



**US Army Corps
of Engineers®**
Engineer Research and
Development Center



A Systems Approach to Ecosystem Adaptive Management

A USACE Technical Guide

J. Craig Fischenich, Sarah J. Miller, and Andrew J. LoSchiavo

November 2019



The U.S. Army Engineer Research and Development Center (ERDC) solves the nation's toughest engineering and environmental challenges. ERDC develops innovative solutions in civil and military engineering, geospatial sciences, water resources, and environmental sciences for the Army, the Department of Defense, civilian agencies, and our nation's public good. Find out more at www.erdc.usace.army.mil.

To search for other technical reports published by ERDC, visit the ERDC online library at <http://acwc.sdp.sirsi.net/client/default>.

A Systems Approach to Ecosystem Adaptive Management

A USACE Technical Guide

J. Craig Fischenich and Sarah J. Miller

*Environmental Laboratory
U.S. Army Engineer Research and Development Center
3909 Halls Ferry Rd.
Vicksburg, MS 39180*

Andrew J. LoSchiavo

*Jacksonville District
U.S. Army Corps of Engineers
701 San Marco Blvd
Jacksonville, FL 32207*

Final Report

Approved for public release; distribution is unlimited.

Prepared for U.S. Army Corps of Engineers
Washington, DC 20314-1000

Under Project number 476549

Abstract

Implementation guidance for Sections 2036 and 2039 of WRDA 2007 and Section 1161 of WRDA 2016 requires that ecosystem restoration projects either include appropriately scoped monitoring and adaptive management plans or provide sound justifications for why adaptive management is not warranted. Under adaptive management, decisions are based on the best available (yet often incomplete and imperfect) scientific data, information, and understanding, recognizing uncertainties that introduce risks to the achievement of goals and objectives. Revision to management actions based upon information derived from ongoing monitoring and evaluation is possible. This guide provides an overview of adaptive management practice, emphasizing underpinning principles. An approach to determine the need for and development of adaptive management plans is presented, and the implementation of ecosystem restoration projects under adaptive management is presented.

DISCLAIMER: The contents of this report are not to be used for advertising, publication, or promotional purposes. Citation of trade names does not constitute an official endorsement or approval of the use of such commercial products. All product names and trademarks cited are the property of their respective owners. The findings of this report are not to be construed as an official Department of the Army position unless so designated by other authorized documents.

DESTROY THIS REPORT WHEN NO LONGER NEEDED. DO NOT RETURN IT TO THE ORIGINATOR.

Contents

Abstract.....	ii
Figures and Tables.....	v
Preface	vii
Unit Conversion Factors.....	ix
Abbreviations.....	x
1 Introduction	1
1.1 Purpose and use.....	1
1.2 Background	2
1.3 Adaptive management defined	3
1.4 Types of adaptive management.....	5
1.4.1 Passive adaptive management	6
1.4.2 Active adaptive management.....	7
1.4.3 Collaborative adaptive management.....	8
1.4.4 Contingency plans.....	9
1.5 Why adaptive management?	9
2 Adaptive Management Fundamentals.....	11
2.1 USACE requirements for adaptive management.....	11
2.1.1 Criteria for determining the applicability of adaptive management to a project	12
2.1.2 Issues of scale.....	15
2.2 The adaptive management cycle.....	17
2.2.1 Traditional adaptive management cycle.....	17
2.2.2 Modification of the adaptive management cycle for the USACE.....	19
2.2.3 Integration of adaptive management with the USACE planning and project management processes	20
2.3 Monitoring in relation to USACE planning guidance.....	27
2.4 Alternative forms of adaptive management	28
3 Developing an Adaptive Management Plan	31
3.1 The Adaptive Management Team	31
3.2 Outside expertise and facilitation.....	33
3.3 Independent external review.....	33
3.4 Development phase	34
3.4.1 Assess.....	35
3.4.2 Design.....	47
3.5 Planning for the implementation phase of adaptive management.....	49
3.5.1 Monitoring	50
3.5.2 Evaluation.....	60

