tools needed to implement a systems approach has progressed to some extent at the Corps Engineer Research and Development Center, most recently under the auspices of the Systems-Wide Water Resources Program (Ashby Undated). Models are now better integrated and are closer to the regional dimensions required, but at substantial cost. That program was completed without replacing it with a sequel, however. A true systems approach will not come cheaply. A fundamental reality is limited programmatic funding necessary to advance more quickly.

Environmental Sustainability and Sustainable Development

Sustainability is an essential aspect of the ecosystem restoration program area, but its importance is not highlighted in policy guidance. Where it is addressed, the PGN emphasizes ecosystem sustainability (which is probably impossible) for what appears to be its own sake over the sustainability of ecosystem elements of high ecological heritage value. The heritage concept of sustainability is rooted in American law and internationally prescribed principles. Sustainable resource use is an important aspect of the natural resource conservation philosophy espoused in laws and other official action since its origins in the Administration of Theodore Roosevelt (Hays 1959). In NEPA policy and goals, the sustainable use concept was broadened into a concept of sustainable development, which results from improved use of the environment while maintaining an intact cultural and natural heritage (Cole et al. 2014a). NEPA had a significant influence on development of the United Nations (U. N.) concept of sustainable development. The widely accepted international principle of sustainable development adopted by the U. N. is succinct: “Sustainable development is development that meets the needs of this generation without compromising the needs of future generations” (WCED 1987). The United States accepted the principle along with most other nations.

Consideration for the welfare of future generations was not new, being encountered in basic governance principles of numerous nations long before, but, after endorsement by the U. N., it became more globally accepted and more completely articulated with respect to economy, society, and the human environment. Thus the general trend of greatest importance associated with principle recognition is the increased global commitment to the intergenerational continuity of human welfare improvement, the need for international collaboration to achieve it, and the improved understanding of how world economy, society, and environment are systemically intertwined and interdependent. Even so, interpretation of the principle into local application within individual NGOs and government agencies has varied widely and to such an extent that some critics have questioned the principle’s utility (Cole et al. 2014a).

The U. N. principle of sustainable development was explicitly accepted in the Corps pronouncement of its EOP in 2002 (USACE 2003), which committed to striving to achieve environmental sustainability. Commitment to sustainability continued to be fostered in the EOP revision of 2012. However, neither original nor revised EOP are clear about the importance of intergeneration equity in decisions affecting the environment or in the proper balance between resource use and national heritage maintenance. This is a curious lapse because of the emphasis on intergeneration equity and heritage preservation in NEPA goals.

Much variation in understanding sustainable development remains in the Corps. The Civil Works Strategic Plan incorporates the concept of "sustainable solutions" in its title (USACE 2011a), as if the management measures used in Corps projects should be sustainable when most unavoidably degrade through time. While implied in Corps planning policy, the principles of sustainable development have yet to be explicitly developed in Civil Works project planning guidance despite direction to incorporate them into all military and civil works programs of the Corps (Cole 2014a). Even though Corps analysts (Martin and Stakhiv 1999, Cole et al. 2014a) have investigated and reported upon the relevance of sustainable development, the relationship of EQ improvement to sustainable development remain incompletely defined and unclear in planning and other Corps policy guidance. Based on international principles, Cole et al. (2014b) recently recommended consideration of definitions and concepts thought to be appropriate for Corps use, including more emphasis on intergeneration equity in decision making. But the issues those recommendations may raise have yet to be fully addressed and resolved.

Corp acceptance of sustainability principles is particularly relevant to program success because the authority for the ecosystem restoration program indicates that desired outputs must be protected for an indefinitely long time. The PGN also indicates that sustained output of desired resources is an essential aspect of objective achievement.

National Interest and Resource Significance

The Corps is authorized to improve EQ that is in "the public interest". As interpreted by the PGN, the justification for investment requires evidence of public interest in EQ associated with ecosystem restoration and protection. Determining the public interest is another source of confusion about the ecosystem restoration mission. The confusion increased when federal project planning policy guidance designed for EQ protection under NEPA (WRC 1983) was applied to ecosystem restoration project planning in the PGN.

Some planners have mistakenly thought the Section 206 authority by itself established a public interest in the ecosystem restoration and output protection. But the authority only permits the Corps to carry out ecosystem restoration and protection measures as long as the public interest in EQ restoration and protection is demonstrated in evidence of some kind. Since the public source of investment funds is national in scope, the assessed public interest also must be national in scope. Inappropriate identification of the national interest has been a major source of confusion over the proper demonstration of benefits in Corps project feasibility studies. Appropriate evidence of a national interest should demonstrate clear interest in restoring desired ecosystem outputs and protecting those outputs for the benefit of future as well as present generations.

The PGN relies greatly on the concept of resource significance developed in federal planning policy guidance (WRC 1973, 1983). In federal guidance, the determination of resource significance can range from evidence of local to national interest because the NEPA process does not discriminate between local and national public interest in environmental resources when making environmental protection decisions. Local laws and public opinions are just as important as national laws and opinions. The federal guidance identifies institutional, public and technical recognition of resource significance as evidence of resource importance (WRC 1983, Doll et al. 1994, Apogee Research, Inc. 1995). Institutional recognition of resource significance is revealed in laws and other official actions. Public recognition is demonstrated in public opinion and controversy. Technical recognition is revealed in technical identification of details necessary to determine if a specific resource actually is of public interest. For example, the ESA shows definite national interest in restoring nationally unsustainable species to a sustainable state, making them significant resources, but identifying which species are unsustainable requires technical recognition. This distinction is not recognized in the PGN.

The federal guidance succinctly describes important differences in the reliability of the different categories of recognition and the relationships among them, which the PGN fails to reflect upon. The federal planning guidance indicates that institutional recognition is more reliable evidence of resource significance than public opinion because public opinion is more likely to change. Public opinion may be important locally if enough of the local public make a point of it. But, unlike institutional recognition in federal law, national public opinions about the desirability of particular project investments are rarely voiced clearly by recognized representatives of the entire Nation. Technical recognition does not indicate broad public interest or even the interest of the experts themselves. Technical recognition plays an important role in carrying out the wishes of the public that have been identified by law or other reliable evidence of public interest by providing specific information about resource condition. While public recognition of the importance of restoring species to a sustainable state is clear in the ESA, for example, the interest in their restoration and protection can only be served by technical recognition of the species status. Technical significance does not stand alone as evidence of national public interest. Thus the national significance of restored resources has been unclear in many project studies.

The national scope of the resource significance justifying restoration and protection has not been universally recognized in part because the PGN does not mention the necessity of using *national* resource significance as the criterion for judging beneficial investment. While the States have their own laws for protecting locally scarce species, for example, those species are not nationally significant if they are nationally common and sustainable. The local laws need to be respected in project considerations of EQ protection under NEPA, but investing federal tax dollars in local improvements is not a cost effective way to restore resources in the national interest.

The failure of the PGN to clearly describe the resource significance differences between EQ protection under NEPA and EQ restoration and protection under Section 206, also abets broad interpretation of the authority to include benefits that are normally monetized. Because EQ protection does not discriminate between degraded heritage value and resource use value, a wide variety of fish and wildlife laws can serve as evidence of resource significance for protection purposes. A long list of federal fish and wildlife laws exist to support management of fish and wildlife for recreational and commodity use with value measured in monetary units. They are

referenced in the PGN for significance determination without clearly indicating the limits of their applicability for ecosystem restoration and protection projects. The PGN even identifies the Federal Water Project Recreation Act of 1965 as an outstanding indicator of resource significance suitable for justifying investment in ecosystem restoration projects. The name of the law alone reveals its inappropriateness. Many feasibility studies have used inappropriate laws to identify a public interest in restoring degraded (presently unsustainable) ecological heritage. Identifying public interest in ecosystem restoration investment requires careful assessment of the benefits targeted by laws. Few laws are in fact relevant. The goal of ESA and similar laws most clearly target increased species-related heritage value independent of any resource use value as the proper measure of objective achievement.

The PGN declares the importance of resource scarcity in determining resource significance, but provides little insight into how it relates to variation in the value of different ecosystem outputs. Knowledge of resource scarcity is essential for determining the relative value of ecosystem outputs restored to maintain ecological heritage. When it pertains to national heritage value, resource scarcity is indicated by the difference in the existing and desired resource states as indicated in law or other firm indicator of what the public desires. The ESA is one of the few federal laws that comprehensively indicate that the desired state for the Nation's living ecological resources is sustainability in a wild ecosystem state. Some species are much more imperiled than other species and the heritage value is much greater, justifying greater investments in their full restoration to a sustainable state. Many more species are judged by scientists to be vulnerable to extinction in the United States than are listed under the protections of the ESA (Scott et al. 2006, NatureServe Explorer 2014). Based on the institutional recognition of species heritage importance and the technical recognition of many unlisted species as vulnerable to extinction, many unlisted species are as at least as significant as the listed ones.

Recently, the role of ecosystem services in identifying the diverse value of ecosystem functions has been promoted by the EPA and other agencies as a way to help identify the significance of ecological resources. The idea has been incorporated into the draft revision of federal water resources project planning guidance that is now under public review. The potential value of environmental or ecosystem service concepts to the Corps has been discussed in work completed by Corps employed analysts over the past two decades (Cole et al. 1996, Stakhiv et al. 2003, Tazik et al. 2013, Murray et al. 2013, Reed et al. 2013). Inclusion of the ecosystem service concept in the PGN could either help clarify or further confuse planners over the benefits that justify ecosystem restoration and protection. Broad acceptance of any ecosystem service improvement would be inappropriate because most services have use value. The ecosystem service concept has clarification potential, however, if biodiversity maintenance service is clearly identified and separated from resource use services (e.g., recreation, flood damage reduction).

Benefits Estimation

The emphasis on basing Corps project investment decisions on a more objective determination of benefits grew through time, especially after the Corps received a nation-wide program authority for flood control in 1936. At first, the project benefits were indicated by physical units of output, such as reduced numbers of stranded river-boats or cargo weight transported per mile traveled. But determining when a planned improvement was not worth the investment was problematic.

Plan formulation and evaluation varied from one project to another as Civil Works activities expanded from the Mississippi River to other rivers and coastal areas. This cost-effectiveness approach was subjective and easily abused.

The problem was compounded as other purposes were authorized and multi-purpose projects were planned. Each purpose required different units of benefit measure that could not be compared directly. This and other problems in public investment decision making contributed to development of contemporary cost-benefit analysis, which required conversion of physical indicators of benefit to fungible dollars, based on a willingness-to-pay standard of value.

The foundations of modern project plan evaluation were set after the 1936 Flood Control Act required the benefits of federal water resources projects to at least equal the costs. The first major application of cost-benefit analysis in the United States was chosen as the main approach to estimating the benefits from anticipated use of project-improved water resources. Few standards existed at first, but came about with time, especially with development of federal guidance for project planning process after WRPA was passed (WRC 1973, 1983). Cost-benefit analysis allowed direct comparison of the benefits estimated from all authorized purposes of the Corps. Benefit discounting was incorporated to more objectively compare plan benefits. Cost-benefit analysis was encouraged more universally among agencies by the Reagan and Clinton administrations and by OMB whenever it could be acceptably applied. OMB (2003) for example, indicated that cost-benefit analysis could be applied in most cases to use value, but had to rely on more controversial techniques when applied to nonuse value. OMB in particular found it useful to have benefits and costs indicated in the same monetary units as much as possible to more objectively recommend federal budget allocations.

The rise of the environmental movement was accompanied by increasing criticism of a strict cost-benefit approach to planning. The big problem was a tendency to treat all values that could not be acceptably monetized as externalities generally dismissed from consideration. Suitable methods for valuing outdoor recreation in monetary units had yet to be accepted. As outdoor recreation boomed during the 1950s and 60s, the growing fraction of the public demanded it be considered more carefully during project planning. Others emphasized the importance of maintaining national heritage, particularly in the form of endangered species. While acceptable economic methods for valuing recreation in monetary units soon appeared, the methods for monetizing any form of nonuse value, including heritage value, remained controversial (OMB 2003, NRC 2005), and intrinsic value was entirely outside the realm of economics (NRC 2005).

The environmental community of the time was very wary of economics in general, linking it to previous environmental damage. NEPA allowed benefit-cost analysis for impact assessment, but did not require it. NEPA implementation guidance took a qualitative approach to evaluation of all environmental protection needs through determination of “significant-effects” and the possible need for impact mitigation. Once a decision was made to mitigate, the costs of mitigation were incorporated in the benefit-cost analysis of a Corps project plan. Measuring the benefits from restoration projects was more problematic, however (Cole 2010, 2014a).

The problems started with confusion over the national interest. Planners generally perceived it had something to do with fish and wildlife habitat because of past experience with FWCA, but

which species were relevant and which were not was unclear. Corps project planners favored methods of benefits indication based on the habitat needs of any species selected as indicators. Few of these metrics were comparable across projects because the species and the conditions changed from one project location to the next. A totally different type of metric had to be devised by the Corps when the Government Performance and Results Act (1993) required some means for comparing the relative contribution of each project to national well-being so as to rank projects for recommended budget allocation. The metric developed for that purpose could not be used for project planning evaluation, however. The incomparability of metrics frustrates communications among nonfederal sponsors, Corps project planners and Corps program planners.

Measurement of ecological heritage value was problematic even when the national interest in ecosystem restoration and protection was properly identified. New methods based on sophisticated public opinion surveys were developed that could be used to estimate the willingness to pay for heritage preservation but are criticized on theoretical and practical grounds (Crowards 1997, NRC 2005a, Snowball 2008). Surveyed people may not have the information needed to accurately estimate the value of maintaining resource options for them let alone estimating the value that would accrue to future generations. There is little evidence to indicate that an existing generation can accurately assess the willingness of future generations to pay for environmental resources and deciding against preserving a resource denies them the option. The authors of the PGN were aware of this problem and prohibited estimating the nonuse value associated with heritage preservation in monetary units (USACE 2000). Positively discounting estimated restoration and protection benefits during planning is inconsistent with serving the interests of future generations (Norgaard and Howarth 1991). The PGN assumes a discount rate of zero for ecosystem restoration projects. The PGN does not explain the reason, however—that the benefits accrue to both present and future generations.

The PGN allows any physical indicator or index for measurement of restoration and protection benefits. The great preponderance of metrics used are based on the habitat unit (HU) concept of the Habitat Evaluation Procedure (HEP) developed by the U. S. Fish and Wildlife Services (FWS 1980, 1981) for habitat mitigation consideration under the FWCA. The HU is the product of habitat acreage and a habitat suitability index (HSI) The HU concept was used by the Corps for mitigation purposes and was transferred over to restoration planning without careful consideration of the limits. HUs are value neutral until they are clearly linked to the needs of the desired species outputs. That linkage has been unclear in numerous feasibility studies. In mitigation use, the HSI is typically determined for a high profile species in the project area, often one valued for recreational or commodity use. Once the acreage of damaged habitat is known, the number of HUs required to compensate for the loss is calculated based on a preconstruction calibration of the HSI model, which is then used to guide habitat replacement. Because the indicator species was sustainable in the project area before the area was damaged, the HU generally was assumed to provide the information needed to assure sustainability of the indicator species in the replacement habitat, assuming that all of the essential qualities of the habitat are established.

Several problems arise when HUs are used to indicate benefit from ecosystem restoration and protection projects. The use of single indicator species or closely related group of species for

determining the needs of other species is unreliable (Landres et al. 1988, Caro 2010), but may be corrected to some extent by using a suite of indicator species (Caro 2010). Yet indicator species do not indicate the relative scarcity of other species or ecosystems, which is essential to judge the value of the restoration investment. Nor do the needs of the indicator species necessarily indicate the ability of the project to sustain the desired project outputs and heritage value. As typically calculated, HUs also fail to indicate the total habitat area needed to sustain the viability of the desired populations (Cole 2014b), which is essential to maintain their heritage value. Since the HUs of different species incorporate different habitat qualities, the metrics of each project are unique and cannot be compared across projects to assess the relative contribution of each project to national welfare.

Despite the growing complexity of environmental benefits metrics, the trend may be reversible for Corps ecosystem restoration projects if it can find a single metric for all project and program-level benefits indication. The Corps has shown interest in resolving problems pertaining to restoration benefits measurement since soon after program inception (Stakhiv et al. 2003). In 2007, a program was established to focus research and development attention on ecosystem restoration assessment. One of the outcomes of that program was concept development of new benefits metric for EQ improvements resulting from ecosystem restoration and protection investments (Cole 2010).

The Biodiversity Security Index (BSI) is based on viable population units of a minimum size needed to sustain an additional fraction of the Nation's presently unsustainable ecological heritage. It indicates the relative scarcity and value of ecological attributes based on the global insecurity of species from extinction, species distinctiveness, and the effectiveness of managing the risk exposure of the desired species so that populations become viable. The value of the desired outputs is based solely on the distinctiveness and sustainability of their attributes and the likelihood that they can be restored to a sustainable status. Consistent with policy guidance, the BSI ignores economic value or other social value. The index is independent of the composition of species at a project site so it can be used to compare the benefits from restoration across all sites and at the program level when calibrated as directed. In concept, the BSI appears to resolve many of the communication and quality control problems caused by the proliferation of different metrics. Guidance for its implementation has yet to be completed, fully tested and applied.

Use of the BSI, or some similar metric, could significantly alter the way that restoration planning is conducted, but faces resistance. The BSI could be an effective tool for eliminating consideration of projects that target recreational or other use value improvement. Some of the projects that had been recommended for implementation would not rank nearly as high for annual budget recommendation. That could narrow the field of suitable nonfederal sponsors and prospects for new projects desired in various Corps districts. Despite the potential, however, established planning habits are difficult to change. Even those who accept the BSI in principle dismiss the idea that it or one like it should replace other metrics. The change would be too great for the existing Corps culture to accept. Of course that would add to the problem, not solve it.

Adaptive Management and Climate Change

Ecosystem restoration professionals recognize the importance of adaptive management and climate change as factors influencing the probability of success (Harris et al. 2005, Suding 2011). Adaptive management was a new concept mentioned in the PGN briefly. Some regional programs had adaptive management requirements built into their authorities. More recently, in WRDA 2007, Congress required monitoring at Corps projects and implied that adaptive management of some kind was suitable. Corp policy guidance has since established the need to develop an adaptive management plan, including monitoring, as part of project feasibility study. It remains minimally supported with federal funding for a short time frame, however. The brevity is inconsistent with the need for long-term continuity that is generally thought necessary.

The bigger issue rests in the nonfederal responsibility for project operation and maintenance. While the project remains a federal investment, with a responsibility on the part of the Corps to assure that benefits flow to the nation, the nonfederal sponsor is expected to operate and maintain the project. Incorporating adaptive management plans into new project feasibility studies was a step toward assuring that those possibilities and costs would be considered by the nonfederal sponsor before a cost sharing investment was made. But nonfederal commitments may vary.

Because it is widely influential in ecological process, climate change could have profound effect on the long-term sustainability of project outputs. The Corps officially recognized the potential importance of climate change only within the past few years and nothing is said about it in the PGN. The Corps has begun to assess adaptation needs, but has yet to assimilate the uncertainties and potential effects associated with rapid climate change into its project planning guidance. Because of the uncertainty associated with projected climate change, adaptive management is essential for assuring that nationally scarce ecological heritage is restored and sustained.

The potential effects of climate change require significant changes in the way the Corps has viewed ecosystem restoration in its objectives and practices. Geographical variation in effects is likely to complicate Corps adaptation (IPCC 2014). Numerous studies have shown that many species adjust to climate and other environmental change individualistically and form new ecosystem arrangements with new alignments of abiotic factors (e.g., Hobbs et al. 2009, Hobbs, et al. 2013, Jackson 2013). Old assumptions that ecosystems can be restored to a more natural condition as a unit and in the same place are no longer accepted by many restoration scientists (Hobbs et al 2013). While it may be possible to restore desired elements of ecosystems to a sustainable state, ecosystem restoration is highly improbable. This paradigm shift in thinking requires a much more nuanced approach to restoration at the level of individual species elements in ecosystems; examining the needs of desired populations carefully and at all ecological scales of potential influence. Corps project planning policy and technical guidance is now quite outdated by the changes that have occurred in restoration science over the past 15 years.