3.5.3	Governance	63
3.5.4	Data management, communications and reporting	75
4	Summary and Key Take-Away Points	77
4.1	Key points.....	78
4.2	Enabling characteristics for effective adaptive management	83
4.3	Benefits of adaptive management	85
	Glossary.....	87
	References.....	98
	Appendix A: Implementation Guidance Related to Monitoring and Adaptive Management	105
	Appendix B: Example USACE ecosystem restoration programs and projects	106
	Appendix C: Regulations Relevant to Adaptive Management Applications	118
	Appendix D: Support Organizations and Capabilities	121
	Appendix E: Adaptive management considerations for program and project implementation	126
	Report Documentation Page	

Figures and Tables

Figures

Figure 1. Decision rubric to assess potential for application of adaptive management	13
Figure 2. Basic steps of traditional adaptive management (e.g., Walters 1986). This diagram includes “double-loop” learning reflecting institutional learning, described by Williams and Brown (2018).	18
Figure 3. Adaptive management cycle modified for compatibility with USACE ecosystem restoration and mitigation projects.	20
Figure 4. USACE risk-informed planning process with the six traditional planning steps shown (from Yoe 2017).	21
Figure 5. Portion of the adaptive management cycle expanding Steps 1 and 2 to emphasize the USACE planning process.....	22
Figure 6. Crosswalk of the six traditional planning steps with the steps in developing the adaptive management plan.	25
Figure 7. The USACE risk management model.	26
Figure 8. Example of a conceptual ecological model (note that this is just the graphical depiction of the model – an accompanying narrative describes the components and linking processes).	38
Figure 9. The design stage often involves development of experimental designs. In this example, the number of years of monitoring required as a function of the number of project/control pairs implemented (i.e. # of Randomized Control Trials [RCT]) in order to achieve a 0.8 and a 0.9 probability of detection is computed.....	49
Figure 10. Schematic of the Implementation Phase for USACE adaptive management.	50
Figure 13. Example of a general decision process for USACE adaptive management projects.	71
Figure 14. Example of a recurring annual timeline involving engagement with agencies and stakeholders (adapted from the science and adaptive management plan for the MRRP).....	75
Figure 15. A well-constructed adaptive management plan should make a clear connection between the plan components.....	80
Figure 16. Example for an outline for an adaptive management plan.....	82
Figure E1. Considerations for implementing adaptive management.....	128
Figure E2. ProACT and Adaptive Management (Source: Runge 2011).	133
Figure E3. Example of online monitoring and assessment results in a “report card” format (from the CRMS website).....	151

Tables

Table 1. Steps and tasks in the USACE adaptive management process.	23
Table 2. Example linking objectives, metrics, targets, decision criteria (triggers), and contingency plans (adapted from the Blind River Project for LCA).....	46

Table 4. Example table of information to guide development of a monitoring and data management plan.	59
Table 5. Components of a decision-making process (Rubenstein 1975).	72
Table 6. Characteristics of an adaptive management strategy and associated benefits.	86
Table B1. Summary of major ecosystem restoration plans and relevance of adaptive management.	106
Table B2. Additional projects or programs employing adaptive management.	114
Table E1. Illustrative Consequence Table Source (USACE Planning Primer).	129
Table E2. Modified Illustrative Consequence Table; differences from Table 9 shown in bold.	130
Table E3. Risk Register Example - Loxahatchee River Watershed Restoration Project.	139
Table E4. Factors affecting adaptive management success adapted from a summary compiled by Marmorek et al. 2006.	153
Table E5. Summary of factors that have been identified to enable or inhibit effective governance of adaptive management programs (adapted from the science and adaptive management plan for the MRRP).	155

Preface

Adaptive management is a powerful tool for managing risks on ecosystem restoration and mitigation projects. When developed with stakeholders, it can provide a framework for collaboratively moving forward with projects and watershed-scale programs in the face of uncertainty (and, potentially, disagreements). Adaptive management builds on information from incremental changes, reduces uncertainties, and facilitates risk communication in planning and operating sustainable systems. It ultimately helps ensure that objectives are met.

The concept of “learning by doing” -- as adaptive management is often described -- is intuitively simple. However, a more apt characterization would be “learning by doing, monitoring, evaluating results, making difficult decisions, adjusting if necessary, and repeating.” The appealing nature of adaptive management as a theoretical construct belies the sometimes challenging and often complex realities of its implementation in practice. These realities underscore the need for guidance on adaptive management that is informed by its practice and the lessons learned in application.