Measuring Ecosystem Restoration Program Success

Accountability trends have increasingly been pressuring agencies to show success. Program success can be evaluated in various ways. Clearly, if program interest and growth is used as a measure, the program has been quite successful. There are indications that the Corps has to some extent mitigated a negative environmental image through the ecosystem restoration program. Although criticisms of the ecosystem restoration program from some environmental quarters have occurred in the past (e.g., NWFTCS 2004, Grunwald 2006) they now appear to be less frequent. The Corps leads one of the world's most ambitious regional restoration efforts in the Florida Everglades. It is a major player in national professional meetings convened under the topic of ecosystem restoration. All of this suggests rapid progress, but some potential problems remain.

With a few small exceptions, objective achievements by restoration projects have yet to be demonstrated by significant improvement in the sustainability of our national ecological heritage. The Government Performance and Results Act (GPRA) is an important mechanism for providing the Administration and the public the beneficial results of agency investments, including the ecosystem restoration program. But the Corps response to GPRA requirements for performance indication has so far failed to entirely please the GPRA administrator, OMB. Reporting acres of ecosystem "restored", for example, is not necessarily a measure of benefit. It does not demonstrate that the acres actually produced the desired results. It could indicate a wasted investment if the desired species do not become established and thrive. The ecosystem restoration program is still too young to expect much. One clear indication of a federal success story would be demonstrable reversal in the decline of native species populations toward extinction and, ultimately, the secured viability of species in the ecosystems they form. This requires monitoring focused on the status of species populations in project areas.

Agreements signed with nonfederal sponsors often have not been very specific about federal expectations and monitoring needs. Uncertainty about project results can stem from the way success is monitored by nonfederal sponsors. Measures of success for the nonfederal sponsor may not be the same as those for the Federal government because the outputs desired by nonfederal sponsors may be economic development benefits, such as recreation or tourism development, or environmental benefits of local interest only.

Another reason for uncertainty is based in the confusion that exists between ecosystem support and desired outputs. A common expectation is that the planned "habitat" construction—the ecosystem support for the desired species—is established and shows signs of persistence. But that observation alone does not verify the establishment of the scarce living resources that justified the investment. In the past, some planners actually avoided targeted restoration of unsustainable species because the risks of failure often are high as restoration has been practiced. They elected instead to restore "habitat" for whatever might show up. While apparently practical, that approach is inconsistent with the objective and a potential sinkhole for scarce funds. Restoring ecosystem support is not beneficial when the desired outputs fail to materialize.

When objectives are unclear or too broad, success can be demonstrated with almost any outcome. That result may be desirable if the nonfederal sponsors are satisfied and continue to seek partnerships with the Corps for reasons that have little to do with the federal interest. But the reasoning remains among the most fundamental impediments to restoration of nationally significant EQ to a sustainable state. As the public's agency for budgetary accountability, the OMB continues to emphasize project achievement of national objectives and project outputs of national significance. However, OMB has been chronically confused about the actual ecosystem restoration program objective based on the types of projects put forth for budget consideration. Too many have looked like NED projects without the cost-benefits analysis to demonstrate their economic viability.

The environmental NGOs that have been critical of economic development projects have been much less critical of ecosystem restoration and protection projects. One likely reason is that restoration projects by their very nature are less likely to do environmental damage than economic development projects. Another possible reason is that every dollar that goes into a restoration project is one dollar less than can go into an economic development project. Issues have already arisen in certain restoration situations, particularly when economic development appears to be a higher priority than restoration. The environmental NGOs collectively have become more attuned to threats of species extinction as concern over climate change has grown. That may portend more criticism of the Corps restoration program if the program objective is not more clearly focused on restoring threatened aspects of biodiversity to a more secure status.

Budget Trends

Overall Trends

While the Corps receives funding from various sources, the ecosystem restoration project planning, construction and rehabilitation budget is normally authorized by Congress through annual budget appropriations. Thus the trends in annual budget appropriations are most relevant to the future of Corps funded ecosystem restoration projects. Civil Works annual budgets were tracked back to the 1930s in past annual performance reports (USACE 2001). More recent unpublished information is also available in Corps records. The annual budget appropriation imposes a fundamental limitation on what the Corps might hope to achieve from its normal project planning, construction, and operations.

In absolute terms, the Corps appropriated annual budget peaked in the early 1960s. But the percentage appropriated to the Corps reached a peak much earlier, in the mid 1930s, when it comprised about 5% of the total and was nearly 30 times greater than today's percentage (about 0.16 %) (Figure 18). The decline occurred as other federal priorities grew and water resources development approached full achievement of its goals within existing constraints.

By the early 1980s, the Corps had developed most of the water resources that could be fiscally and legally justified. Between 1983 and 2000, the Corps inflation-corrected budget (1995 dollars) stabilized, but varied annually between 10 to 15 % around $ 4.5 billion per year (Figure 19). Budget allocation has varied between $4.5 and 5.5 billion since 2001 (Carter and Stern 2011a). In sum, the inflation-corrected annual budget for Civil Works has varied little over the

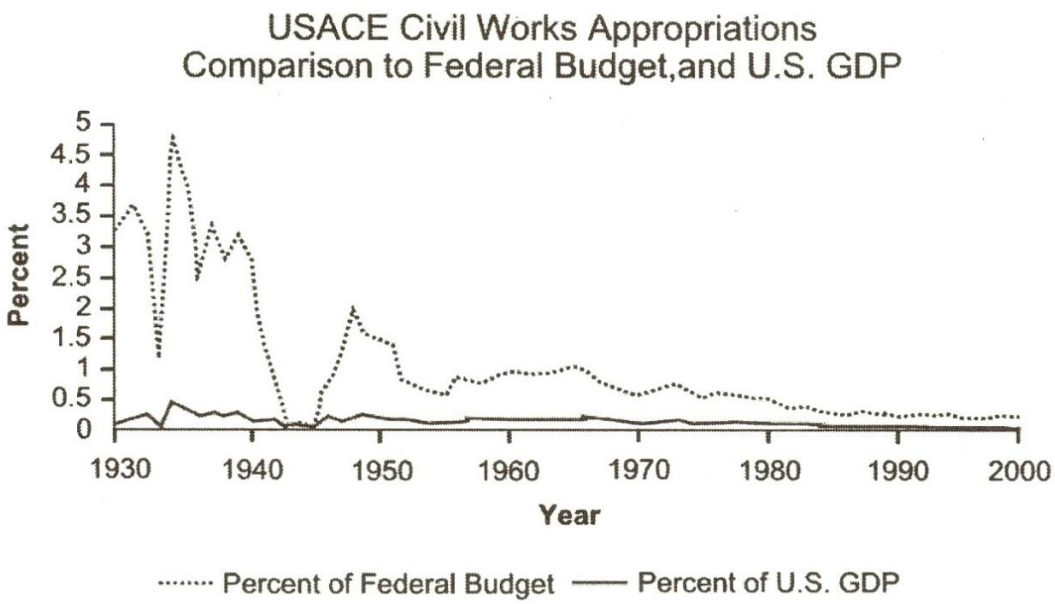

Figure 18. The Corps budget as a percentage of Gross Domestic Product and federal budget from 1930 through 2000 (from USACE 2001). The fractions remained about the same since until the recession of 2009 when it increased slightly.

past 30 years despite changes in congress, administration, and political parties in control; a major attack on the Nation; an aging water resources infrastructure; and the worst economic slump since the Great Depression.

Public preferences have remained more highly committed to mandatory programs for social security and Medicare than to discretionary programs funded by the federal budget. Funding to achieve discretionary goals and objectives decreased from 13.6 % of GDP in 1968 to 7.9% in 2005 in response to public demand for greater social and medical security, the costs of which rose from 3.4% of GDP in 1968 to 11.3% in 2005 (OMB 2007). Taxpayers have tolerated little long-term increase in total tax burden across local, state and federal taxes. Most natural resource agency budgets have either leveled or decreased. Within the federal budget, entitlement spending has continued to increase disproportionately as discretionary spending has decreased. Recent deficit spending places an additional burden on future budgets. While there has been increased emphasis on cutting mandated spending, the only significant recent cuts have come out of the discretionary budget.

Since its inception, ecosystem restoration funding increased rapidly and then leveled off by 2001as a fraction of the annual budget appropriated to the Civil Works Program. The percentage of the total budget appropriated for ecosystem restoration has varied around 10 percent of the total budget without any indication of change.

This is consistent with a more general trend in gradual redistribution of funding for natural resources development and management to environmental protection and improvement funding at all levels of government. From the tables provided by OMB (2007), the rate of environmental funding increased at more than twice the rate of the federal tax increase between 1968 and 2006

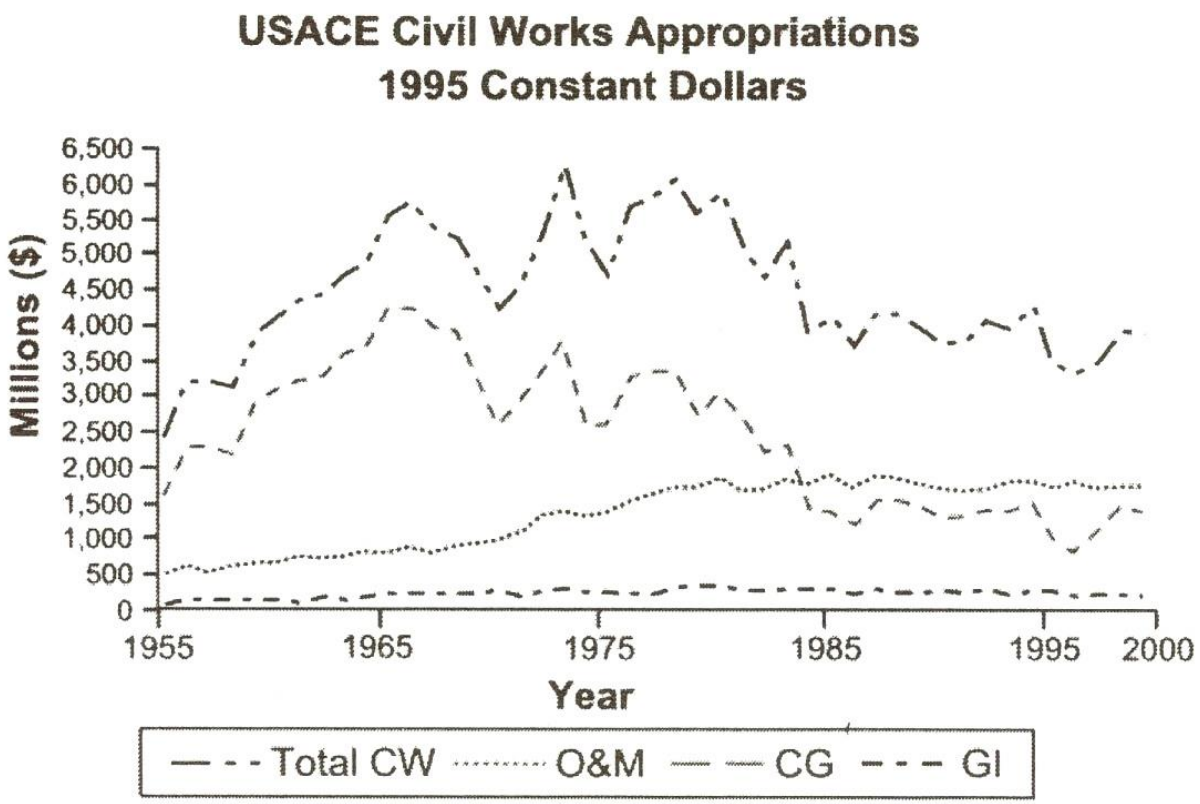

Figure 19. The Corps Civil Works appropriations in 1995 constant dollars from 1955-2000 (from USACE 2001). The trends since 2000 have remained about the same (Congressional Research Service 2011) except for an increase in 2006-2010 of about 30 % for construction and about 10 % for the total.

while the natural resource development and management funding increased at half the rate of the federal tax increase. This general redistribution of tax dollars from resource development to environmental protection and improvement appears to reflect decreasing public demand for the services enhanced by federal development of natural resources and increasing demand for undeveloped ecosystem services (Daily 1997).

However, the recent failures of storm protection systems around New Orleans and New York City, and significant costs of flooding in New England and the Midwest, among other locations, has elevated attention paid to infrastructure condition and increasing needs for major rehabilitation and adaptation to the effects of net sea-level rise associated with climate change. Recent budget allocations suggest a leveling of investment rate in ecosystem restoration. It is too early to tell whether these changes may signal the beginning of a period of greater development funding and less restoration funding

Project Trends

Until the 1960s the operations budget increased roughly in proportion to the number and size of projects built by the Corps. Relatively few new projects were built after the 1960s, but new environmental and other requirements increased operations expenditure by roughly 10 % during

the 1970s. The operations budget is now about half of the total Corps annual budget. The 1986 WRDA helped maintain consistency in federal spending on operations by requiring the operation and maintenance of many new projects (including all EQ improvement projects) to be assumed by a nonfederal sponsor. In recent years interest in reducing O & M costs through improved "asset management" has grown. The Corps is seeking more efficient resource allocation through various means including user fees, asset transfer to local government or private control, and public-private partnerships. More funding may become available for General Investigations and Construction if this form of cost cutting becomes significant. On the other hand, Congress could reduce the federal budget proportionately and transfer the revenue saved to other needs.

The inflation-corrected project planning budget (General Investigations) has decreased steadily over the past three decades, proportionally more than other budget categories. In 2010 it was about 3 % of the total budget. This reflects the *de facto* capping of the congressionally authorized Civil Works budget, the continued demand for sustaining the project O & M and construction budgets, and the accumulation of unfunded authorized construction. The fraction of the planning budget going to EQ improvement increased dramatically to about $75-80 million since the Corps was first granted environmental improvement authority in 1986, but has peaked and in 2010 was about $59 million (from data in Carter and Stern 2011b). It remained about 36 % of the total planning budget, however.

By 2010, over 1,000 authorized feasibility studies and project constructions, totaling to over $60 billion in estimated costs, remained unfunded (Carter and Stern 2011a, b). Few new projects have been included in the federal budget in recent years. Budget appropriations have emphasized completion of ongoing project activities, correcting safety problems at flood and storm damage reduction projects, and project rehabilitation. In 2010, one third of the entire Corps budget request was for dam safety investments (Carter and Stern (2011b). A recent Corps report (USACE 2011) estimated that to deal adequately with aging infrastructure the Corps annual budget needs to be doubled for an unidentified period of time. There is some concern in the Corps that continued investment in ecosystem restoration projects could compete too much with infrastructural improvement and major rehabilitation needs for navigation and flood and storm risk-management purposes. The concern may be reinforced if, as suspected, many of these projects primarily serve recreational, property-value, or commodity interests.

Forecasting future program trends would be informed by a better understanding of nonfederal partner interests. Some sponsors are clearly interested in securing the viability of threatened natural heritage. But the fiscal advantages of the restoration program over traditional program missions are attractive to other nonfederal sponsors more interested in improved resource use than heritage restoration and protection. Ecosystem restoration does not require the rigorous cost-benefit analysis that a development project requires and is more easily justified based on a subjective rationale. Using restoration measures to manage resource use problems also may be more favorably viewed by some critics of Civil Works projects. These advantages have begun to wear thin, however; especially if OMB in particular remains doubtful about the national benefits returned from many proposed ecosystem restoration projects and the extent to which the benefits are truly not measurable in monetary terms.

The project construction budget began to decrease before the total Civil Works budget peaked in the 1960s and continued to do so as physical, legal, and economic limits were reached (its development goals were achieved). The project construction budget trend stabilized from the early 1980s to about 2005. In 2006-2010, the construction budget increased nearly a third for dam repair. In 2010, 32% of the budget request was for dam safety investment (Carter and Stern 2011b). Ecosystem restoration project construction has remained a relatively large fraction of the total ecosystem restoration budget over the past decade, averaging close to 90 % in recent years. It was about 22% of the total construction budget in 2010 (Carter and Stern 2011b) and shows signs of leveling. The 2011 budget indicated a slightly smaller fraction for ecosystem restoration (Carter and Stern 2011b). Recent funding criteria have prioritized projects associated with established, regional programs, such as the Everglades restoration program.

Aquatic ecosystem restoration projects are increasingly competing with development projects for limited funding. Because there is no objective way to compare the benefits of restoration and development projects, the ranking of projects for funding will remain complex and controversial. The unclear objectives of the restoration program and unclear assessment of expected benefits contribute to the controversy.

Program Trends

Another important trend in budgeting has favored maintenance of project funding (including multi-project regional programs) over national program funding, which has translated into greater personnel declines in Corps Headquarters (HQ) review than in the Corps Districts. The project review process dropped off precipitously after 1992 when the Board of Engineers for Rivers and Harbors was eliminated by Congress. Two significant recent changes may slow that trend, however: an Engineer Circular that requires District Commanders to present projects to review by the Director of Civil Works and requirements for external project review in WRDA and policy.

Corps program budgets have always been small compared to project budgets and have decreased faster despite increasing demands on program-level activities, including strategic and budget planning, project review, policy review and updating, project and program performance monitoring, research and development, and all of the coordination, communication, and collaboration required at national and regional levels. In general, proportionally more cost-cutting has occurred at the program level than in project-based budgets. The trend has reduced resources available for long-term improvement of the Corps through research, development, and strategic planning. This trend is consistent with public pressure to control costs, but possibly contrary to an increasing public demand for government accountability evident in the most recent movement to reform the Corps (e.g., Costenbader et al. 2004, O' Keefe et al. 2007).

GPRA was passed and administered by OMB in response to public demand for greater government accountability. It established performance-based budgeting linked back to agency strategic plans that establish budget priorities through plan objectives. Corps compliance with GPRA required nearly a decade and the results in general have fallen short of OMB expectations. OMB wants more defensible program performance indicators and prioritization of agency

activities based on the public service objectives stated in strategic plans. Congress has independently requested the Corps to set priorities for its backlog of unfunded projects.

Infrastructure failures at New Orleans during Hurricane Katrina led to a major evaluation of the impacts and possible Corps culpability (IPET 2009). The Corps leadership responded to the evaluation through a program entitled "Actions for Change". Numerous activities have been investigated and recommendations made pertaining to improved approaches to systems planning and management, sustainable development, adaptive management, risk and uncertainty assessments, communications, and other aspects of the Civil Works Program. Critics have complained for years that the federal water resources project planning guidance (WRC 1983) needed revision and Congress requested it in Section 2031 of the 2007 WRDA. The Corps was asked by the Administration to work with other federal agencies to develop new guidelines for the revision, which was recently completed and signed by the President for agency use. The new guidance increases emphasis on ecosystem restoration in all federal water resources project and program planning as well as careful consideration of all significant ecosystem services. For now, the Corps is an agency exception, since Congress has not allowed the Corps to rewrite its agency guidance consistent with the new federal planning guidance.

OMB has a well established history of consistently pressing agencies for greater cost effectiveness. It prefers agency activity prioritization based on economic benefits and costs, but has accepted nonmonetary measurement of ecosystem restoration project benefits. However, confusion over the means by which the Corps measures restoration benefits and sets priorities for ecosystem restoration projects remains a chronic issue. Because the Corps has built up a large backlog of recommended projects yet to be funded, and because the Corps construction budget has, if anything, decreased over that time, it is now faced with prioritizing the backlog, including anticipated new projects. Among those projects is a growing list of needed major rehabilitations of Corps-operated projects. Setting priorities is difficult enough for NED projects. Ecosystem restoration projects present special problems because of the confusion that exists over what comprises ecosystem restoration benefits.

Competition for new ecosystem restoration projects

In the broadest sense, "*ecological* restoration" has become quite popular (Aronson and Alexander 2013). Other federal agencies have a lot of discretion over how they manage their lands waters, including ecological restoration if they so desire. State agencies are increasingly doing things called restoration. The interest in "*ecosystem* restoration" is less clear, however, since restoration science is largely abandoning the concept of holistic restoration as impractical. But restoration of ecosystem elements is still widely accepted as feasible and desirable even as ecosystems continue to change. In many cases, other federal agencies have special needs supported with full funding, which generally limit them to their land or water holdings. Authorities and regulations often partition agency activities in ways that reduce competition. Other agencies rarely have the more expansive authority of the Corps to do aquatic restoration most anywhere the agency can find a nonfederal partner to help sponsor the project.

The Corps has a reputation for being expensive; however, leading critics to demand justification for the Corps high costs when the Fish and Wildlife Service or other agencies appear to do the

same type of job more cheaply. Good evidence that other agencies are more cost effective than the Corps is difficult to produce, however, because comparisons of projects of the same scale that attempt to restore, or at least simulate, a more natural condition are difficult to find. Much of what the Fish and Wildlife Service or other federal and state agencies do on their lands and in their waters is either ecosystem protection or ecosystem creation (wetlands creation especially) of comparatively small scale. For numerous reasons, ecosystem protection and creation often are less costly than restoration. However, created ecosystems often are not self-sustaining either. A tendency to overlook the need for self-regulating sustainability and reduced maintenance costs can bias the results of such assessments. The high-cost reputation of the Corps, whether justified or not, places more pressure on the Corps to thoroughly and transparently document its costs and benefits, including the uncertainty involved.

Competition from NGOs is limited. NGOs rarely have the resources to afford the full price of large projects. However, some are attracted to partnering with the Corps on small projects financed under Corps continuing authorities. NGOs with biodiversity conservation missions are particularly excellent partners because of the compatibility of their mission with the ecosystem restoration mission of the Corps. Congressional allowance of NGO partnering with the Corps in 1999 was a boon to The Nature Conservancy, for example, which could leverage its investment dollars by nearly two to one in a Corps partnership. But the Corps, Congress and the administration have shown less interest in the CAP than in large regional programs and large individual projects, which the NGOs cannot afford to sponsor on their own. State governments are the more usual nonfederal sponsors of large projects.

Perhaps the greatest asset the Corps has to offer nonfederal partners is the roughly two for one match in federal funding, much of which can be provided by the required nonfederal operation and maintenance of the project. Private firms are not very competitive because they do not bring financing with them. The Corps (or any other federal agency) would find it much more difficult to compete for ecosystem restoration projects sought by nonfederal “customers” at 100% nonfederal funding because the expertise exists in private enterprise as well as larger state governments. Florida is an example of a state that could manage a large restoration effort in the Everglades, if it were not for federal interest in Everglades National Park and the federal match. Yet the match does require tradeoffs in a federal project planning process that is often viewed as too prolonged and costly. Most state governments are not so capable as Florida and other larger states, however, and are likely to tolerate the inconveniences associated with federal planning. Some states may decide to do more on their own.

At this time, the greatest threat from competitors appears to depend on how much the Corps can improve project planning and implementation services with both the national objective and the nonfederal sponsors in mind. That probably requires greater transparency up front about Corps authorities, purposes, and policies; more consistent planner understanding and communication of the relationship between objectives and the benefits used to measure federal objective achievement, improvement of benefits metrics that clearly measure objective achievement at the project and program levels in the same basic ways, and provision of a more timely and acceptable product for no greater cost. Finally, it must show clear examples of restoration success and advertise them well.

Cultural Trends

Organizational culture forms around shared sense of purpose, values, assumptions, and experiences, but those who study it vary in their approaches and definitions (Martin 2002). There is general agreement that the culture of an organization has much to do with how the organization identifies and acts upon its purposes, whether cohesive or divisive, consistent or inconsistent. In large organizations, the culture often forms subcultures with somewhat different assumptions and values. This diversification of culture can be a challenge to organization leaders seeking more focused pursuit of purpose. Organizational culture is shaped largely by organizational history, but is also influenced by the experiences of its membership in and outside the organization. Cultures change through time as subcultures emerge and replace older cultures.

A major force operating internally to sustain the cultural status quo in government agencies is a desire for stability in the work environment. Instability disrupts work flow and diminishes employee confidence. The institutional memory of influential older employees is often a strong stabilizing force. They can frequently recall from their perspective changes that proved unnecessary, or even more harmful than good, such as repeated internal reorganization. But the major forces behind more permanent cultural changes typically originate in outside events. In the Corps, those forces have derived largely from new authorities, regulatory laws, and interactions with particularly influential members of the public.

The culture of the Corps has an important influence on the attitudes toward the program areas it is authorized to manage, preferences for specific measures taken, and the way in which projects are valued (Cole 2014a and 2014b). Corps culture has had and most likely will continue to have significant impacts on how the ecosystem restoration program area is planned, implemented, measured for success, and improved through time. Civil Works culture has been shaped basically by the engineering roots of the Corps corporate identity, long association with the Army, strong ties to Congress and special interest groups, certain laws, and a project-focused budget process. Trends in these forces have combined to create and sustain an identity more like a customer-oriented private engineering firm than a strategic resource management agency with a long-term vision for the condition of the resources it manages. The trends also dampen the Corps institutional ownership and protection of sustainable project outputs that contribute to national heritage preservation.

Several major trends have significantly influenced the evolution of Corps cultural attitudes toward its authorities in general and its ecosystem restoration and protection authority in particular. They include increasing 1) corporate division and decentralization; 2) public demand for accountability; 3) diversification of purposes, responsibilities, and personnel; and 4) reorientation from water resource development to water resources management. These trends, and many of their effects, have not been explicitly described elsewhere, but are interpreted from an extensive history of the Corps and other water resource development agencies (e.g., Maass 1951, Morgan 1971, White 1971, Gais et al. 1984, Arnold 1988, Cortner and Auburg 1988, Schubert 1988, Shallat 1994, Graves 1995, Clarke and McCool 1996, McCully 1996, Pilkey and Dixon 1996, Reuss 1998, USACE 1998, Viessman 2009). Recent history is determined from events and behaviors observed personally or shared by other Corps personnel.

Corporate Division and Decentralization

Corps culture is far from monolithic. That fact has been a chronic cause of concern for Corps policy leaders, most recently signified in slogans like "one door to the Corps". Past organizational decentralization opened numerous doors to the Corps. The effects of decentralization show up in cultural variation among Corps districts, in Civil Works and Military programs, and in Corps partnerships. Over the years, decentralization has led to greater independence of the districts from the influence of Corps headquarters on national norms. Corps headquarters has shrunk to about 0.1% of all Corps personnel as a consequence of Congressional cuts in program area budgets, which tend to preserve districts.

Many Corps employees grew up within district boundaries before they were employed and often relate to and reflect off of local attitudes and preferences. Regional differences affect district personnel attitudes toward federalism in general, Corps headquarters in particular, and interpretation of national policy, goals and objectives at the local level. Sensitivity to NER and other national environmental needs also vary significantly. The trends and effects of three major expressions of division and decentralization are described below: geographic, civil and military, and shared local and federal responsibilities.

Geographic Decentralization

The first Civil Works activities took place when the Corps was centrally directed by the War Department in Washington, emphasized national security, and followed a relatively strict command and control military protocol focused on territorial road and canal construction, and navigation improvements in the Mississippi and Ohio rivers (USACE 1998). For the navigation improvement purpose, decentralization from central military command began almost immediately with the formation of a western rivers division headed up by an experienced civilian (Shallot 1995). That established a pattern of Corps proposals endorsed by members of Congress with the stipulation that projects be developed by locally experienced builders who were not only practical but also loyal to the reigning political party. While West Point officers developed the grand plan, the builders adapted it to local needs and with substantial independence. West Point officers were almost always trained engineers from the only institution in the United States with a civil engineering curriculum.

Decentralization forces grew as territories became states, the nation became more secure from foreign powers, and members of Congress sought greater control to assure state needs were met. Local interests petitioned their congressional representatives to support improvements through project planning and implementation authorities. This practice became the routine after the navigation purpose was authorized. Local special interests, Corps offices, and members of Congress formed "iron triangles" devoted to seeking federal subsidy of local projects (e.g., Gais et al. 1984, Cortner and Auberg 1988). The Corps was organized into regional divisions and local district offices to more effectively provide local services. It underwent various reorganizations until assuming the present continental organization within river basin boundaries. The number of continental districts once reached 42 (Maass 1951), but have since been reduced to 38.

Attempts at reversing the decentralization trend periodically dampened it but failed to reverse it. The more important counteractive forces imposed project quality control through centralized policy guidance and project review and approval. Early in the 20th century, the Rivers and Harbor Committee of Congress created the Board of Engineers for Rivers and Harbors to review and recommend actions to the Chief of Engineers. This centralized quality control, but had little effect on the way projects were brought to the Corps for consideration. Members of Congress continued to have final word on project approval, however, and totally eliminated the Board in 1992. More recently, in response to Corps levee failures during Hurricane Katrina, Congress required external review of large and controversial projects. The Corps has acted to strengthen its internal review process, but its effectiveness has yet to be demonstrated.

The decentralization trend has influenced all Corps purposes. Decentralization leads to differences in the way Corps policies are interpreted. In the case of ecosystem restoration, the vagueness of Corps planning goal and objective allows significant latitude in interpretation and local cultural preferences may influence how far the interpretations may vary from the expected.

Military and Domestic Missions

Early in Corps history, national security and domestic missions were inseparable. Settlement was one means for securing the Nation's boundaries and establishing dependable transportation for commerce was a critical need. Regional growth depended upon it. At that time, the only national source of civil engineers was the West Point Military Academy. After initial resistance, Congress accepted the commerce improvement purpose of federal government and began competing for regional development funding and limited engineering expertise. Congress assumed greater control of the Civil Works Program budget. It also reached into the War Department to assign the number of officers needed for Civil Works activities and determined the conditions for their promotion, thereby driving a wedge between them and commanding offices. Local citizens and builders frequently resented the West Point military engineers, who were often sons of wealth and privilege and not well informed about local conditions (Shallot 1994).

As the Civil Works Program became more independently funded, the Corps' military programs remained separately funded through Army programs focused largely on base construction and improvements, and on wartime needs. Massive expansion of domestic-project funding during the Great Depression dwarfed spending in the Military Program until World War II when most Civil Works resources were diverted to the war effort. Just before the war, President Franklin Roosevelt temporarily gained much greater executive control of national natural resources planning and management, including water resources. But after the war, Congress reasserted domestic control and a return to "iron-triangle" practices.

Congress also resisted executive moves to transfer Civil Works responsibilities to other agencies. Most of the presidents between Truman and Carter repeatedly attempted and largely failed to wrest greater control of the Corps from Congress and to split it from the Army by integrating it into the Department of Interior or newly proposed natural resources departments (Clarke and McCool 1996). Until September 11, 2001, Secretary of Defense Donald Rumsfeld considered transferring the Civil Works Program to consolidate Army mission and reduce costs. USACE

began to strive harder to more fully incorporate Civil Works into the Army to support nation building needs in Afghanistan and Iraq. Headquarters reorganization of USACE in 2003 was designed in part to improve interactions between Civil Works and Military Programs.

Separate federal budgeting is a major impediment to closer ties between the Civil Works and Military Programs. In times of national security need, the Army must reimburse Civil Works for services provided in support of the Army mission, much as it might do with an agency in a separate Department or a private engineering contract. The reimbursable service mission is more like a business-customer interaction than different units of one organization focused by a common mission. This type of interaction reinforces Civil Works identity as a customer-focused engineering firm with no long-term ownership of the project. Even before September 11, 2001, Civil Works employees suspected that the Army had little interest in the domestic missions of the Corps and viewed Civil Works mainly as a source of support for the national security mission. The suspicion was reinforced by Army initiatives to require civilian Civil Works personnel to respond as needed to Army needs. Those initiatives faded without success.

The ecosystem restoration mission is the newest and most exceptional of the Corps missions. It may be the least interesting to the Army because of its emphasis on nontraditional management measures and the least applicable to its national security mission. There may be, as a consequence, less interest among some in the Army leadership in building and sustaining a strong ecosystem restoration program area than the more conventional engineering program areas of the Corps despite various statements of policy and periodic pronouncements of support.

Nonfederal Partnerships

Before 1986, Corps projects were largely funded from federal resources. The 1986 WRDA further decentralized Civil Works power by requiring nonfederal cost-sharing sponsors for many types of new projects, including all ecosystem restoration projects. The 1986 WRDA also required the nonfederal sponsor to assume all operations and management responsibilities for many new projects, including all ecosystem restoration projects. The assumption of project operation and maintenance by the nonfederal sponsor focused the Corps activities much more on project planning and construction than on long-term operation to assure output sustainability. This encouraged a change in the Corps culture from one accepting full ownership of the project from planning to retirement to one more like that of an engineering firm that designs and constructs and then leaves the operation and maintenance to the owner-customer.

There is a problem with this approach, of course. Achievement of the federal objective, paid for largely by the federal taxpayer, must be assured to protect the national interest in the project. But foregoing a sense of full project ownership and responsibility is easier than if the Corps were managing the project itself. The Corps ecosystem restoration and project planning policy guidance (USACE 1999, 2000) does little to assure close involvement in project operation and maintenance. It emphasizes guidance for the restoration aspects of the authority while minimally guiding a process that assures the very long-term protection needed to sustain the nationally desired output. This is one reason behind an emphasis on restoring self-regulating ecosystems.

Sharing responsibility with nonfederal sponsors reduces Corps control and complicates attempts at long-term programmatic adaptive management and the development of regionally well-integrated restoration strategies. The effect on EQ improvement and protection is especially profound because addition of the outputs to the long-term resource sustainability of the desired output is essentially the value added by a project. Without responsibility for the long-term consequences of its restoration projects, the Corps culture had less investment in program quality, including sustainability, than if it remained in the hands of the federal government.

The shared responsibility also has contributed to the tactical power of Corps districts over the programmatic power of Corps headquarters centered on achievement of national objectives. Whereas national water resources development policy emphasizes NED and NER, local partnerships between the Corps and NGOs often are biased toward regional economic interests. District power and sense of independence from Corps headquarters varies widely depending largely on the project funding they control. The districts compete with each other for funding primarily through their local partner and congressional connections. The past trend indicates that a few districts could dominate the ecosystem restoration budget for several decades to come. These are the districts that have been able to win support for large, regional restoration programs composed of numerous projects. The extent to which the trend continues depends on the effectiveness of project and program review, the influence of nationally focused stakeholder groups, executive branch commitments, and power shifts in Congress.

Accountability

Much like other federal agencies, increasing economic and environmental accountability changed Corps culture. The Corps has always been directly accountable to the specific publics it served. Early Corps personnel soon felt the ire of property owners, survivors, and their government representatives when destructive snags and shoals the Corps was supposed to remove damaged yet another river boat. The Corps took its responsibility for property and lives seriously and, as its engineered “solutions to problems” grew more diverse, extensive and effective, it took commensurate pride in its engineering success stories. The Corps sense of accountability became closely connected with its sense of engineering competency and its responses to Congress, who controlled the appointments of military leaders. Economic accountability was a secondary concern and environmental accountability was unheard of. As Corps accountability grew and budget decreased, its cultural sense of agency superiority and invulnerability has diminished. The Corps is a more socially sensitive agency than it once appeared to be.

Federal natural resource management activities grew slowly until the 20th century, when they began to expand rapidly (Hays 1959). As the number of Corps and other federal water resources development purposes expanded, the demand for economic accountability grew. The federal water resources agencies were among the first agencies to be held more economically accountable in law, largely because they were so visible in federal government by the 1930s, when water resources development received close to five percent of the federal budget. Despite government interest in job provision by water resources projects during the Great Depression, the efficiency and effectiveness of federal water resources programs was increasingly questioned by members of Congress and the Administration.

What was then considered environmental concerns also grew. Reducing water resources development damage to fish and wildlife resources—especially anadromous fishes—was addressed primarily through greater coordination with other agencies in the Fish and Wildlife Coordination Act of 1934. The 1936 Flood Control Act also required coordination with other agency actions. It required the federal water resources agencies to evaluate whether project benefits justify public costs (Arnold 1988) and established the basis for applying economic cost-benefit analysis to the evaluation of water resources development projects ever since. These new forms of accountability took the Corps farther afield from its engineering orientation, opening the agency to the influence of economists, professional planners, and fish and wildlife specialists. But the Corps continued to be viewed as an economically wasteful and arrogant bureaucracy too proud to accept constructive criticism (Mass 1951, Morgan 1971, McCully 1996). Similar criticisms have waxed and waned ever since. The last "reform-the-Corps" movement occurred during the past decade. Some of this attention was motivated by the environmental bogeyman image of the Corps, which seems to generate membership contributions to organizations pressing for Corps reform.

As it was then practiced in the 1950s and 60s, economic accountability was not enough to satisfy a growing number of critics concerned about economic "externalities" not normally measured in monetary terms. At that time, fully accepted methods for estimating the net economic benefit from public outdoor recreation and pleasing surroundings had yet to be developed. Also ignored in economic accounting were environmental impacts on human health and increasing loss of cultural and natural aspects of national heritage. Federal environmental laws were weak. The environmental movement following World War II had a major influence on the passage of much stronger federal laws that favored environmental accountability in federal project planning. By opening the door to public oversight in federal environmental impact analysis, NEPA transformed the environmental accountability of Federal water resources development from one that was legally unaccountable to one faced with costly law suits when the NEPA process was violated. A series of powerful regulatory laws passed in the 1970s also opened agency process to public oversight and potential law suit. The growing strength of the environmental NGOs was the real force behind sustained environmental accountability once strong laws were passed.

In 1986, the first WRDA passed in 12 years further increased Corps accountability. The Corps had to eliminate use of "regional benefits" in cost-benefit analysis, "which had allowed the agency to grossly inflate project benefits" (Clarke and McCool 1996). It required fish and wildlife impacts to be mitigated simultaneously with project construction rather than as an afterthought. It also established a mitigation fund and required cost sharing with nonfederal sponsors for many types of projects, including EQ improvements. The required partnering made the Corps generally more responsive to local interests.

Passage of GPRA in 1993, placed more strategic responsibility and accountability on federal agencies. GPRA required most agencies to prepare five-year strategic plans with goals and objectives directed at benefiting the taxpaying public. It also required budget allocation planning to be consistent with achieving the strategic objectives and objective achievement had to be measured and reported. The Corps has been slow to improve strategic plans and project ranking protocols for annual budget proposals. Program performance metrics are often questioned by

OMB. Unlike the agencies with broad programmatic authorities, predisposed to strategic planning, the Corps culture was not so predisposed. The project-based engineering authority and culture of the Corps is primarily responsive to problems identified by others. National water resources development and management strategy has been left largely to Congress and the President. Neither Congress nor OMB has been willing to give the Corps more programmatic planning authority to strategically identify priority needs in place of the piecemeal approach now used, which is determined largely by nonfederal interests in Corps project funding. These are not necessarily the ones that could bring the greatest benefit to the nation.

One effect of increased accountability was more careful attention of Corps planners to details that might result in delays to project planning and implementation. However, the increased time taken to plan so carefully created its own delays. Nonfederal sponsors increasingly complained about the slow process and the need to be more responsive to nonfederal sponsor needs. Now the Corps is often caught between hard places created by nonfederal sponsor demands for a faster, more "customer" oriented process, limited to "the letter of the law" and NGO demands for extra effort in a more carefully informed planning process. No doubt, the Corps can be more efficient and has recently invested significantly in new guidance with that intent in mind. But the more fundamental problems rest in the increased complexity of national welfare improvement and protection, and the abilities of Congress, Administrations and the Corps to deal with it.

In general, the environmental community has spared the restoration program from the skepticism and accountability demands often leveled at more traditional projects (e.g., Costenbader et al. 2004). The latitude could shrink, however. The Everglades restoration program, for example, has received its share of criticism from the environmental community, which desires more positive environmental outcomes sooner rather than later (e.g., Grunwald 2006). The Corps developed its EOP in 2002 in response to growing environmental NGO criticism. It probably adapted as well as most other agencies to incorporating the new environmental constraints imposed in the 1970s into its programs (Clarke and McCool (1996), which culminated in the publication of its EOP in 2002 and in revised form in 2012, but it has not been as strategic in developing improved relationships with its critical publics.

Part of the problem is the failure of Corps environmental policies to consistently show up in Corps actions. The Corps has been slow to implement the EOP, for example. Much is blamed on a limited budget and new priorities, such as the safety of Corps constructed infrastructure. Critics in the environmental community continued to complain about ineffective project operations and maintenance and less than sufficient progress redirecting efforts toward improvement (Costenbader et al. 2004, O'Keefe et al. 2007). More recently, the USACE Environmental Community of Practice (ECoP) has renewed the EOP implementation effort with an emphasis on improved implementation of recent executive orders and the NEPA process.