Adaptive management plays an important role in the planning and implementation of U.S. Army Corps of Engineers (USACE) management actions. Its widespread application underscores the need for a competent, effective, and straightforward approach in the design and implementation of adaptive management across diverse USACE programs and projects under its ecosystem restoration authorities, and for the mitigation of fish and wildlife impacts from other business lines. This Adaptive Management Technical Guide was prepared to help agency practitioners and their partners meet this need.

This report was initially drafted by the USACE Adaptive Management Product Delivery Team. The team consisted of Mr. Ken Barr (lead and core team liaison), USACE, Rock Island District; Ms. Tomma Barnes, USACE, New Orleans District; Mr. Steve Bartell, E2 Consulting Engineers Inc.; Ms. Marci Johnson, USACE, Portland District; Mr. Craig Fisichenich, USACE, Engineer Research and Development Center, Environmental Laboratory; Mr. Elmar Kurzbach, USACE, Jacksonville District (retired); Mr. Andy LoSchiavo, USACE, Jacksonville District; Mr. Richard Thomas, USACE, Great Lakes and Ohio River Division; and Mr. Bradley Thompson,

USACE, Omaha District. Subsequent revision and updated content includes selected materials provided by Mr. David Marmorek, Aquatic Ecologist for ESSA Technologies, and Dr. Barry Noon, Conservation Ecologist at Colorado State University. Technical reviews and input from Dr. Dennis Murphy, University of Nevada, Reno, Mr. Graham Long, Compass, Dr. Kathryn McCain, USACE St. Louis District, and Dr. Mick Porter, USACE Albuquerque District, are gratefully acknowledged. The Chief of Engineers' Environmental Advisory Board (EAB) provided critical input based on the draft and discussions with USACE personnel engaged in adaptive management activities. Our sincere thanks for valuable contributions made by all participants in the Monitoring and Adaptive Management Workshops held in 2017 at the Albuquerque and St. Louis Districts and the USACE Institute for Water Resources, whose discussion of the Tech Guide informed approaches, organization and detail, particularly Mr. Brian Zettle, Ms. Jeanette Gallihugh, Mr. Jeff Trulick, Ms. Michelle Mattson, and Mr. Mark Matusiak. The final report addresses input from the Chief's EAB, Dr. Fred Sklar and Dr. Charles "Si" Simenstad, and HQUSACE.

The technical work was performed by the Ecological Resources Branch (CERD-EE-E) of the Ecosystem Evaluation and Engineering Division (CERD-EE), U.S. Army Engineer Research and Development Center, Environmental Laboratory (ERDC-EL). At the time of publication, Dr. Jen Seiter-Moser was Chief, CEERD-EE-E, and Mr. Mark Farr was Chief, CEERD-EE. The Technical Director was Dr. Al Cofrancesco. The Deputy Director of ERDC-EL was Dr. Jack Davis and the Director was Dr. Ilker Adiguzel.

This was conducted under Project Number 476549.

COL Teresa A. Schlosser was the Commander of ERDC, and Dr. David W. Pittman was the Director.

Unit Conversion Factors

Multiply	By	To Obtain
Acres	4,046.873	square meters
acre-feet	1,233.5	cubic meters
cubic feet	0.02831685	cubic meters
cubic inches	1.6387064 E-05	cubic meters
cubic yards	0.7645549	cubic meters
gallons (U.S. liquid)	3.785412 E-03	cubic meters
Hectares	1.0 E+04	square meters
Inches	0.0254	meters
Microns	1.0 E-06	meters
miles (U.S. statute)	1,609.347	meters
ounces (mass)	0.02834952	kilograms
ounces (U.S. fluid)	2.957353 E-05	cubic meters
pints (U.S. liquid)	4.73176 E-04	cubic meters
pints (U.S. liquid)	0.473176	liters
pounds (mass)	0.45359237	kilograms
pounds (mass) per cubic foot	16.01846	kilograms per cubic meter
pounds (mass) per cubic inch	2.757990 E+04	kilograms per cubic meter
pounds (mass) per square foot	4.882428	kilograms per square meter
pounds (mass) per square yard	0.542492	kilograms per square meter
quarts (U.S. liquid)	9.463529 E-04	cubic meters
Slugs	14.59390	kilograms
square feet	0.09290304	square meters
square inches	6.4516 E-04	square meters
square miles	2.589998 E+06	square meters
square yards	0.8361274	square meters
tons (long) per cubic yard	1,328.939	kilograms per cubic meter
tons (2,000 pounds, mass)	907.1847	kilograms
tons (2,000 pounds, mass) per square foot	9,764.856	kilograms per square meter
Yards	0.9144	meters