The new federal planning policy guidance recently signed by President Obama appears to create a more balanced objective for sustainable economic development, which encourages environmental improvement greater than environmental impact mitigation for water resources projects. Combined with growing NGO pressure, this apparent emphasis on environmental improvement in federal water resources activities could raise the national profile of the Corps restoration program and increase the prospects for reimbursable work, if the Corps can

demonstrate cost-effective capability. However, the interactions could continue to reinforce the Corps cultural identification with engineering firms concerned more about short-term "problem solution" than with natural resources management agencies committed to long-term problem management.

Despite the numerous issues addressed here, increasing accountability has made the Corps culture as a whole more sensitive to societal needs in general; not just the needs served by traditional Civil Works purposes. The Corps accepted environmental considerations reluctantly at first, then dutifully, and finally as an integral part of its water resources mission. Compared to other agencies, some analysts believe the Corps has adapted to new circumstances quite well (Clarke and McCool 1996). The depth of real change has continued to be questioned by others, however (e.g., NWFTCS 2004). While the limits to change rest largely with Congress and Administrations, some can be addressed by the Corps.

Diversification of Purposes, Responsibilities, and Personnel

The Corps culture has become increasingly diverse and complex as its authorized purposes and legally binding responsibilities diversified. Disciplinary backgrounds and sexual and racial makeup have all diversified substantially since the 1960s when the large majority of professional employees were white, male engineers. As Corps program demands became more multifaceted, structural engineering gave ground to multidisciplinary approaches, including nonstructural solutions to problems that depend to large extent on economic and ecological understanding. Nowhere is this clearer than in the ecosystem restoration mission. Disciplinary diversification has occurred more in project planning, stewardship of Corps lands, and the regulatory program than in project construction and O & M activities.

The Corps started out as a water resources management agency, charged with improving navigation safety on the Mississippi River. Management efforts were led by military engineers, however, who influenced Congressional investment in more engineered solutions to water resources problems. The Corps' official history (USACE 1998) emphasizes the importance of its engineered structures. Civil works engineering reached a peak during the era of large flood-control dam construction and modern waterways development from 1930s-1960s, when its identity with large structure engineering dominated agency culture.

The Flood Control Act of 1936 was an important initial step toward disciplinary diversification. The Corps was required to show that project benefits justified investments through a more elaborate project planning process. It was also required to place greater emphasis on a watershed approach to planning and coordination with other agencies (Cole et al. 2005). Regional planners (often geographers) and surface water hydrologists were among the better prepared to meet plan formulation needs, and economists were the best prepared to do cost-benefit analysis, relying almost exclusively on net economic benefits to guide investment decisions. Project land-management obligations increased as more projects were built and operated by the Corps. Greater emphasis was placed on management of forest, range, fish, wildlife, and other recreational resources, including employment of professionals from diverse fields.

The federal environmental laws signed in the 1970s were a major force behind Corps disciplinary diversification. Through the public participation and right to sue authorized in the laws, environmental NGOs encouraged Corps project planners to consider all value assigned to and held in environmental quality; not just economic value associated with water resources use and acceptably measured in dollars. Personnel with environmental specialization were hired to implement NEPA. The CWA expanded Corps environmental regulatory authority (materials discharge permitting). The ESA introduced an entirely new aspect of fish and wildlife consideration that had little to do with recreational or commercial value. One result of these changes was personnel diversification into an array of environmental disciplines. The new professionals added new dimensions to the Corps structurally focused, engineering culture.

In response to civil rights legislation of the 1960s, this period was also a time of rapid change in the biological diversity of Corps personnel. The ratio of men to women changed particularly rapidly. While the number of women in engineering increased slowly, the number of women associated with the growing environmental program was much closer to the number of men. This added to the dimensions of differences among the disciplines comprising the Corps professional work force. Racial diversity increased much more slowly.

Corps culture only modestly changed with diversification. Still led largely by male engineers accomplished in long standing practices, the Corps identification with its cultural history, focused largely on engineered structures, was slow to change from within. When President Carter attempted to terminate what the administration considered economically or environmentally imprudent projects from the Corps budget in the late 1970s, the old iron-triangle allegiances regrouped and "the agency emerged essentially intact and unreformed" (Clarke and McCool 1996). Even so, the diversification of disciplines and people that occurred rapidly during the 1970s, established a force for gradual internal change within the Corps.

The EQ improvement authorities of 1986 and 1996 were an added force for disciplinary change, but not as much as one might expect. As the demand for new projects had diminished and operation and maintenance costs increasingly dominated the budget, the Corps became increasingly concerned about diminished engineering capability. The Corps viewed the new authorities as a means for reinforcing traditional personnel needs in engineering, hydrology and other geophysical sciences. The persistence of the concern was captured in the 2004-2009 Civil Works Strategic Plan, which included a goal for the Corps to be recognized as "world-class engineers". The EQ improvement authority of 1986 had not differentiated creative solutions through engineering from ecological restoration. The emphasis on traditional structural solutions remained strong even after Congress authorized ecosystem restoration and protection to improve EQ in 1996. The Corps did not go out of its way to recruit and be recognized for its "world class" ecosystem restoration ecologists. Engineering was emphasized in Corps policy guidance for ecosystem restoration as most appropriate for Corps involvement in ecosystem restoration projects (USACE 1999). That policy still stands.

The agency retains a strong engineering identity, but in large part because of internal diversification, the Corps has adapted to a somewhat broader view of national needs. Nonstructural and "nature-based" measures are much more likely to be recognized as appropriate for ecosystem restoration as well as other missions when cost effective, but policy guidance has

been slow to catch up. For many Corps employees, engineering solutions still imply structural solutions, as opposed to nonstructural management of problems (including structure removal). And there is a real need for structural engineering in future Corps activities. Corps culture has yet to fully embrace the ecosystem restoration mission in part from concern that too much emphasis on nonstructural and nature-based management will dilute engineering design emphasis and capability.

The situation has not favored rapid assimilation of state-of-the art ecological science in Corps project planning and implementation practices. The Corps has placed disproportionate emphasis on restoring geophysical features of ecosystems, in effect assuming that "if you build it they will come"—an assumption that has been debunked as myth by restoration ecologists (Hilderbrand et al. 2005). Whether or not desired species actually come to the prepared site depends on planning based in the sophisticated ecological knowledge of species functions, behaviors and tolerances to conditions much broader than those in the project area. The engineering culture has resisted moving in that direction, depending too much on a few research ecologists and outside expertise for its ecosystem restoration mission, mitigation considerations, and project stewardship.

Paradigms of ecological science and restoration have shifted significantly since the Corps produced its last project planning guidance in 2000. The guidance needs to be updated to accommodate significant changes. Improvement in the ecological knowledge of Corps planners has been slower than needed. This weakness has resulted to some extent in nonfederal sponsor dominance of project planning process. Without as much Corps capability and leadership as needed, ecologically well-informed nonfederal sponsors, with intentions consistent with an ecological heritage restoration and protection mission, are much more likely to produce desired results than sponsors with more traditional NED purposes in mind.

Age diversification is rarely thought about, but has had an impact. Like the society it comes from, the average age of Corps personnel has been growing older with less even distribution of age groups. The leadership is largely from a large employee cohort first hired 35 to 40 years ago. In the early 2000s, federal personnel managers grew more concerned about massive retirement as federal personnel approached retirement age. Then many retirements were postponed when the worst recession since the Great depression happened in 2008-2009 and the recent surge in retirements has caused exceptional rates of personnel turnover and uncertainty in the Corps. The aging of the Corps may have contributed to a period of exceptional stability in Corps environmental policy guidance, which has changed little over the past 15 to 20 years. As the retirements continue and the agency regroups, a destabilization shift toward more inexperienced personnel is likely to slow agency adaptation to climate and other change.

Transitioning from Project Focus to Collaborative Systems Management

Among all of the forces operating on cultural change, the transition from a culture focused on project development to one more oriented toward collaborative water resource systems rehabilitation and management may be one of the most difficult and consequential for Corps culture. It has been one of the least consistent trends affecting Corps culture in part because of changes that originated in Congress and Whitehouse Administrations and in large part because of the difficulty inherent in systems concepts.

Long before the systems concept was formalized, the early Corps was in effect, a rudimentary navigation-system management agency. Corps engineers comprehensively planned and managed snag removal and shallow shoal dredging for a more functional navigation system. The system was driven by the continuous forces of nature and continuous funding of the Corps program by a government concerned about keeping its territorial waters navigable for commerce and national security. It was not a collaborative effort, however, nor did collaboration become part of the Corps' common cultural vocabulary until much later.

More project-focused planning and management came about as territories became States that competed for federal funding. National strategy and the management system became less clear. The congressional rush to fund Corps projects without much national strategy in mind met a growing political backlash during the late 1800s. Strong members of Congress pushed for a more coordinated, multipurpose and systematic approach to river-basin management. By the early 1900s, regional planning was enthusiastically endorsed by the administration of Theodore Roosevelt who assigned commissions to the task of mapping out such efforts. But contentious disagreements often discouraged collaboration among the agencies as federal government grew in size and number of agencies. Disagreements often had some basis in competition for limited federal budget and collaboration itself added costs than some saw as unnecessary. The Corps, for example, did not see much point in coordinating planning with agencies adopting a watershed-management approach to water supply problems, including navigation issues, even though reliable water supply was a major justification for creating national forests in the eastern United States after 1911 (Cole et al. 2005). A common approach to resolving such issues was to direct greater interagency collaboration through Presidential Order, laws and other official actions.

The concept of a project as a system evolved over this time. A project was conceived, informally at first, as an engineered entity (in effect a system) with inputs that affected project performance and outputs that satisfied navigation and "flood control" needs. The inputs were largely hydrologic, economic, (demand for an "improvement" and project funding) and work. Performance was monitored (systems feedback) and adjusted as needed. As more hard structure was used, the concept of a project life-cycle slowly emerged, analogous to the birth, life, and death of an organismic system. As time passed this concept of an engineered system became more formally defined, but largely after the emergence of general systems theory following World War II. It remains the prevalent concept of a system in the Corps even though the project concept of an ecosystem is generally recognized as more complex.

After waning a bit, the emphasis on more comprehensive and integrated planning and management increased once again with authorization of nationwide river-basin development plans in 1927. Responding to the need for rural electrification, the river-basin plans emphasized integration of hydropower into multipurpose flood control, navigation, and irrigation development (Viessman 2009). The plans set the stage for a Congressional rush to fund project study and construction over the next several decades. While nationally comprehensive, the plans were systemically superficial by today's standards and not particularly coordinated across agencies. But they provided a development location blueprint for project-centered planning and the basis for basin-based resource systems development and management. One of the better examples of success in this regard was a system of waterway, hydropower, coal-fired power

plants, watershed treatments and other projects developed and managed by the Tennessee Valley Authority to lift the region's economic welfare. In general, however, little attention was paid to comprehensive analysis of cumulative economic and environmental effects, which were "externalized".

The Flood Control Act of 1936 encouraged more coordination between the Corps and agencies responsible for upper watershed management; especially the new Soil Conservation Service (Arnold 1988). The FWCA promoted a coordinated approach to mitigating damage to fish and wildlife habitat. The administration of Franklin Roosevelt tried to centralize and internally coordinate natural resources planning, but was ultimately defeated by Supreme Court decisions and a quick return to congressional competition for project-based funding after World War II. Impacts on sediment distribution, flood displacement, fish movement, and endangered species elements of ecosystems could have been more completely considered with more of a systems management approach to planning, but insufficient science and computing capability were limiting factors.

A huge regional development program for water resources of the Missouri River Basin was also conceived of as a systemically integrated approach to flood control and navigation, irrigation, and power development and management. It also provided a good example of limitations. Few were thinking, for example, about the cumulative effects of reservoir construction in the Missouri River Basin on sediment discharge (NRC 2011a) and delta maintenance in southern Louisiana. Now, of course, a large effort is underway to restore the delta for flood risk management, fisheries, wildlife-based recreation, and biodiversity preservation. In addition, several endangered species present major systems management problems (Galat et al. 2005). But even if sediment and other systemic effects could have been considered in the Missouri River Basin planning, political expediency may have still ruled the decisions. Economic and environmental assessments were rudimentary and the benefits were thought to far outweigh any future costs.

The emphasis on independent project planning continued even after Congress passed the WRPA in 1965, which authorized the development of guidance for a more systematically integrated approach to national, river-basin, and project planning for water resources development and management. Only guidance for project planning ever got published. River-basin planning was left to local interstate agencies, which have been relatively few and functioned unevenly, and independent of any national planning since the 1970s. The net result was even greater reinforcement of the Corps' project-focused approach to planning and management.

In the 1970s, strong environmental legislation and a new EPA were powerful forces behind more compliance-based "cooperation" and increasing emphasis on managing the environment with more of an eye to visualizing and managing human impacts on environmental systems. The NEPA process encouraged more communication with the environmental community than would otherwise have occurred and the potential threat of lawsuits that forced a form of "collaborative" planning. NEPA and other new laws opened the water resource planning process to public scrutiny and oversight, which often resulted in greater cooperation in solving economic and environmental problems jointly than might otherwise have occurred.

The 1986 WRDA was an exceptional force for more collaboration in the Corps. Before the WRDA was passed, the Corp managed most of the water resources projects it constructed from "cradle to grave". The WRDA required full collaboration with nonfederal, cost-sharing sponsors of environmental improvement and flood-risk management projects. The WRDA did nothing to diminish the project-focus of the Corps and it reinforced a business model concept of collaboration, in which the nonfederal sponsor became the Corps "customer", with the Corps acting more like a private engineering firm than a public service agency. The business model reinforces an emphasis on resource use services while weakening the commitment to restoring and sustaining threatened biodiversity for the potential benefit of future generations (Who is the customer in this case—the nonfederal sponsor or future Americans everywhere?).

The most recent trend toward more of a systems approach to planning and management probably began with passage of the1996 ecosystem restoration and protection authority. The system part of the ecosystem concept helped bring home the need for a collaborative systems approach particular in regional restoration programs and the systems approach was directed for all Civil Works project planning in the revised PGN (USACE 2000). Computing capability had expanded rapidly by then, providing the means for much more sophisticated systems planning and management. In addition to an ecosystem restoration and protection authority, the 1996 WRDA authorized planning for two multi-project regional programs with restoration aspects —one in South Florida and the other in the Upper Mississippi. Implicit in the intents of these programs was regional rehabilitation to achieve optimal systemic integration of beneficial resource use and heritage maintenance (the heritage aspect is clearer in the South Florida program).

Those regional programs became models for pursuing regional programs elsewhere in the Nation. The Corps has since become involved in several major regional plans with restoration aspects. Probably because they deal with problems of more nationally significant scale, regional programs have been more likely to be among Presidential priorities. In many respects, the integration of the ecosystem restoration program-area objective into regional approaches to water resources rehabilitation has been the most promising way to sustain long-term investment interest in the ecosystem restoration mission.

More than a decade after the NRC (2004c) promoted the concept of "portfolio planning" in a river basin context and congressional programmatic authority to carry it out nationally, neither Congress nor OMB has shown much interest in the national scope. But other changes toward more of a systems approach to planning and management have taken place within the limits of existing authorities and budgets. A systems approach is advocated in Civil Works Strategic Plans (USACE 2004, 2011a) and to some initial extent in Corps planning guidance (USACE 2000). The failures of the New Orleans storm management system during Hurricane Katrina stimulated the emphasis on implementing a systems approach. Corps operations is gradually adopting a systems approach to sediment management through the efforts of the Sediment Management Program (ERDC 2008). The program seeks to integrate new science about the sources, movement, and redistribution of sediment to inform various Civil Works project operations activities that impact and or rely on certain sediment behaviors.

For a time during the past decade, the Corps Engineer Research and Development Center and Hydrologic Engineering Center made significant progress developing watershed-based systems

tools, but mostly in geophysical aspects. Ecological improvements have been more limited (reflecting an internal contention that other agencies have more responsibility). The development of effective systems management tools is essential, but probably more complex and expensive than what has been expected and budgeted for programmatically. Recent budget allocations for basic development are even smaller. Some of the regional programs have made substantial progress, but their tools may be difficult to adapt to other environments. Some technical guidance updates for NED planning methodologies and improvements in computer-aided shared-vision planning process, have also made small contributions to a substantially greater need. These are modest advances. The improvement trend seems to be slowing.

The systems approach in the Corps remains largely project-focused and not very conscious of risk identification and management needs outside project boundaries as they are ordinarily defined. The need to adapt to climate change is just beginning to penetrate the Corps planning process. The development of national technical guidance for applying more contemporary concepts of water resources systems rehabilitation and management has not kept pace with the policy guidance commitments to the systems approach. Policy implies that both single-project and multi-project program planning require a sophisticated systems approach to analysis that has yet to be developed to the extent needed. Cost consciousness and recently rapid personnel turnover may be effective counter forces. Each project and regional program has had to proceed without nationally consistent technical guidance.

Corps culture may be an underlying problem. Many biologists, physical scientists, and civil engineers are not well prepared for large-scale systems approaches to ecosystem restoration and its integration with other Corps purposes and conditions outside Corps purview. Systems engineers are needed, but systems thinking also needs to be stimulated among ecologists, hydrologists, economists, and civil engineers. The systems approach can provide a common basis for clearer communication among the disciplines, but only with more technical guidance and dedication to education than now exists. For ecosystem restoration, deficiencies in ecological staffing are an issue. Relatively few are formally educated in the highly relevant fields of ecosystem science, restoration ecology, landscape ecology, and conservation biology. The Corps has tended to rely on other agencies to make up for these deficiencies. But, their ecologists are in general occupied with their own agency's issues, which are not necessarily the Corps' issues.

Many Corps personnel think first of engineered project infrastructure and engineered systems interactions. The concept of "nature-based infrastructure" (green infrastructure) and its systemic integration with engineered (grey) infrastructure is less prevalent, but growing in importance with more public emphasis on "building with nature". Old orientations toward project-focused engineering and management in Congress and the Corps continue to slow transition to a more harmonious integration of engineered and wild systems.

A more complete transition requires a new sense of corporate identity. The new identity is less aligned with engineering structures for "permanent" solutions (then moving on to "solve" the next problem) and more aligned with flexible and adaptive management of flood and coastal plain systems. That approach often requires analysis of many interactions among human activities and system properties. The actual practice of adaptive management is just beginning to

make inroads into Corps thinking, particularly where it is required by law in some of the regional programs, but more general application of the concept has been difficult for the Corps.

"System" remains a buzzword for many; often slipped over in reading or conversation and not well understood or assimilated. The Corps is still wrestling with how to further transition from project-focused planning and management to fuller systems planning and management. The evidence exists in the absence of technical guidance for the application of many of the ecosystems concepts relevant to restoration planning or adaptation to widespread environmental change. Progress has been slow. Nearly two decades of experience with ecosystem restoration projects and regional programs has increased Corps awareness of the complexity, risks, and uncertainties involved, but management is challenging. With old ecosystem concepts of stability, coherency and stationarity now rejected, the Corps needs to not only master old concepts of systems development and management, but also accommodate added complexity.

Future Outlook

Overview

In the most likely future scenario, the global human environmental footprint will continue to grow over the next three decades in response to continued population growth and increased *per capita* energy and materials development and use. While the rates of impact growth may be moderating with increased awareness of environmental impacts on human wellbeing, adverse effects will continue to accumulate and the feasibility of holistic ecosystem restoration based on "natural" reference conditions will further diminish. More scientific emphasis will be placed on restoring unsustainable elements of ecosystems in different biotic assemblages in changing environments at larger geographical scales of management consideration. The primary forces determining rates of environmental improvement are rates of human welfare improvement and government commitments to more sustainable development. Environmental improvement and sustainability is more likely to advance with a strong recovery of the world economy. Prolonged economic stagnation would most likely dampen interest in environmental improvement in general and biodiversity conservation in particular. The least likely scenario, sustained economic deterioration, could reverse environmental improvement trends.

Because American population growth and *per capita* environmental impact are among the highest among developed nations, American management of environmental impact must be exceptionally effective to sustain world environmental improvement. Political commitments to this course of action have been mixed, although political trends are increasingly positive. An aging population with challenging retirement concerns and the past trend in world-wide redistribution of wealth from more developed to less developed nations could continue to pressure American investment in short term economic "fixes" over long-term welfare maintenance and improvement, including restoration and maintenance of ecological resource options for a sustainable future. Environmental concerns have been increasingly reorienting to climate change mitigation and adaptation while recent trends indicate that federal discretionary spending is more likely to be reduced than increased over the next decade. This could divert

environmental funding away from local restoration action, including R & D, which in general could also suffer from decreasing public confidence in scientific and government institutions.