Abbreviations

AAMR	Annual Adaptive Management Report
AAR	After Action Report
AM	Adaptive Management
AMT	Adaptive management team
ANOVA	Analysis-of Variance
BA	Before-After
BACI	Before-After-Control-Impact
BiOp	Biological Opinion
CAP	Continuing Authorities Program
CEM	Conceptual Ecological Model
CEP	Critical Engagement Point
CEQ	Council on Environmental Quality
CERP	Comprehensive Everglades Restoration Plan
CESU	Cooperative Ecosystem Studies Unit
CI	Confidence Interval
CRCIP	Columbia River Channel Improvement Project
CWA	Clean Water Act
DOI	Department of the Interior
DQO	Data Quality Objectives
EA	Effects Analysis
EAB	Environmental Advisory Board
ECR	Environmental conflict resolution
EIS	Environmental Impact Statement
ER	Engineering Regulation
ERDC	Engineer Research and Development Center
ESA	Endangered Species Act
ESC	Executive Steering Committee
FACA	Federal Advisory Committee Act
FWG	Federal Working Group
FWS	Fish and Wildlife Service
FY	Fiscal Year
HQ	Headquarters
HQUSACE	Headquarters of the U.S. Army Corps of Engineers

IJC	International Joint Commission
ISAP	Independent Science Advisory Panel
LCA	Louisiana Coastal Areas
MRRP	Missouri River Recovery Program
NEPA	National Environmental Policy Act
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NRC	National Research Council
O&M	Operation and Maintenance
OMRRR	Operations, Maintenance, Repair, Replacement, and Rehabilitation
PA	Programmatic Agreement
PCX	Planning Center of Expertise
PDT	Project Delivery Team
PgM	Program Manager
PIR	Project Implementation Report
PM	Project Manager
PMBP	Project Management Business Process
ProACT	Problem Definition, Objectives, Alternatives, Consequences, Tradeoffs
QA/QC	Quality Assurance and Quality Control
QAPP	Quality Assurance Project Plan
R&D	Research and development
ROD	Record of Decision
ROPE	Reservoir Operations and Planning Evaluation
RPA	Reasonable and Prudent Alternative
RPM	Reasonable and Prudent Measure
RPMA	Recovery Priority Management Area
S&T	Science and technology
SDM	Structured Decision Making
SMART	Specific, Measurable, Attainable, Risk Informed, Timely
SP	Strategic Plan
T&E	Threatened and Endangered
TBD	To Be Determined
TNC	The Nature Conservancy

UMR	Upper Mississippi River
USACE	United States Army Corps of Engineers
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
WG	Work Group
WRDA	Water Resources Development Act

1 Introduction

1.1 Purpose and use

The primary purpose of this technical guide is to present an operational definition of adaptive management and describe a scalable approach to developing and implementing adaptive management plans for USACE ecosystem restoration programs and projects. The guide is intended to support and be congruent with current USACE implementation guidance related to monitoring and adaptive management, including guidance regarding section 2036 of WRDA 2007, section 1161 of WRDA 2016, SMART planning, and risk-informed decision making. It is intended to provide a foundation for adaptive management that can mature and conform to future guidance. The guide is somewhat aspirational, describing practices that are not yet common because adaptive management practice is relatively new, both within the USACE and more generally within the practice of ecosystem restoration.

Adaptive management is an exciting new paradigm for the USACE because it can increase the likelihood of project success, especially in situations where the outcomes of management actions or decisions have a relatively high degree of uncertainty. Indeed, it is the only risk-management tool available after a project's implementation. Adaptive management can be used to enhance the flexibility, robustness, and resilience of USACE projects and programs. The collaborative form of adaptive management promotes conflict resolution among agencies and stakeholders, scientists and managers while moving the state of science and understanding of ecosystem restoration forward in a deliberate way.