One possible trend shifter depends on the extent to which mandated federal spending is moderated to reduce pressure on discretionary spending. Another depends on the degree to which international instability moderates or increases, affecting the demand for national security investment. Given an aging population that depends on entitlement programs and trends toward increasing global instability over the past two decades, these potential trend shifters are unlikely to be major forces for environmental improvement investment over the next few decades. What happens beyond that time frame depends largely on how perceptions of personal welfare, environmental events, and social institutions have changed.

Within the Corps, public demand to cut government spending and growing needs to repair and rehabilitate aging infrastructure are likely to delay single-purpose ecosystem restoration and protection investment and encourage most ecosystem restoration to take place in regional water resources rehabilitation programs. Multi-project, regional programs have been politically favored because of public visibility and their potential for major improvements. They seem to assure an important role for ecosystem restoration for decades into the future. But the future success of Corps EQ improvement investments could be compromised by too much reliance on its traditional engineering capabilities and incomplete assimilation of the ecological aspects of mission into Corps practice.

The expansion of systems thinking from single-project focus to regional integration of wild and engineered systems requires disciplinary development and integration has been slower than allowed by advances in ecological science and management technology. The recent surge in high-level retirements is likely to slow advances until replacement personnel adjust. Without more emphasis placed on developing Corps personnel strengths in ecosystems management science, the slow pace towards more effective systems management is likely to continue or even lag. Recent trends indicate that the Corps recognizes that it cannot afford to be as decentralized as it has been in its project, regional-program, and national-program planning processes, which need to be better integrated and more strategically coordinated. Considering the forces operating on the program, incorporating EQ improvement into regional approaches to infrastructural rehabilitation may be the most likely context for most future restoration spending in the Corps and most effective way to sustain engineering interest in a mission focused largely on ecological heritage restoration. It is not clear, however, how well the Corps can proactively integrate its restoration and protection activities with other conservation agencies and NGOS. A major trend shifter rests largely with the ability of the Corps to invest more of a limited budget in nationally comprehensive long-term and strategic planning that includes much improved national to local coordination and collaboration with the missions of other organizations.

Becoming more strategic and proactive probably requires a major shift in cultural identity from the nation's engineering firm, ready to respond to the strategies of others, to one more proactively focused on assuring sustainable development of future human welfare using a systems approach. The forces against that happening remain strongly established in the relationships of the Corps to Congress, the Army, nonfederal partners, and its engineering identity. An important aspect of Corps sustainable development is restoration of the Nation's

aquatic ecological heritage to a sustainable state that is protected from future abuse. The extent to which future Corps restoration projects will focus on ecological heritage over a broader mix of resource use and heritage benefits depends largely on how the Corps clarifies its ecosystem restoration and protection objective in future policy guidance. The 15-years of stasis in Corps ecosystem restoration policy and technical guidance does not bode well for improvement of this kind.

The future holds three possible policy scenarios. The Corps could elect to accept policy guidance as it is, without significant clarification. Or it may more explicitly adopt a broader objective that emphasizes economic development as well as heritage restoration and protection. In the third scenario, the Corps fully clarifies and embraces ecological heritage restoration and protection as the objective of the program. The first scenario is easiest, and in many respects most likely, but would not resolve a number of nagging issues. The second scenario would encounter resistance because it pushes the limits of "mission creep", although it could be useful in complex rehabilitation settings as long as use needs do not trump heritage needs. The third scenario seems most consistent with the restoration and protection authority and more clearly complements development of beneficial use for this generation with maintenance of resource use options for future generations.

There also is an ethical imperative to strive for the third scenario because the world's ecological heritage is eroding away very quickly and resources to combat the trend are so limited. Rapid climate change adds to that imperative because ecological restoration is an essential strategy for preserving ecological heritage as change occurs. But the idea of investing in heritage restoration and protection appears to be hard for many in the Corps to assimilate after nearly two centuries of focus on improved use of water resources. The pressures from many nonfederal sponsors to vary from the heritage objective are likely to continue without a concerted effort to clarify the objective and screen out projects serving other objectives.

The Big Picture

General Trends and Forces

Population growth and *per capita* growth in energy and materials development and use are likely to remain the major drivers of environmental impacts over the next three decades. The future rate of global environmental improvement depends on economy improvement, social stability, and social attitudes, which will vary among nations. The idea that environmental sensitivities and investment in environmental improvement is a function of economic improvement has been a generally accepted tenet of international sustainable development philosophy since its inception in a report of the United Nations (WCED 1987). In one model of that relationship, the rate of development and environmental impact is greatest in developing nations. It was generally thought that as nations become wealthier the rate of development and environmental impact slows while investment in environmental improvement increases. That is not always the case, however (Mills et al. 2011), since governmental institutions and policies also play important roles in determining the degree to which environmental improvement increases (Dutt 2009).

Based on recent trends, the balance between the socio-economic forces promoting environmental degradation in some circumstances and environmental improvement in other circumstances is likely to reduce the rate of future environmental degradation without significantly reducing the global human environmental footprint over the next 30 years. A likely scenario for the next three decades is somewhat slower but continued growth of the human environmental footprint, both globally and in the United States. Without greater investments in environmental protection and improvement than appear likely at this time, the effects of increasing *per capita* use of energy and materials are great enough to sustain net environmental degradation. If so, the feasibility of holistic ecosystem restoration will further diminish because of irreversible changes in the environment and biotic communities.

A more optimistic scenario depends on more rapid development of countermeasures for the adverse effects of rapidly increasing *per capita* use of energy and materials as well as more rapid social stabilization than demographic and cultural conditions now indicate. Yet the cultural and institutional barriers to more rapid investment in environmental protection and improvement are difficult to change quickly even in rapidly improving economies. More pessimistic scenarios are based on economic stagnation and further social destabilization, which could result from conflict among major economic powers. Strong deterrents to worse-case scenarios are believed to exist in widespread human desire for improved material welfare and the intricate interdependencies developed by world trade. Many nations bank on this assumption.

Future trends in the United States very much depend on the world economy and social stability. One of the few structured environmental forecasts of the North American environmental outlook to 2030 (DSR Sustainability Research and Stratos, Inc. 2010) emphasized the uncertainties associated with environmental forecasts, but generally concluded that past trends and forces affecting environmental improvement investments will continue into the future, but could vary among scenarios with changes in public attitudes and government policies. The major environmental trends of greatest concern and far reaching effect are continued global warming, invasive species impacts, accumulating effects from chemical contamination, and biodiversity loss. The trend interpretations for the forecasts were based on information available before the 2008-2009 recession. Environmental concerns weakened a bit in the stressful economy.

The North American economy has improved more than average since the last recession and is expected to continue to improve while its fraction of the world economy decreases. The rate of environmental improvement is likely to increase faster with a strong recovery of the world economy. Prolonged economic stagnation would most likely dampen interest in environmental improvement in general and biodiversity conservation in particular. Future technology development can be a force for positive or negative environmental effects. Which will prevail is not entirely certain, but past trends indicate an increasing national policy emphasis on technological development that promotes environmental improvement.

Public Environmental Concern and the Economy

A fundamental public policy dilemma is an old one—how much should people use the environment in ways that may compromise welfare maintenance and improvement choices for us and for future generations? History suggests that the American public tends to be most

considerate of its own future needs and the needs of future generations when the economy is improving. Over a century ago, President Theodore Roosevelt expressed deep concern for preserving natural heritage to future generations following a period of rapid environmental improvement in the United States. Past trends in the United States suggest an increasing social sensitivity to future needs beyond our own, but the sensitivity fluctuated depending on changes in social circumstances. While the trend was complicated by periodic reversals, the past century also saw tremendous welfare improvement in the United States and other developed nations. It was also a period of environmental awakening and legislated action, which peaked in the United States during 1970s when NEPA formally stated as a matter of policy the obligation of the federal government to provide beneficial use while preserving important aspects of cultural and natural heritage. The goal of the ESA more specifically targets preservation of the national fish and wildlife heritage. These and other federal environmental laws responded to the environmental movement of the 1950s, which also was a period of economic improvement.

After the worst economic set back since the Great Depression in the recession of 2008-2009, the United States entered into a prolonged period of perceived economic uncertainty despite sustained economic growth that mostly benefited the wealthiest Americans. A national poll conducted by Gallup (2010) found American perceptions of environmental importance faded a lot during the last recession and has remained less certain than it was before the recession for many Americans. Americans are also aging in unprecedented numbers because of the post-World War II baby boom. Many boomers have not prepared well for retirement. Without politically unpalatable policy modifications, an aging population could place a significant economic burden on younger Americans who would be expected to sustain the social and medical security of older Americans. Continued uncertainty about the global economy and the redistribution of wealth raises some doubts about the degree to which past trends toward growing public emphasis on environmental sustainability and sustainable development will continue over the next several decades.

Concern over growing world debt, national debt and the federal budget deficit contributes to economic uncertainty, which has forced significant cuts in government services and may continue to force cuts in the future. Until they feel more economically secure, voters are likely to prefer retention of federal programs that favor present-day welfare maintenance and improvement over investments producing future benefit. This is particularly true of an aging population in the United States, many of whom are not well prepared for the retirement income they would like to have. Older voters are most likely to vote. In this climate, the challenges facing continued environmental protection and improvement in general and the Corps ecosystem restoration and protection program area in particular, are substantial.

Past periods of economic malaise have, sooner or later, returned to a long-term trend toward improved general welfare and possible solutions to climate and other environmental change may contribute. The economic and social condition in the United States over the next 30 years may improve significantly as new technologies emerge and investment in their American development increase. Depending on the strength of world commitment to sustainable development, “green technology” is one potential avenue for decreasing dependency on fossil fuels, which contribute largely to climate change (IPCC 2007, 2014). But the more obvious recent trend has been the development and use of natural gas, which contributes less to

greenhouse gasses than coal and oil and is more price competitive than other alternatives. The popularity of a carbon tax designed to curtain greenhouse gas emissions is slowly growing and is more likely than standards-based regulations to control environmental treatment costs. Past history favors an optimistic economic scenario over the long term, which would favor restoration investments, but the Corps needs to be prepared for uncertainty and a range of eventualities within the next three decades. The future prospects discussed in this section contribute to assessing the probabilities of scenario realization.

Growth of Human Impacts

World population growth is expected to slow gradually over the next 30 years. Most of the future rise in population number is expected in nations with low income and literacy rates. In its median forecast for the 21st century, the U. N. estimates a world population of 9.3 billion in 2050; leveling to about 10 billion in 2100. However, the range in forecasts is high and depends on numerous economic, demographic, and environmental assumptions (Bloom 2011, Lee 2011). The projected eventual stabilization of human population is encouraging for future achievement of global sustainability because much of the earth's land, water, and atmosphere has already been physically and chemically altered by humanity (e.g., Halbern et al. 2008, Rockstrom et al. 2009).

Median forecasts by the U. S. Census Bureau (2008) indicate a national population of 440 million in 2050. This 41 % increase over the 2010 estimate exceeds the world estimate of 36 %. American population growth is larger than most developed nations because of a high immigration rate, which can be influenced by national policy. The forecasts of population increase indicate that natural resource demand will continue to increase over the next several decades placing additional strain on the lands and waters of the United States (DSR Sustainability Research and Stratos, Inc. 2010). Similar to other developed nations, American life expectancy has continued to increase. Because population growth rate increased markedly during the baby boom generation following World War II, the American population is aging quite rapidly. Similar trends exist elsewhere in the world for which the old-age dependency ratio is expected to double by 2050 (Lee 2011). The trends present significant challenges to sustainable social support of older people and sustainable development of human well-being.

Even optimistic scenarios for the next several decades indicate that future human impact will increase significantly, further degrade future resource use, and accelerate species decline as the effects of global climate change accumulate on top of other environmental change. Global warming is expected to increase for many decades, even after effective action is taken (IPCC 2014). Global climate change could have enough of a devastating effect on world capacity to grow food, supply freshwater, and control disease to raise significant national security concerns (Matthew 2000). Sustainable development faces very difficult challenges because various political, technical, economic and other social concerns remain impediments to corrective action.

Public Perceptions of Environmental Issues

American public awareness of environmental issues has undoubtedly grown in the past and could continue to grow as information becomes more widely available and discussed. However, much misinformation also exists and is more accessible than in the past. The value of thoroughly vetted

information seems to be in decline. The recent history of the Corps also has shown tendencies to mix propaganda with more worthy information—a practice that may backfire in the future. While the Internet may now play at least as important an "educational" role as the vetted mass media, formal education will continue to be an important avenue for informing influential citizens. To be most effective, information must be directed where it will do the most good, which requires some research. Postings on the internet face tremendous competition for public attention. The Corps may claim incidental recreational and other economic benefits as part of its restoration program achievement, but should definitely report the more relevant results for biodiversity restoration and protection—the intent of the program. The community most interested in a biodiversity restoration and protection objective is a relatively select group that should be specifically identified and accurately informed to assure continued program support. But that depends deeply on program achievement and sufficient monitoring to accurately represent that achievement. Past efforts in this regard have not been very strong.

Public perceptions of environmental-issue criticality and need for corrective action varies widely geographically and temporally. Polled opinions of environmental quality tend to be rosier when the economy is bad and gloomier when the economy is healthy. Following recent economic recession, the percentage of the public who thought environmental quality is good to excellent increased sharply (Gallup 2010). Perceptions often fall prey to information manipulation and misrepresentation, however. Even among the better educated, most people are generally ignorant of environmental problem complexity, problem management options, and costs. Environmental policy is likely to remain contentious because, in part, of misinformation about costs, issues, the scientific process, and real uncertainties associated with the outcomes of environmental policy implementation. Economic uncertainty aggravates the problem.

Sustainable development, including the sustainability of ecological heritage, is based on an ethical obligation to future generations that is difficult for many people to grasp. People tend to relate to the environment primarily through their own recreational and other use values. The concept of valuing environmental elements only for their *possible* but uncertain future use by others is more abstract. As it has in the past, the restoration and protection of ecosystem elements in the interest of heritage maintenance requires the continued commitment of government agencies assigned the task and the volunteered commitment of interested NGOs. Because of limited funding, collaboration between government and NGOs is essential. The challenges will place additional demand on the Corps to demonstrate it has the expertise and commitment to cost-effectively restore and sustain the scarce elements of ecosystems for present and future potential use consistent with its EQ improvement and protection authority.

The challenges of convincing the public of ecological heritage importance have become great enough for conservation leaders and organizations to reorient their efforts to showing ecological benefits to present generations, with the ultimate intent of conserving heritage through that approach (Daily and Ellison 2003). Similar thinking has seeped into the Corps, where some believe it makes sense to accept nonfederal demand for economic outputs from restoration projects, as long as some environmental benefit can be expected, because that is where most of the nonfederal interest lies. This is a practical response to frequently encountered issues associated with this program-area requirement. The emergence of large regional "restoration" programs involving many NED aspects may encourage this thinking. However, other than its

inconsistency with the intents of the authority, this approach comes with the risk that the ecosystem restoration and protection mission will become so driven by existing resource use needs that scarce funds will be ineffectively used to restore and protect scare ecosystem

Challenging Costs

Despite past increases in the funding of a new program area, other trends and existing forces indicate that the annual budget for the ecosystem restoration program is more likely to decrease than increase in future years. The American public has resisted increased taxation for decades and has increasingly placed government in an untenable position as it demands or requires at least the same quality and quantity of services. Combined with tax rate limits and low revenues from a depressed economy, increasing public demand for correcting growing budget deficits will require federal budgets to be kept in check. If the costs of mandated social and medical security programs are not significantly curbed, discretionary budget cuts are the only recourse. Continuing international instability is likely to sustain funding for national security budgets at disproportionately higher levels than other federal programs for the foreseeable future.

The effects of global climate change are increasingly difficult to ignore or rationally deny. The costs of mitigating and adapting to the effects of climate change probably will add significantly to the total cost borne by the public over the next several decades (IPCC 2007, 2014). The costs of sustaining environmental parts and process, most evident in recovering species at risk of extinction to a sustainable state, are already high in the minds of some, but will need to increase if full recovery and environmental sustainability are to be achieved. The Corps ecosystem restoration program could contribute, but needs to adapt appropriately to the uncertainties that potential climate change effects can have on the mission. The growing concern for the costs of government portends closer scrutiny of all expenditures and evidence of public benefit, including those associated with the Corps restoration program. In the Corps, public attention, operating through Congress, will most likely be paid first to public safety and related immediate needs. The budgets of potential nonfederal sponsors of projects also are likely to be significantly affected by the perceived state of the economy.

The Bottom Line

Despite many issues and barring catastrophic economic collapse, large-scale trends are more likely to continue in the same general direction than to strongly shift into worse or improved environmental conditions. Future uncertainty rests more in rates of environmental trend change than in the general directions of change. A complete reversal of the global trend toward more sustainable development is unlikely, but the willingness to give up present welfare for future considerations varies widely. Because of economic uncertainty in the near term many people in the world are likely to be much more concerned with their own welfare than with the welfare of future generations.

In the long run, however, differences among nations may have less to do with the desire to achieve world-wide sustainable development than how to do it. Some developing and developed nations, including the United States, bank largely on technological solutions that will not threaten present welfare and economic development even at some risk of losing natural heritage.

Other nations are less fixated on more development, more tolerant of regulation, and more likely to accept some social-political limitation of this generation's wealth if it sustains options for future generations, including maintenance of natural heritage. Income redistribution may already be occurring in response to global business competition. More specifically, the numerous issues standing in the way of sustainable development are likely to be addressed in diverse economic, technical, and political ways through the cooperation of many different agents of change, including the Corps.

While megatrends indicate increasing awareness and concern about environmental impacts of human activity world-wide over the long run, future trends in the attitudes of the American public toward the environment, social equity, intergenerational responsibilities, and ecosystem restoration may not change much from past trends over the next few decades. Much depends on economic improvement for most people, international stability, political uncertainties, further scientific clarification of human impact on environmental process, the disproportionate influence of the aging baby boom generation, and recurrence of harmful events that are perceived by the public to be a result of human impact on the environment (e.g., coastal storms and flooding; extended droughts).

Future Need For A Corps Ecological Restoration Program

Ecosystem restoration was conceived as an alternative to engineered creation of new ecosystems based on the assumption that nature is often better at designing sustainable delivery of desired environmental services. The services may be based in ecosystem uses that satisfy existing needs or in offsetting consumptive use (nonuse) to preserve options for future generations in an intact ecological heritage. As interpreted here, the point of the Corps ecosystem restoration and protection program area is the maintenance of a diverse ecological heritage that sustains options for future Americans. The existing biodiversity within and among ecosystems cannot be sustained without that heritage maintenance. This program objective is consistent with the goals of NEPA policy, which clearly serves human interests.

The need for environmental quality improvement is clear, especially in the aquatic realm. Cole (2009) described the increasing decline and loss of America's native ecological heritage through imperilment and extinction of aquatic species associated with changes in the Nation's freshwaters. Corps Districts with the greatest number of imperiled freshwater fish and mussels were also identified. Over half of the freshwater species are now imperiled and imperilment and extinction are likely to increase if actions are not taken to reverse the trend. Protecting what is left is insufficient since conditions in the protected ecosystems are likely to change as a consequence of climate and other environmental change. As climate change interacts with land use and other environmental changes, species imperilment is anticipated to increase if management proves ineffective. Based on present distributions of ecological attributes and potentially destructive forces, the need will not be equally distributed across the nation.

Chaplin et al. (2000) identified about 15 % of the geographical surface area of the lower 48 states in watersheds that harbor most freshwater species at risk of extinction. They believed those watersheds (or alternatives like them) need to be maintained in a condition suitable for support of native species to minimally sustain most freshwater biodiversity in the United States. Few of the

rivers draining those watersheds are free of physical alteration that could cause ecosystem degradation, which qualifies for ecosystem restoration investment by the Corps. Some of that impact may be addressed through operations modifications as well as through ecological restoration. Aging infrastructure also indicates a potential need for integrating EQ restoration into project rehabilitation and retirement, especially in "hotspots" identified by Chaplin et al. (2000), Cole (2009), and others. One of those hotspots, the Florida peninsula, could be a prototype for Corps effectiveness.

However, the effects of climate and other environmental change have not been taken into consideration to the extent needed for forecasts of ecological heritage needs and ecosystem restoration feasibility. For biodiversity maintenance objectives, the paradigms of ecological restoration science are shifting rapidly away from attempting holistic restoration of ecosystems to some previous "more natural" condition to paradigms focused more specifically on restoring the scarcest elements of biodiversity to a sustainable state somewhere if not precisely where the elements once occurred (e.g., Hobbs et al. 2013). Holistic ecosystem restoration to a sustainable state is increasingly dismissed as infeasible because the effects of climate and other environmental change are beyond the reach of individual projects. A program that persists in a holistic approach to ecosystem restoration is likely to fail. Ecological restoration more focused on restoring unsustainable species to a sustainable state as ecosystem conditions change is challenging but more likely to succeed. Species recovery to a sustainable state in supportive and resilient but different ecosystems will require a new and more rigorous approach different from a holistic ecosystem restoration approach. Even the best scenarios call for a more species-focused approach to ecological restoration because of the improbability of holistic ecosystem restoration.

Future Corps Authority and Policy Guidance

Authority

There are no indications that any new civil works authorities are on the visible horizon. The last resource-use improvement authority for the Civil Works program was passed for recreation improvement over half a century ago and nearly two decades have passed since the Corps was authorized to improve EQ using ecosystem restoration and protection measures. While some interest has been expressed, further expansion of the Corps' EQ improvement authority has limited prospects given recent trends and existing political resistance to federal government expansion.

The NRC (2004c) recommended congressional authorization of a broad "portfolio" approach to planning through national and regional perspectives. In theory, a national portfolio approach would allow the Corps to more cost effectively assign limited budget to the most effective expenditures in the national interest. The past history of Corps interactions with Congress and the Office of Management and Budget has not indicated much promise. Making a convincing case would require strong support from environmental NGOs, who also may yet to be totally convinced the Corps would use the authority wisely. In addition, the increased number of regional programs including ecosystem restoration has co-opted investment recommendations outside their frameworks. If it is not resolved, chronic confusion over the program objective will continue to raise suspicions in the Administration about the merits of the program.

Effectiveness might be further improved if restoration projects could be initiated, planned and implemented independently of nonfederal sponsors whose interests are not always in alignment with national interests. The 1986 law that required project cost sharing was passed in large part to curb Corps budget requests and to force more collaboration with local interests affected by Corps projects. Reversal of the requirement will require a strong case to be made that cost-sharing significantly curbs the national interest in environmental improvement. The case would probably fare better coming from outside the Corps. Little interest has been shown in this approach. Doubts remain about the Corps past "empire building" tendencies and its commitment to ecological sustainability. Short of that approach, clarifying the program objective should reduce the attractiveness of the program to nonfederal sponsors with resource-use in mind.

A much expanded authority that would include restoration for any benefit that justified the investment is also unlikely in the foreseeable future. The past propensity of water resource development agencies to pursue "empire building" raises suspicions in the Executive Branch and Congress whenever Corps recommendations suggest significant "mission creep". Limited expansion of authority that incorporates specific use benefits is more probable. For example, higher priority could be given to those restoration projects that increase human safety.

Many Corps feasibility studies indicate a strong nonfederal interest in what amounts to urban development projects. The pressure to pass a separate urban waterway improvement authority could grow if the Corps more tightly limits project recommendations under its ecosystem restoration authority to those that actually restore and protect nationally significant ecological heritage. That type of authority could compete intensively for a limited Civil Works budget, however. It would also run contrary to a general trend in Congress to limit federal involvement in development that more properly belongs with the States and municipalities. On the other hand, if it is connected with urban recovery from catastrophic events, such as hurricanes, Congress could also raise urban development restoration to a high priority status. The value of the restoration program for restoring national biodiversity to a sustainable state could be gradually reduced the list of priority projects increasingly incorporates coastal zone use and other use value. Once again, the importance of program objective clarification is clear.

At least one evaluation of the Corps ecosystem restoration and protection program area has implied that the Corps does not have the ecological capability to restore ecosystems (e.g., NRC 2004c). A decade later, a legislated end to the program area seems unlikely. Program authorities are more likely to be starved of budget than to be rescinded outside the context of major government reorganization. While disappointing results from the restoration program area could ultimately change the situation, the prospects for a major administrative change are limited. No agency has the ideal balance of disciplines for ecosystem restoration and any agency would require adjustments about as substantial as Corps needs. The only other agency with an aquatic restoration authority is the Department of Commerce, which has an estuary-restoration grants program. Significant expansion of federal investment in the aquatic ecosystem restoration program seems unlikely in the foreseeable future. While unlikely, other agencies could be authorized to pursue aquatic ecosystem restoration using some of the budget allocated to the Corps, if there was enough public interest. Little interest has been shown thus far.

Policy Guidance

Policy guidance stands out as one of the forces for change that the Corps can control. The recent rewrite of the federal water resources planning guidance (CEQ 2014) may ultimately require refinement of the PGN, but its applicability to the Corps was unclear at the time of this writing. The new guidance can be interpreted quite broadly, however, leaving substantial latitude for individual agencies to develop or refine their agency guidance. Whether or not the new guidance is an influence, the Corps has recently shown interest in updating aspects of the program planning guidance. The Corps could be tempted to conservatively change guidance because of resource limitations, general satisfaction with what it has, and the unanticipated complications that can arise with any change in complex guidance. A conservative course seems most likely in the short run because of rapid turnover in Corps leadership ranks, continued confusion over the program objective, uncertainties about policy guidance change, and acceptance of the status quo.

Even though the objective of sustainable economic development expressed in the new federal guidance (CEQ 2014) is not explicit in the PGN, it would be relatively easy to add and is generally consistent with the Corps Environmental Operating Principles. A more aggressive approach would be to provide a much clearer definition of sustainability principles as they apply to Corps purposes, including ecosystem restoration, and clear criteria for determining when sustainability is achieved. This would be consistent with the greater emphasis on transparency in the new federal guidance, but may entail more effort than a conservative approach would allow.

The new federal guidance also emphasizes identification of all significant ecosystem services provided by projects. Incorporating the concept of ecosystem services in a revised PGN provides an opportunity for identifying the important differences between service to present users and future potential users of resources in improved description of how NED and NER projects differ. Recent assessment of the ecosystem services concept by the Corps has predisposed changes that include ecosystem goods and services consideration (e.g., Murray et al. 2013). Done well, the ecosystem service concept can help to clarify the ways in which resource-use services, measurable in monetary terms, differ from the heritage maintenance service (a nonuse service) provided to future generations. This would help explain why the benefits from ecosystem restoration projects are not measured in monetary units.

In the longer run, the Corps may eventually respond to continuing confusion and recent restoration paradigm shifts by clarifying and updating program objectives, objective achievement measurement (benefits metrics), and the critical considerations for achievement success. The confusion that has resulted from an unclear statement of program-area objective and indication of benefits has caused numerous communication problems among collaborators, the Corps and OMB, planners and reviewers, and anyone otherwise interested in the program area. This confusion fails to inspire confidence and complicates the very difficult task of recommending annual budget allocation. It could contribute to the endangerment of program support, which also faces technical, fiscal, cultural, legal, and political challenges that are less Corps manageable. Changes in the paradigms of ecosystem restoration practitioners will only add to the confusion if Corps guidance fails to keep pace.

Changes are likely to be increasingly difficult as past project planning practices become more entrenched. Yet retaining the same statements of objective and description of objective achievement measurement will only aggravate the existing condition. To be most effective, changes in the policy guidance should clearly reflect the objective of the most recent version of the restoration and protection authority (Section 2020 of the 2007 WRDA) and adapt to the changing paradigms of restoration scientists and practitioners. Because ecosystems and habitats are now considered quite profoundly influenced by climate and other human-caused environmental change, and are extremely difficult to restore to some previous condition, restoration professionals are reorienting toward restoring the scarcest elements to a sustainable state in continuously changing ecosystems (e.g., Hobbs et al. 2013).

Perhaps the most misleading aspect of the current study objective for ecosystem restoration is its linkage of ecosystem degradation (and implied value) to a less natural condition. Most, if not all, ecosystems are now continuously changing and novel ecosystems are quite thoroughly influenced by human impact. Indeed, the challenge of defining what is natural, or more natural, has been overwhelmed by the widespread effects of human-caused climate change, non-native species, chemical contamination, and the process of ecosystem restoration itself. While restoration of a more natural ecosystem condition is improbable, the Corps can identify species abundances that are more like they once were in a more natural state and ecosystem support needs that contribute to environmental diversity. It can promote a more comprehensive risk assessment and management approach centered on establishing the needs of those species in wild but unnatural ecosystem settings. It can also encourage use of benefits indicators that reflect greater sustainability of biodiversity and ecological heritage maintenance.

The confusing concept of "resource significance" needs to be clarified to more pointedly focus on the sole importance of a biodiverse heritage in the context of the aquatic and estuarine ecosystem restoration and protection authority. To maintain the respect of the restoration community concerned about biodiversity maintenance, the objective of the program area ought to target restoration and protection of the scarcest elements of aquatic and estuarine ecosystems. The revised guidance should make the unsustainable species the public has shown the most interest in restoring for their heritage value clearly the significant resources. Few laws are as explicit about this public interest in restoring significant resources for their heritage value as the ESA. While ecosystems and habitat are beyond restoration to a sustainable state, unsustainable species may be restored to a sustainable state somewhere in the Nation if not precisely where they once were. The rationale for these recommendations was described under past trends.

Future Budget Expectations

Total Federal Budget

Future ecosystem restoration program funding will depend on federal budget allocation. Based on nearly a half century of consistency, about the same federal tax rates are likely to continue into the future, with some variation depending on the economy. In the near term, increases would more likely be used to reduce the deficit than to increase discretionary spending significantly. The extent to which growth of mandatory budget spending comes under control may have some effect. Despite some resistance in Congress, the Corps Civil Works Program

budget is likely to be supplemented for exceptional needs, such as those following hurricanes Katrina and Sandy, but funding of this type for ecosystem restoration is highly unlikely.

As it has recently, infrastructure maintenance, repair, and major rehabilitation will continue to demand more of the Corps Construction, Planning and O & M budgets for some time. More attention is likely to be paid to constructing already approved restoration projects than to new planning. Most new restoration planning is more likely to be included in regionally comprehensive rehabilitation planning than new individual projects. Such programs have increased in frequency and have political visibility that favors their future dominance in Corps activities.

The predilections of Congress and the Administration are likely to continue to be the more important variables in determining changes in Corps direction. Depending on changes in Presidential priorities and where future committee power rests, the budget may be directed toward or away from restoration projects and program areas that seem to dominate the horizon. Nonfederal sponsors and Congress may be showing less interest in recent years, which were economically difficult. Interest may return as the economy improves. Changes could cause estimated completion of many projects in regional programs to be extended farther into the future. These types of changes are difficult to predict. The authorization of a national assessment of need and firm congressional commitment to address those needs could be stabilizing events, but unlikely based on past history and more politically pressing matters.

Operation & Maintenance Budget

Because O & M takes up such a large share of the total budget, its reduction could result in more funding for General Investigation and Construction, if the cost savings are returned to water resources rehabilitation and expansion needs. That cost savings could also influence funding potential for associated ecosystem restoration activities. Past trends alone suggest that O & M will continue to demand about the same or a slowly increasing slice of the total budget. Safety inventories and related maintenance have increased since Hurricane Katrina and the complexity of O & M regulations is more likely than not to increase and elevate costs somewhat. But the trend could change depending on a number of factors.

Over the long run, a major factor affecting the O & M trend is the extent to which rehabilitation feasibility study reveals insufficient benefits and projects are decommissioned, which may provide opportunities for restoration. The extent of effect is unknown, however, and may prove to be small. Pressure from local interest operating through Congress to rehabilitate, regardless, may dampen this trend, although increasing competition for more justifiable rehabilitation needs elsewhere could act as a counterforce. In the short term, possibilities for transfer of project O & M costs to nonfederal agents, either private or public, continues to be considered under asset management study, but a more realistic pursuit may be charging user fees modeled after the Harbor Maintenance Trust Fund or Corps agreements with private electrical power providers.

Pressure could increase to cut or offset operation costs, including doing no more than is legally necessary to comply with environmental laws. That could deter Corps partnering with The Nature Conservancy and others to restore more natural hydrology through operations changes to

the extent allowed by law and funds. But the chance of that happening is slim. Such cut-backs would be inconsistent with Corps policy, meet stiff resistance from environmental NGOs, and adversely affect interactions with environmental agencies that are often included among stakeholders in ecosystem restoration projects.

Planning and Construction Budgets

The future of the General Investigation and Construction budgets has the most relevance to the future of ecosystem restoration projects in the Corps. Based on the demands for O & M budget and resistance to total budget increases, annual project planning and construction budgets are more likely than not to stabilize or decrease further. Growing demand for rehabilitation will increasingly dominate those budgets as Corps infrastructure ages. Efforts to moderate the effects of those demands through expansion of recapitalization funds from private sources could dampen the pressure on federal budget funds, but modify the overall effect on Corps activities. Compared to the past, relatively few new single-purpose ecosystem restoration projects are likely to be authorized for planning and construction for decades to come. NRC (2011b) concluded that most restoration will occur in connection to Corps project operations and maintenance, upgrading infrastructure, and project rehabilitation.

From the standpoint of total funding, most ecosystem restoration is likely to occur in association with water resources project rehabilitation, including large efforts now underway that are in effect regional rehabilitation programs. These are often regional "replumbing" programs that include ecosystem restoration objectives, such as programs in southern Florida and southern Louisiana. NGOs will continue to demand integration of EQ improvements as well as protection into project and program rehabilitation plans. This need for project and regional program rehabilitation is likely to determine where and how much ecological restoration is done, and how cost effective it will be in generating ecological heritage benefits. Because rehabilitation needs are not likely to be closely correlated with restoration needs, such as in the hotspots identified by Chaplin et al. (2000) and Cole (2009), the program area probably will be less cost effective than if it were not "held hostage" to rehabilitation needs and to nonfederal cost sharing. Setting national priorities for rehabilitation—including heritage needs—requires a national assessment approach that has so far not garnered much support.

Depending on restoration budget allocation, eight to ten regional programs could capture much of the General Investigations and Construction budgets for the next three decades. Regardless of a labeled restoration purpose, most regional program authorities incorporate large NED rehabilitation costs and benefits. Nonfederal sponsors benefit from presenting regional rehabilitation as a single purpose restoration program because the restoration purpose does not require economic analysis. The need for NED project rehabilitation then becomes a constraint—and a restoration cost—that does not have to be justified based on cost-benefit analysis.

Yet Congress may not be willing to allow project funding to be totally dominated by a few large regional programs as the perceived needs of other congressional districts arise. This implies that, as it has in the past, project planning and implementation in any one region will stretch out over much longer time frames, contributing to delays and additional expenses that nonfederal sponsors often resent. This habit could cause some nonfederal sponsors to quit the partnership or

to avoid partnering in the first place. Regardless of scale, the national cost effectiveness of future ecosystem restoration investments is likely to be influenced more by where NED rehabilitation demands occur than by where national ecosystem restoration benefits would be greatest.

The economy and clarity of the ecosystem restoration objective and benefits are likely to influence the degree to which ecosystem restoration and protection benefits are weighed against NED rehabilitation benefits in determining the "optimum" combination for national welfare improvement in annual budget allocation deliberations. Clarifying the national ecological heritage objective and metrics for achievement reduces doubt about the type of value (use or nonuse) justifying the restoration investment. The tradeoffs and the rationale for making them would be clearer to stakeholders. While there is no historic basis for predicting the effect of clearer objectives and objective achievement needs on NED and NER tradeoffs, planners and stakeholders could make more certainly informed tradeoff decisions.

Reimbursable Funding Possibilities

The Corps Civil Works Program could provide significant restoration services to other government agencies for full reimbursement if it builds a reputation for more cost-effective achievements than can be produced elsewhere. But the prospects appear slim. Reimbursable service to other agencies is permitted and most likely would highlight Corps project design capability once the customer determined the appropriate plan. The Department of the Army is an obvious agency "customer". Its restoration needs are largely terrestrial, however, and may exceed the restoration planning capability of the Corps.

State agencies and NGOs are largely interested in leveraging the favorable cost share of the Corps. The Corps has a reputation for being expensive, however, especially for small projects. Many state and some other federal agencies, such as the Fish and Wildlife Service, might compete favorably on a reimbursable basis, for smaller projects. Private firms are increasingly capable as well and do not have the same constraints as agencies. For large projects, Corps expertise may make it quite competitive with other agencies, but not necessarily with large private firms. Many private restoration companies have emerged over the past several decades. Most are small, but large firms can acquire the expertise of small specialized restoration companies and the Executive Branch frowns on obvious competition with private enterprise.

Future Corps Culture

Corporate Division and Decentralization

Regardless of past decentralization trends and its effects on Corps culture, further decentralization is uncertain because of forces that may be operating to resist or even reverse pass trends. The possible consequences of either continued or reversed trends have significant implications for Corps culture and the Corps ecosystem restoration mission. How the objectives are viewed by Corps leadership is important in this regard. If it remains unclear about the national interest, the significant resources, and the intended benefactors from program investments, the door is likely to be open to more possibilities.

The required cost-sharing partnership with a nonfederal sponsor in 1986 was a major step toward relinquishing unilateral federal control over civil works activities. Further decentralization of federal spending on water resources could ultimately lead to the equivalent of grants to the states, municipalities, NGOs, and other local jurisdictions. That could allow recipients even more independent spending discretion and potential reduction of the federal ecosystem restoration focus on nonuse benefits that accrue to the present and future generations across the entire Nation. However, the new federal guidance for water resources planning requires a much broader application across agencies, projects and programs, including grants NGOs (CEQ 2013, 2014). The requirement is consistent with a centralizing trend that the Corps will most likely have to accept ultimately to maintain collaboration and coordination consistency across the agencies. The rigor imposed on any group receiving federal funds will depend in large part on how the administering agency handles its guidance, but is generally expected to be comparable to the rigor expected of the administering agency. How that would be enforced is unclear. Protection of the national interest in the ecosystem restoration program will depend on the clarity of Corps guidance and Corps commitment to the national objective of the program as it is described here. But if that commitment is weak and the Corps continues to accept water resource use improvement as an acceptable output for justifying investment, the effectiveness of the program in preserving ecological heritage of national interest could further diminish.

A similar issue pertains to the presently required nonfederal partnership and assurance that the nonfederal sponsor will follow through in assuring project objectives are achieved and sustained through adaptive management. The required maintenance and operations of ecosystem restoration projects by the nonfederal partner complicates and may be inconsistent with assuring long term sustainability of nationally desired resources (e.g., NRC 2004d). It begs questions about how effective the Corps can be in meeting its own sustainability standard for nationally significant resource if much of the control of operations and maintenance rests with nonfederal sponsors who may be less interested. One key to resolving this dilemma is to make certain the nonfederal partner has the same standards in mind (which has not been very carefully followed in the past). In that context, a grants program with clearly defined federal objectives, adaptive management requirements, and strong federal oversight and involvement in the planning process may be a logical next step. The grantees then become responsible for planning, implementation, and management, including an obligation for nationally significant sustainable results if built into the spending obligations. The problem would then be finding nonfederal partners with the same interests and the resources to make good use of the program funding. They are much less likely to be state agencies than more globally concerned NGOs.

Converting to a grants program is not very likely over the next three decades, however. The success of restoration projects often depends on interstate systems planning and implementation actions. A grants program may be practical for new projects and regional programs within the boundaries of some larger states or coastal state programs at the terminus of interstate drainages, such as Florida, Louisiana, California, and Washington. Inland and smaller states are less likely to enjoy such advantages. A grants program for states may end up spreading federal funding more evenly among states than the trend toward regional programs suggests, thereby diluting regional efforts in the future. A grants program designed for interstate regional designations would be complex and probably viewed by the states as too federally coercive to have much chance of success. Interstate programs have tended to encounter more impediments due to the

complexity of inter-jurisdiction management (e.g., Chesapeake Bay). The need for managing interstate water resources management problems is a strong argument for retaining at least some federal control of funding, if not complete control. The regional rehabilitation programs that now dominate program funding are a stabilizing force for resisting change over the next few decades.

National NGOs could have significant impact on whether a move towards more local planning discretion came to fruition, depending on how much they thought the federal influence was worth. But different NGOs have different priorities. National NGOs that exert influence through strong environmental regulation could respond quite differently than NGOs that invest funds in conservation projects. Despite regulatory NGO criticism of the Corps, a single federal agency is easier to hold accountable than 50 state agencies and numerous NGOs. On the other hand, a grants program might increase opportunities for conservation-investment NGOs to partner with States in smaller individual projects outside the large regional programs that are increasingly dominating federal spending. There would be much variation and uncertainty among the states about how such partnerships might work. Once again, working with a federal entity is likely to be preferred, preserving the status quo. That would also be consistent with the stabilizing effect of the existing regional rehabilitation programs even though gaining a restoration project outside a regional program context may be increasingly difficult.

Congress and the Administration have not shown much interest in grants and recent events suggest some interest in slowing or reversing decentralization trends in water resources management. Congress recently established a requirement for outside review of feasibility studies for all large projects. The new federal guidance for water resources planning, has greatly enlarged the reach of the guidance and the potential for a more systematic and fully integrated water resources management planning process across a wider array of agencies and NGOs that receive federal funds. The two most recent Administrations have favored the regional program approach to regional rehabilitation including ecological restoration.

A potential counterforce may emerge from Congress, however. Many in Congress may not be so enamored by the regional rehabilitation programs, however, because of the increasing difficulty associated with obtaining funding outside those contexts. While a grants program reduces the flexibility of future congressional priorities for restoration investments, it would allow all areas of the country to have some fixed amount of funding. If the funding were proportioned based on national ecological heritage needs and its investment enforced, a grants program could be an improvement. But that contingency is unlikely given the uncertainties about the program objectives and the many designs of local interests.

Also unlikely is the elimination of the 1986 WRDA requirements for nonfederal cost sharing and establishment of a more programmatic approach to regional rehabilitation of water resources infrastructure funded entirely by the federal government. That action would alleviate the complications imposed on “national” objective achievement by required cost sharing with sponsors more concerned about local interests Congressional return of the ecosystem restoration program area to 100 percent Corps funding of planning, implementation and management may be the most effective way to assure Corps sense of responsibility for long term sustainability of the desired resources. If combined with a programmatic planning authority, it would allow the Corps to set ecosystem restoration investment priorities nationally. It would also allow the Corps

more freedom to adapt the program to global climate change and associated environmental changes, which will most likely require a broader planning perspective across state boundaries than many nonfederal sponsors would countenance.

Strong forces operate against that much Corps control, however, because of residual concerns over Corps "empire building" and a confused vision of the program objectives within the Corps. OMB has been suspicious of any actions that would give the Corps more independent programmatic authority and how effectively the restoration program is producing outputs other than for recreation, urban, flood risk management and other water use benefits measured in monetary units. They may not clearly understand the heritage focus of the authority either because the Corps has not been effective explaining it, but they also may believe the restoration program is often a way to avoid cost-benefit analysis for bad NED projects. Doing away with cost sharing requirements also would be inconsistent with political trends in Congress toward granting more local control of and responsibility for government expenditures.

At a larger level of administration, little recent interest has been shown in consolidating the Corps Civil Works Program with other water resources agencies, beyond promoting more consistent water resources management planning in the federal guidance for water resources investments. The administration and Congress are still greatly concerned about national security. Transferring departmental management of Civil Works out of the Army would rupture nearly two centuries of Corps history. Yet the cases for such reorganization have been strong enough in the past for it to have been considered by previous administrations numerous times. If the Corps were to separate entirely or in part from the Army, the national security mission of the Army may have less of an impact on the domestic focus of Civil Works, including ecosystem restoration. A partial separation might be more feasible if another agency could be identified to assume the ecosystem restoration mission. Administrations vary, but, in general, the Army might be expected to have less interest in a mission that relies less on traditional structural engineering more consistent with its national security mission. Interest in agency reorganization could return to a priority consideration in the future—especially if the interacting effects of climate change and infrastructural decay become major forces for greater coherency in resource management. But the natural resource programs in total are relatively small concerns compared to national security and economic issues.

Federal adjustment to the realities of climate change uncertainties and infrastructural decay seem so far to be a slow and inconsistent process. Recent experience with Hurricane Sandy indicates that while local concerns about the effects of climate change on coastal conditions appear to be heightened, Congress was much less consistently impressed. Economic, the cost of nondiscretionary federal spending, and national security concerns are likely to continue to dominate the attention of the federal government well into the foreseeable future. However, the future frequency and intensity of human-caused and natural events would likely have major influences on public preferences.

If natural disasters and failures in aging infrastructure are perceived by the public to be more of an immediate threat to their welfare than in the past, more proactive attention may be paid to domestic natural resource and environmental needs than has been shown by federal government in the last few decades. The tide could turn away from decentralization back to more federal

centralization of natural resources and environmental planning and project implementation. That could have a major impact on the Corps, especially if more funding and programmatic latitude are provided. More "normal" disaster occurrences and continued economic and national security woes would leave the Corps and other natural resource and environment agencies about in the same position—fighting to keep up with insufficient budgets and reacting with supplemental funding when disasters occur.

Based on recent indications of possible trend reversal, further geographical division and diversification of the Corps is not as likely as future consolidation of some districts and of planning functions. More centralized planning appears to be the more workable near-term adaptation to a long decline in budget for General Investigations. A more centralized planning process could be a force for a more proactive and consistent interpretation of the ecosystem restoration mission across the diverse subcultures of the Corps and a force for reducing the confusion of nonfederal sponsors and project review in and outside the Corps. There is likely to be resistance to such centralization in Corps Districts if it translates into fewer employees and less local control.

In general, the corporate division and centralization trend scenarios discussed here are quite unpredictable and depend on perceptions of changes in Administrations, Congress, the public, and the Corps itself. If extreme events appear to be more frequent and logically linked to some human or natural cause, the status quo could be redirected toward where the sources of the problems appear to occur. Less frequent extreme events and more gradual changes are more likely to be ignored, promoting the status quo. Unless Congress, OMB and the Corps dramatically change their ways, the Corps is likely to remain pressured between Congress and nonfederal sponsors, representing local interests, and by OMB, representing the national interests and the President's interests, to put forth projects as they have for the past several decades. The most likely planning scenario for the foreseeable future seems to be slow change toward a more centralized planning process. Depending on other variables, such as the state of the national objective, centralization could result in a more uniform approach to ecological restoration.

Accountability

The increasing accountability trend has continued most clearly through OMB administered GPRA requirements and more recent requirements for external review of large projects. OMB has had long standing doubts about the Corps ecosystem restoration program because the national objective is unclear, numerous projects have looked like recreational or urban development that should have undergone cost-benefit analysis, and the program is exempted from cost-benefit analysis for unclear reasons. Accountability to OMB is not likely to change in the future, nor are OMB suspicions without some significant changes.

The case has been made here that the success of the ecosystem restoration mission rests on the restoration and long-term sustainability of threatened biodiversity in wild ecosystem settings with nonuse value that numerous economists do not believe can be dependably measured in monetary terms. But the importance of ecological heritage, unsustainable species, and their long-term population viability in project outputs does not show up consistently in Corps accounting for GPRA purposes. The Corps relies heavily on measures of geographical area

restored without noting much about objective achievement on that area. Past doubts and concern about rapid restoration program growth without clear objectives resulted in OMB limiting the Corps restoration budget to about 25 % of the total budget for one year (2005). OMB doubt about how well the national interest is served by ecosystem restoration projects is likely to continue if the program objective is not clarified and acted upon more deliberately.

Scrutiny of the ecosystem restoration program area is likely to continue or intensify as Corps program competition for annual funding intensifies. Closer attention is likely to be paid to "essential' aspects of federal spending as long as deficit reduction and balanced budgets dominate domestic issues. Continuing concerns about the economy indicate that more emphasis could be placed on the economic benefits of ecosystem restoration projects. Some critics are not likely to view new ecosystem restoration projects as essential as infrastructure repair and new project investment for economic benefit. Critics are more likely to tolerate some restoration in a project rehabilitation context, if it can be linked to environmental compliance needs and cost reduction, such as the costs associated with a need to list species as threatened and endangered under the ESA. Some economic benefits may become clearer if the Corps clearly explains the role ecosystem restoration can play in reversing the decline of unsustainable species before they need to be listed under ESA protections.

A theme that has continuously emerged from this analysis is the confusion that often results from Corps communication about its ecosystem restoration program purpose, national objective, and benefits. At first happy to see the Corps involved in ecosystem restoration, some of the environmental community have grown more suspicious of Corps intents. The Everglades restoration program has been a target for such criticism (e.g., Grunwald 2006) because too much of the benefit in the near term is from assured domestic and industrial water supply, a constraint placed on everglades restoration. There is concern that interest in continued funding will wane once those constraints have been met. The critics of the ecosystem restoration program can continue to gain ground if the program appears to be a cover for resource use purposes that should be evaluated using economic cost-benefit analysis.

Reducing criticism probably requires more corporate introspection about the predisposition of the Corps culture to respond to its mission more like a consulting engineering firm bent on getting a project in place and moving on, than on a resource management agency truly focused on the long-term sustainability of national biodiversity. Focusing the national objective of ecosystem restoration more clearly on a more sustainable ecological heritage may reduce its attractiveness to some potential nonfederal sponsors, but more clearly shows its relevancy to achieving national goals expressed in NEPA, ESA and other law. Some critics may question the importance of those goals, but would be less justified questioning the federal interest.

Diversification of Purpose, Responsibility, and Personnel

The emphasis of Corps culture on managing water resource problems with engineered structures has substantial effect on approaches taken to ecosystem restoration and to Corps attitudes toward protection. Its geotechnical engineering orientation has favored an interpretation of the mission more in terms of hydrologic and geomorphologic restoration measures than on the expected biological condition of the restored ecosystems. Cultural emphasis on structural construction

also encourages a relaxed attitude toward assuring nonfederal protection of output sustainability over an indefinitely long future. The Corps has invested substantially more in geophysical restoration research and development than in biological considerations of at least equal importance. It claims that ecological research should be left to other agencies better suited to the task even though it is not their responsibility to assure Corps success.

This focus on the geophysical aspects has encouraged acceptance of the old restoration myth, "if you build it they will come". As in successful retailing, the location of the geophysical restoration often favored by the Corps is profoundly important. The perfection of the geophysical restoration will be to no consequence if the ecological support system for the project area and connections between that support system and the project area are inadequate. Making certain of these needs requires ecologists well versed in principles of modern population, landscape, conservation, and systems ecology. Both in hiring practices and internal training, the Corps has not kept pace with those needs.

There are indications of change that bode better for the future of the program. The beginnings of disciplinary diversification have had positive effect, including an increasing emphasis on biological aspects of ecosystem restoration, which must complement geophysical management of a project area for success to occur. The Everglades restoration program has led the advance, perhaps because of its large program size and exceptional funding resources. The program has enlisted Corps ecologists and ecological authorities and researchers of high caliber from outside the Corps to help guide planning. Regional program planners use the needs of a number of native species to help guide geophysical restoration, but they may still rely too much on the assumption that, if they "get the hydrology right", the desired species will colonize and flourish. That assumption may have greater credence there than many other project locations because of the large scale of the program and the reasonably high integrity and protection of resources in and around the Everglades National Park. Yet the program has encountered difficulties associated with altered water quality, invasive species, and climate changes that also have to be considered.

Success is more difficult to achieve where many risks other than hydrologic change have to be managed to assure colonization by the desired species; especially for small projects. Reliance on collaborative agencies and outside consultants for ecological capability requires Corps ecologists sophisticated enough to assure that project objectives will be met. Continuation of the trend toward greater disciplinary diversity and capability is needed to improve ecological and interdisciplinary expertise, and its thorough integration into planning and implementation process. Planning improvement is a critical need for program success. Thorough interdisciplinary integration of ecology, hydrology, and geophysical engineering is required to develop effective ecosystem designs that will sustainably support the desired outputs. That requires planners and restoration designers with exceptional ecological understanding to apply principles of dispersal, colonization, population, ecosystem process, and landscape ecology where ecosystems are always changing in response to climate and other environmental change. Economists also can play important roles. They are frequently better trained in general evaluation and tradeoff analysis than other disciplines.

The disciplinary diversification trends and growing influence of outside stakeholders on Corps planning process may indicate more acceptances of nonstructural (e.g., economic incentives,

water conservation) and soft-structure (e.g., piped sediment, biodegradable structure) solutions in ecosystem restoration projects and regional programs. The new federal water resources planning guidance emphasizes greater reliance on solutions other than hard-structure engineering (e.g., concrete, packed earth, rock) whenever feasible and cost effective. That is likely to lead to consideration of more nonstructural and soft-structure measures, but the hard-structure engineering approach to water resources management in the Corps continues to be favored by Corps culture, although that is beginning to change with pressure from outside the Corps and increasing diversification of engineering skills within the Corps. Yet most of the recent regional rehabilitation program plans prominently feature hard-structure engineering and they could dominate future planning and implementation of projects in the Corps restoration program for decades to come.

This does not mean there is no room for hard structure engineering, especially in the complex multi-project regional rehabilitation programs involving ecological restoration either as a single purpose or in a multipurpose context. Hard-structure engineering is often the only feasible approach to sustaining certain benefits required as a precondition for ecosystem restoration, such as for water supply, navigation, and flood risk management. Nonstructural measures often require large land purchases that are often expensive and politically controversial. Removal of old structures also may be much more expensive and not that much more effective than engineered measures (e.g., controlled release dam bypasses). Old-structure safety issues also can play an important role in decision making. It remains highly likely, therefore, that even though nonstructural measures should and will be given more consideration in the future, hard structure engineering will remain a very important aspect of regional restoration programs. But the choice of hard measures over softer measures will continue to be scrutinized by the environmental community. Evidence of continued cultural bias toward hard-structure engineering could alert critics who would call into question how much the Corps should guide future restoration planning process.

Past trends indicate that the Corps needs to be more careful in its hiring practices and training programs. Many biologists and environmental scientists are not well trained in ecological principles or ecological resource management, including basic planning principles. One-week training programs administered by the Corps are not very effective for making up large deficiencies and may sometimes reinforce bad habits incorporated in Corps restoration planning. A better but more expensive approach to training is to promote enrollment of deficient personnel in university ecology courses combined with specific planning applications taught in Corps training.

Employee hiring needs to be better informed about the interdisciplinary education of the biologists they consider. For example, ecologists with natural resource management backgrounds are more likely to have some economic training, orientation toward management by objective, and planning appreciation than those who graduate from a biology department in a liberal arts program. In addition to ecological generalists, the Corps needs to add ecological specialists who can contribute, as needed, to planning from support centers. The existing ecosystem restoration center of expertise is not funded well enough for the needs. In addition, the Corps could benefit from an ecosystem restoration center with connections to outside expertise in academia, NGOs and private firms. Too much future reliance on traditional approaches could

risk the success of the ecosystem restoration program and increase doubts among potential supporters about Corps capabilities.

Unfortunately, the needs for better prepared employees and planning and design improvement come at a time when funding for planning is in decline. Whether this decline will stop and reverse depends largely on how expansively the Corps, Congress and the Administration view the need for infrastructure rehabilitation with ecosystem restoration as an integral part. There is little sign that Congress is interested in national priority assessment of integrated economic development and ecosystem restoration needs, however. The state of the Corps water resources infrastructure indicates that those individual projects and regions most immediately in need of rehabilitation will be favored for funding over the next decade or longer.

Transition from Project Development to a Systems Approach

In policy statements, at least, the Corps reasons that, when done properly, a systems approach is more likely to produce complete, efficient and ultimately effective plans than a project focused on an area as if it were isolated from important considerations, especially in the context of rapidly changing climate. The importance of a systems approach to ecosystem management is self-evident. But the heavy reliance of the Corps on geophysical "restoration" within a project area without much regard for the effects of climate and other environmental change is not a full ecosystem approach to restoring unsustainable elements of the Nation's ecological heritage. This constrained view the ecosystem is in part a consequence of the project-focused concept of a system. The Corps needs to adopt a much broader systems approach to planning in which the project is a subsystem among other subsystems if it is to achieve ecosystem restoration program success. Numerous hurdles impede progress.

One hurdle is inadequate information. The Corps has not progressed much beyond generalities for describing the systems approach for the ecosystem restoration program. The systems approach is still defined largely by the infrastructure and operations of a project—a project-focused approach. A complete hurricane protection system, for example, has the capacity for complete levee and flood gate closure and a workable evacuation plan scaled to meet the level of storm risk exposure expected based on evidence gained largely at the project area. Generally, the objective of the project—to manage the risks faced by people and property—assumes the people and property will in general stay put for the life of the project. If there is significant evidence to the contrary, the project may be rejected as too expensive for the benefits. The beginning and the end of the engineered system is defined by the project life cycle.

Ecosystems, in contrast, are highly open systems with very porous boundaries through which many different adverse and beneficial risks move into the area where desired outputs are exposed. Other risks originate within the area where the desired outputs are expected to occur. The project-focused engineering approach emphasizes management of the geophysical risks within area while often assuming conditions about the sources of risk from outside the area that are not conducive to success. The species appropriate inputs and outputs of water, sediment, nutrients, organic matter, temperature, oxygen and many other materials need be carefully considered and often managed at remote sources of the risks they carry. Many ecological factors that are critical to assembling a supportive community for the desired species have to be

considered and the "ecological filters" that influence that assemblage have to be better understood and considered in planning and implementation than they have been. Regional programs with more resources seem to have fared better, but these are still works in progress with relatively little to show in the way of studies and recommendations for others.

The concept of a structural "life cycle" is not very meaningful for ecosystems either, which continuously change through time while functioning without discernible end. The life cycle of an engineered structure is analogous to the life cycle of a non-reproducing organism. Ecosystems differ markedly because they are composed of structures that reproduce or otherwise continuously reinvent themselves (such as the geophysical dynamics of river flows, beds, and floodplains). Internal interactions and species composition continuously change while generally sustaining gross function (nutrient processing, community productivity, total biomass) except when exposed to extreme stress. Species are sustained either because they can adapt to the changes or they can move to other more suitable locations. Many of the scarcest species elements are not very adaptable and either have to redistribute or die out.

The ecosystems approach to problem management has to be flexible and adaptive because of the complexities and the ecological and engineering uncertainties. It requires deep collaboration and consistent dedication across multiple levels of government agencies. It needs tools that have been developed for the scale and complexity of regional system dimensions, typically larger than the watershed perspective alone. At some forecast rates of possible species redistribution needs in response to climate change (e.g., Burrows et al. 2011), the region that needs to be considered over a 50 to 100-year project planning period may span hundreds of miles to sustain the restored species populations by allowing redistribution.

As interpreted in policy, the surface-hydrology boundaries of Corps authorities also complicate transition to a more spatially comprehensive systems approach. The Corps civil works authorities are largely limited to water resources development and aquatic ecosystem restoration purposes. Corps districts, as a consequence, focus plan formulation on management measures located in river channels and along coasts. A more comprehensive and proper systems approach to resource management planning extends fully to system boundaries in ecoregions with significant influence on restoration prospects. The Corps is just beginning to seriously consider the links between upper watershed, flood plain and coastal conditions, and how they might be managed for ecological heritage as well as flood and storm risks. But they also need to consider cross watershed interactions as well and very different conditions in coastal zones.

While Corps policy guidance has tried to move the culture toward more of a systems approach, the push has been limited. The technical challenges and costs are a big factor in addition to project-based nature of its authorities. Corps districts are unevenly and rudimentarily informed about how a contemporary systems approach differs from what they have been doing and what practices are more appropriate, especially in a single-project setting where resources often are more limited. Districts participating in multi-project regional programs have gained more experience and savvy, but little has been done to organize systems thinking into a national perspective of systems planning standards and needs. And the Corps has yet to address personnel recruitment, training, and best approaches for transitioning from decentralized to a more centralized planning process.

The increased benefit expected from a systems approach is believed to be enough to justify added costs. Yet many uncertainties remain. The possibility of a cost increase at this time is much more likely to capture the interest of the public and Congress than the expectation of greater benefit, which the lay public may have a harder time understanding, especially if the results are as uncertain as they are. Recent economic conditions and scrutiny of federal programs indicates that an era of tighter program review and budget management is likely for years to come. Adaptive management is a primary tool for managing risks, but it adds costs when done well and even then may not save a bad investment made without careful enough consideration of the remaining unmanaged risks.

History indicates that Congress is much better at responding to needs when the situation becomes dire than acting more proactively. While supplemental funding is likely under such circumstances, it will not be used for ecosystem restoration independent of management responses to imminent and actual devastation. As a consequence, of this funding approach, the rate of needed improvement in personnel, policy, technology, planning and other aspects of a more integrated approach to resources management is likely to be slower than the major rehabilitation and restoration needs of environmental resources requires to restore and protect threatened ecological heritage.

A more comprehensive approach also considers other systems created by humans, such as transportation and energy-production systems. Other than waterway solutions, transportation-system solutions are rarely considered among plan alternatives, but could play an important role in determining the feasibility of ecosystem restoration in waterways. Energy supply systems are not carefully considered either. Hydropower has global carbon emissions advantages of course, but it also has been identified among top threats to freshwater biodiversity (Richter et al. 1997). Such larger perspectives are of course more cost effectively planned programmatically by a collaborative group of agency planners. Once again, Congressional perspective and funding conditions have been, and are likely to continue to be, limiting factors.

If the project-centered systems approach is to become an effective ecosystems approach, more research and development is needed to provide tools and information of appropriate scope. Research and policy guidance must be carefully coordinated to provide the essential systems modeling for systems planning and management. Some efforts have advanced to some degree through research at the Engineer Research and Development Center and through activities initiated by the Corps Actions for Change. However, the coordination between research and guidance needs has not been up to the task, which results too often in false starts and inefficiency. Project-focused district program reviews can impede progress. The project centered funding process reinforces the common district perception of research and guidance needs, which reinforces the project-centered approach. While programmatic funding is the key to mitigating this impediment there continues to be little congressional or White House interest in increasing programmatic funding. Another possibility, redirecting more O & M budget to systems approach improvements, is likely to be resisted strenuously based on past history. Given these conditions, rapid progress in this area seems highly unlikely for the foreseeable future.

The systems approach is of necessity a collaborative approach. The past trend toward greater inter-organizational collaboration comes out of the necessity to solve complex problems effectively. Past trends have been "encouraged" by legal requirements. Although they will continue to be a strong motivation, there are few indications that changes in law will make collaboration any more effective in the foreseeable future. Collaboration is as effective as the commitment of collaborators to achievement of common objectives and process. Effective collaboration requires a clear statement of objectives, which the ecosystem restoration program area of the Corps has yet to achieve. It also requires a common understanding of the systems approach. Many potential nonfederal sponsors are more interested in achieving local objectives than national objectives. Among federal agency collaborators, different mission emphases, incomplete understanding of collaborator authorities and limitations, and a history of tension between regulating agencies and development agencies continues to interfere with effective collaboration.

The systems approach also requires data. Much data now exists but much more specific "on the ground" information is required; often more than any single program can afford to gather. An effective systems approach requires cross organizational collaboration in the design and operation of information systems suitable for landscape level restoration and protection of the Nation's rich biodiversity. Information systems might best be developed in concert with the development of broadly applicable adaptive management plans and models that organize information into simulations useful for analysis of systems sensitivity to variation in least known factors and indication of the most important research gaps. The Corps cannot and should not do this alone, but as one of the acknowledged leaders in ecosystem restoration, it could improve and cement its reputation by taking more of an initiative and by investing more in the knowledge of its employees.

The new federal guidance for water resources planning attempts to resolve one aspect of the collaboration problem. It requires each federal agency that affects water resources in any significant way to write its internal guidance consistent with the new federal guidelines. For the first time, the federal guidance applies to programs and perhaps to certain project operations (regulatory programs are exempt). The new federal guidance reflects the trend toward more policy emphasis on a more spatially and temporally integrated systems approach to planning and on ecosystem protection and restoration. It also emphasizes a focus on identifying ecosystem services clearly (but does not acknowledge differences between use and nonuse services). Arguably above all else, the systems approach is a state of mind. Personnel who either cannot or refuse to thing systemically may not be able to adapt. The choice of new employees is a critical factor in determining future adaptability. It takes time to develop systems oriented personnel. Whether or not agencies plan well enough for an effective systems approach depends largely on that and other challenges. Because of tight funding, knowledge limits, time constraints, and internal politics, the new guidance for each agency's project and program planning is most likely to fall considerably short of the ideal. In this social-economic environment, significant clarification of the ecosystem restoration objective in the new Corps planning regulations is in serious doubt.

The systems approach probably has its greatest chance for success in large regional rehabilitation programs now underway and, possibly, in future programs. The number of these large programs

proposed for comprehensive planning has increased significantly since the 1996 WRDA was passed. Many of the Corps projects favored by the President's budget are parts of such programs. Making ecosystem restoration work within the context of regional programs will require more systems planning expertise and technical guidance than the Corps or any other organization now has on hand. The sufficiency of personnel knowledge is worrisome. Interests favorable to a regional program approach could wane if competencies are questioned, forcing a return to the old project-by-project subsystem approach. Nonfederal interests in individual projects also could wane if public sentiment supports more rigorous screening of inferior projects.

But the long-term dominance of regional programs is not necessarily assured. Their enthusiasm for regional program support could diminish as new members of Congress come to realize that much of the budget available for improved asset management in their districts has been co-opted in regional programs with 30 to 40 year planning horizons. Returning more to the old project-centered approach would cause regional program schedules to stretch out so long that restoration objectives may not be achievable before desired ecological heritage and resource use is greatly degraded or entirely lost. A fear among some environmentalists is that regional restoration programs will be subverted to serve local water supply, flood risk management, navigation, and tourism needs and then dropped before the restoration objective that justified the investment is achieved. That has been an issue raised for the Everglades restoration program (Grunwald 2006).

A political dynamic set up over the last three decades shows little sign of change in future decades. The major changes in the Corps came about as a consequence of changes in law and executive actions. A major change in Corps programmatic funding for systems planning and management is one change that could have a significant effect. But the prospects are slim. Few outside changes appear to be on the horizon that could shape the Corps culture and process in a major way. If change does not come from within, to the extent it can, Corps culture and process are likely continue much as they have. Even with a concerted effort to address issues mentioned here the change to a much more effective ecosystems approach to ecological heritage restoration and protection is likely to take decades.

Summary Outlook for the Corps Program

The results of this outlook analysis are consistent with a recent NRC (2011b) conclusion that the Corps Civil Works Program, while "providing some degree of ecological restoration" in modified aquatic and riparian environments, will be less oriented toward implementation of new projects and more focused on project O & M, rehabilitation, and upgrading existing infrastructure. The major variable in the Corps ecosystem restoration outlook is the extent to which NER investment is supplanted by the repair and improvement of NED projects. This depends on priorities perceived by Congress and the President, but may also depend on how clear the signs of Corps commitment to NER are to nonfederal agencies and NGOs who are concerned about biodiversity loss. It also depends on how rigorously the Corps evaluates further investment in NED projects and on how well it communicates the tradeoffs between NED and NER projects. Program objectives and achievement measurements need to be transparently clear or scarce funds may be diverted from biodiversity maintenance to improved recreation, commercial fisheries, urban development, flood risk management, or other water resource uses. Diversion of scarce funds to unintended purposes may sustain program success as judged by the

designs of some nonfederal sponsors and Corps project managers, but not by the objective of the program.

For the last three decades at least, the budget has been stabilized between forces originating out of the perceived need to address many water resources problems and the perceived need to hold down federal discretionary spending. For much of that time, the Corps has recommended many more projects for study and construction than the budget allowed while also warning that old infrastructure needed repair, rehabilitation, or decommissioning. The ecosystem restoration and protection authority of 1996 contributed to the increased demand for new projects in response to a public interest in restoring unsustainable ecological heritage to a sustainable state and protecting it from destructive use after nearly two centuries of accumulated impact. But the total annual budget was not increased. Doubts about Corps motives have persisted since the 1996 authority. Federal water resources development agencies have a long history defending their public investment recommendations against claims of agency bias toward bureaucratic self-perpetuation. The Corps has to more forcefully make the case that it has changed through its actions and communications to assure future program success.

The Corps has learned much in nearly two decades of experience with its newest mission, but still remains stressed by the challenges, including continued confusion over what the mission means. Despite limited funding and increasing awareness of the depth of the challenge, finding ways to continue to improve and gain trust in the environmental community is critical to sustaining the program. One approach to Corps improvement may lie in its proud history of scientifically based engineering, periodically blemished, but, by and large, well performed within the constraints of what it does best—physical management of waterway shape and flow (Clarke and McCool 1996). Advice from within and outside the Corps has emphasized sticking to its engineering strengths and improving them (e.g., NRC 2004c). But, although very important, those strengths alone are not enough to achieve success.

Perhaps the Corps should never have been authorized to lead ecological restoration projects and it may have been better placed in support of other lead agencies. But what could or should have been is not how the authority played out. The Corps is the responsible party for all aspects of ecological restoration; not just the hydrology and geomorphology. It recognizes its weaknesses in ecological acumen, but has not fully committed to overcoming them for fear of risking its more traditional competencies. To succeed, the Corps must invest more in ecologically trained personnel who are well schooled in and aware of the recent paradigm shifts of ecological restoration ecology. The recent Congressional emphasis on addressing old problems before investing much more in new projects probably contributes to this caution. Building on the historic Corps strength in managing water resource use problems with structural engineering may favor a bias toward Corps recommendation of resource-use improvements over restoring and protecting ecological heritage.

Another unfavorable factor is the increasing awareness of the uncertainties associated with the program, and the need for long-term adaptive management. Traditional problems seem more tractable to many Corps employees. Because the adaptive management of the project to establish and sustain objective achievement becomes the responsibility of the nonfederal sponsor, adaptive management planning and partnership agreements must be clear about those responsibilities.

Some nonfederal sponsors would not agree to the obligation, once uncertainty about the objective of the ecosystem restoration program is eliminated. The tradeoff considerations and possible biases would also be clearer to stakeholders. Because the project will remain a federally funded project, the Corps must assure the project objective continues to be achieved for the national public. The 10-year limit placed on Corps monitoring is a force operating against this principle.

A restoration program area more explicitly focused on restoring presently unsustainable aspects of the Nation's rich ecological heritage may lose the interest of some potential nonfederal sponsors, resulting in a smaller but possibly more effective program area, if Corps competencies are up to the task. This may relieve competitive pressure on Corps needs, especially if restoration objectives can be effectively integrated into major rehabilitation of existing projects, but the Corps systems planning and ecological acumen need improvement to meet the program objectives.

The Corps has been characterized as one of the most adaptable and successful federal agencies to serve the United States (Clarke and McCool 1996). Yet, like all other environmental agencies, it faces a difficult future challenged by growing infrastructural problems, a public that has minimal insight, a Congress and President besieged with many pressing and contentious issues, environmental changes that grow in complexity, and never enough budget to meet all needs. Among the most difficult of its challenges is determining the proper balance to recommend between rehabilitation of resource use now versus restoration and preservation of a diverse ecological heritage for present and future generations. The Corps may only recommend decisions, but it has significant influence.

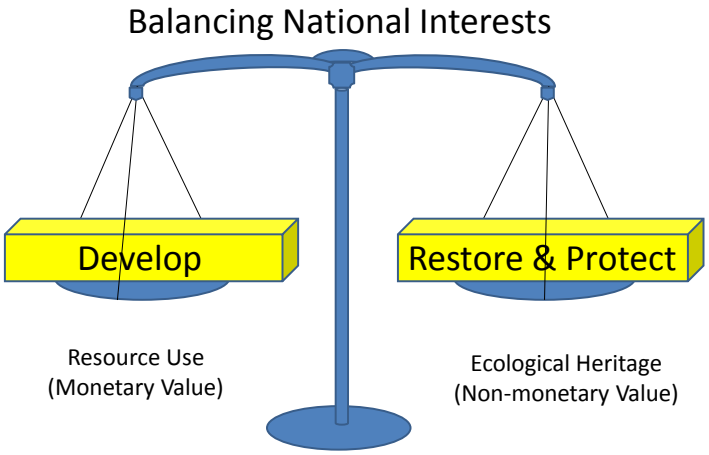

Figure 20. Balancing National Interests

Summary Points

1. Environmental trends confirm an increasing need for ecological restoration and protection of significant resources. Adverse environmental impact has grown rapidly to global proportion and increasingly threatens ecological sustainability. Despite improved impact mitigation by federal agencies, climate change is likely to interact with land use alterations to continue past impact trends over the next several decades. The integrity of the Nation's native biodiversity is eroding rapidly. Freshwater species loss rate is particularly high in large warm-water rivers of the southern United States. Reversing decline requires significant restoration and protection investment and a continuously adaptive approach to dealing with the many uncertainties.

2. The Corps is programmatically authorized to carry out ecosystem restoration and protection as long as EQ is cost-effectively improved and in the public interest. As described in NEPA, where the concept originated, EQ is improved when environmental resources are beneficially used and/or national heritage is preserved. In the interpretation offered here, the emphasis on protecting restored ecosystems for an indefinitely long period indicates that the EQ improvement objective is to restore and sustain the ecological heritage maintained in the Nation's biodiversity. In this assessment, the success of the program is judged by its contributions to the achievement of that objective.

3. Confusion over the restoration program-area objective and its achievement is common. Despite reflecting important aspects of the Corps restoration authority, including the expected national heritage preservation outcome of protection, the national heritage focus is not clearly articulated in PGN statements of program objective, in the objectives of numerous projects, or in descriptions of the mission directed at the general public. This lack of clarity and the local focus of many nonfederal partners have contributed to inefficient achievement of the program's national objective and growing questions about program merits.

4. Budget allocation trends indicate increasing program-area competition for scarce funds as aging civil works infrastructure demands project repair and rehabilitation. Except for temporary supplemental funding, the Civil Works annual budget allocation trend has remained nearly flat for decades. A significant increase in Corps budget is unlikely without resolution of public deadlock over taxation and mandatory spending.

5. The budget for the restoration program grew rapidly at first, but leveled at about 10 percent of the total budget within a few years. The fraction planned in the context of multi-project regional programs has been growing and are likely to dominate restoration activities for several decades. New project funding outside existing programs has decreased markedly in recent years and is likely to remain relatively low over the next several decades, unless changes in Congress upset the status quo. The trends may assure a future role for the restoration program, but the heritage benefits often are unclear in plans and national interests may be less effectively served than could be with a clearer sense of

program area objective. The projects that have been installed are too recently implemented to judge success based on heritage restoration and protection.

6. If a restoration program area is more explicitly focused on securing the Nation's ecological heritage, the program will most likely lose the interest of numerous potential nonfederal sponsors, resulting in a smaller but possibly more effective program area, if Corps competencies are up to the task. This may relieve competitive pressure on the full suite of water resources needs, especially if restoration objectives can be effectively integrated into major rehabilitation of existing projects, but Corps systems planning and ecological acumen need improvement to more fully succeed.

7. Sustaining restoration competency in the Corps requires considerable investment. The Corps has not invested enough in its ecological personnel. Ecological restoration paradigms have shifted markedly since the last planning guidance was written in response to many influences, but particularly recognition of climate change. Old concepts of ecosystem restoration are in doubt. Policy and technical guidance need to reflect those changes to increase prospects for success.

8. When effectiveness is gauged by increased security of the Nation's ecological heritage, positive forces and trends operating to increase the ecosystem restoration program success over the next several decades include:

    a. Increasing scientific awareness of threats to native aquatic biodiversity;
    b. Growing public awareness of human impact on aquatic environments;
    c. Growing recognition of the insufficiency of protection strategies alone;
    d. A two-thirds federal contribution to project planning and implementation costs;
    e. Some continued Corps awareness of a need to clarify the restoration program objective and achievement measurement;
    f. Improved Corps bridge building with other mission-oriented organizations;
    g. Increased Corps emphasis on a collaborative systems approach to planning;
    h. Increasing Corps effort to improve and integrate ecological, economic, and engineering knowledge; and
    i. Increasing professed dedication of the Corps to EQ improvement and protection.

9. Forces and trends that continue to operate against the long-term success of the ecosystem restoration program over the next several decades are more numerous and include:

    a. Growing competition for limited public funding;
    b. Continuing confusion over ecosystem restoration program purpose, objective and metrics for achievement and growing questions about program merits;
    c. Continued pressure to apply the program to problems inconsistent with policy;
    d. Poor documentation of program success (in part because of unclear objectives);
    e. Uncertainty and risks associated with global climate change and other effects;
    f. Continuing public criticism of the Corps restoration program;
    g. Persistent Corps predisposition for project-centered engineering and NED;
    h. Possible capping of the ecosystem restoration budget at a lower level;

i. Possible decreased federal contributions to costs or conversion to grants;
j. Insufficient ecological thinking and technical guidance needed for success;
k. Continued legal constraints and cultural attributes that impede full Corps embracement of long term sustainability and heritage maintenance; and
l. Possible expansion of project priorities that favor projects with greater use value over projects with high heritage maintenance value.

10. The success of the ecosystem restoration program in protecting and restoring ecosystem integrity for an ecological heritage depends on some things the Corps can control, other things it may influence, and still other things beyond its control. The Corps:
    a. can further improve program restoration objectives, benefits metrics, guidance for integrated and collaborative systems planning and operations, cooperative interactions with other organizations, personnel skills in appropriate disciplines, mission communication to the public, and, with time, restoration success stories;
    b. may influence new authorities favoring a nationally coordinated systems approach to addressing national biodiversity preservation priorities, more effective integration of resource management across agencies, and increased systems-oriented research and development; and
    c. has little or no control over large-scale forces and trends in the economy, society, and environment that could influence public priorities and future funding of the ecosystem restoration program.

11. This report highlights the uncertainties in the program-area outlook. Managing project and program uncertainty requires a willingness to increase investment in continuous monitoring of events, trends and forces; assessment of alternative scenarios and approaches; and proactive planning for adaptation to change as some uncertainties are resolved.

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The Institute for Water Resources (IWR) is a U.S. Army Corps of Engineers (USACE) Field Operating Activity located within the Washington DC National Capital Region (NCR), in Alexandria, Virginia and with satellite centers in New Orleans, LA; Davis, CA; Denver, CO; and Pittsburg, PA. IWR was created in 1969 to analyze and anticipate changing water resources management conditions, and to develop planning methods and analytical tools to address economic, social, institutional, and environmental needs in water resources planning and policy. Since its inception, IWR has been a leader in the development of strategies and tools for planning and executing the USACE water resources planning and water management programs.

IWR strives to improve the performance of the USACE water resources program by examining water resources problems and offering practical solutions through a wide variety of technology transfer mechanisms. In addition to hosting and leading USACE participation in national forums, these include the production of white papers, reports, workshops, training courses, guidance and manuals of practice; the development of new planning, socio-economic, and risk-based decision-support methodologies, improved hydrologic engineering methods and software tools; and the management of national waterborne commerce statistics and other Civil Works information systems. IWR serves as the USACE expertise center for integrated water resources planning and management; hydrologic engineering; collaborative planning and environmental conflict resolution; and waterborne commerce data and marine transportation systems.

The Institute's Hydrologic Engineering Center (HEC), located in Davis, CA specializes in the development, documentation, training, and application of hydrologic engineering and hydrologic models. IWR's Navigation and Civil Works Decision Support Center (NDC) and its Waterborne Commerce Statistical Center (WCSC) in New Orleans, LA, is the Corps data collection organization for waterborne commerce, vessel characteristics, port facilities, dredging information, and information on navigation locks. IWR's Risk Management enter is a center of expertise whose mission is to manage and assess risks for dams and levee systems across USACE, to support dam and levee safety activities throughout USACE, and to develop policies, methods, tools, and systems to enhance those activities.

Other enterprise centers at the Institute's NCR office include the International Center for Integrated Water Resources Management (ICIWaRM), under the auspices of UNESCO, which is a distributed, intergovernmental center established in partnership with various Universities and non-Government organizations; and the Conflict Resolution and Public Participation Center of Expertise, which includes a focus on both the processes associated with conflict resolution and the integration of public participation techniques with decision support and technical modeling. The Institute plays a prominent role within a number of the USACE technical Communities of Practice (CoP), including the Economics CoP. The Corps Chief Economist is resident at the Institute, along with a critical mass of economists, sociologists and geographers specializing in water and natural resources investment decision support analysis and multi-criteria tradeoff techniques.

The Director of IWR is Mr. Robert A. Pietrowsky, who can be contacted at 703-428-8015, or via e-mail at: robert.a.pietrowsky@usace.army.mil. Additional information on IWR can be found at: http://www.iwr.usace.army.mil. IWR's NCR mailing address is:

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