Adaptive management applies throughout the full life cycle of USACE programs and projects. Initial consideration of adaptive management begins with the traditional planning process and, except in cases where adaptive management is determined to be unnecessary (Section o), continues through the construction, operation, and maintenance phase of a project. Adaptive management accommodates (often necessitates) iterative planning, design, and implementation cycles. The adaptive management process typically terminates when monitoring and assessment results demonstrate that goals and objectives have been

achieved or are imminent and additional adjustments are no longer needed or anticipated.

This guide is intended for USACE program and project managers, project delivery team (PDT) members, and technical staff involved in efforts related to managing ecosystem restoration, fish, wildlife, and wetland mitigation.

Chapters 1 and 2 provide important context and outline the fundamental aspects and scales of adaptive management; these chapters are relevant to all readers. Individuals charged with planning and implementing adaptive management will find guidance for the development of adaptive management plans in Chapter 3. Appendix C addresses adaptive management implementation, related challenges, and available support.

1.2 Background

USACE civil works missions have historically placed an emphasis on post-project inspections in support of operations and maintenance (O&M) rather than on monitoring and evaluation of performance outcomes relative to project objectives. However, USACE Implementation Guidance for Section 1161 (Monitoring ecosystem restoration) of the 2016 Water Resources Development Act, and Section 2036 (Mitigation for fish and wildlife and wetlands losses) of the 2007 Water Resources Development Act (WRDA; Appendix A) require monitoring sufficient to evaluate ecosystem restoration and mitigation success. Importantly, these guidance documents stipulate the need for adaptive management (or contingency plans) for ecosystem restoration projects and mitigation projects. A principal objective of this Adaptive Management Technical Guide is to provide a comprehensive, defensible, and technical approach for developing and implementing adaptive management in support of the USACE Implementation Guidance and across all relevant USACE missions.

Adaptive management was designed to facilitate effective environmental decision making under circumstances involving incomplete knowledge and scientific uncertainty (Walters 1997). USACE programs and projects often require management decisions to be made under conditions of substantial variability and uncertainty, which carries some risk. Historically, decision-making processes defined by other federal regulatory requirements, for example, the Endangered Species Act (ESA) and the Clean Water Act (CWA), have been relatively inflexible and

insensitive to variability and uncertainty. Changes have occurred with ESA consultations, which now frequently demand adaptive management (e.g., the Missouri River and Columbia River system descriptions in Appendix B). Adaptive management approached in partnership with regulatory agencies and interested stakeholders can generate information for developing novel management options and improved decision-making processes that recognize and incorporate the implications of uncertainty.

1.3 Adaptive management defined

Before describing a methodology for undertaking adaptive management, it is necessary to define what adaptive management is and what it is not. A clear definition is required because both confusion and genuine disagreement exists regarding the nature and scope of adaptive management due to its broad and nuanced application, as well as its continued evolution as a concept and practice. In this section, some of the subtleties and complexities of the language in the adaptive management literature are highlighted and a definition consistent with the USACE's application is provided. We also emphasize the fundamental tenets of adaptive management that make it a powerful tool for application to USACE restoration and mitigation efforts.

ADAPTIVE MANAGEMENT

A formal, science-based approach to risk management that permits implementation of actions despite uncertainties. Knowledge gained from monitoring and evaluating results is used to adjust and direct future decisions.

The theory of adaptive management has been around since at least the early 1900s (Taylor 1911), but it was first postulated as a conservation and resource management tool by Walters and Hilborn (1978) and Walters (1986). It was subsequently pursued in the context of harvesting, particularly for waterfowl and fish, and more recently has been explored in numerous areas of environmental management (Hauser and Possingham 2008). The U.S. Department of the Interior developed guidance for identifying the appropriate settings and use of adaptive management within its agencies (Williams et al. 2009); however, the USACE has not previously done so.

The following paragraph presented in *Adaptive Management for Water Resources Project Planning* (National Research Council 2004) provides the

conceptual basis for adaptive management used in developing this USACE technical guide:

“Adaptive management promotes flexible decision making that can be adjusted in the face of uncertainties as outcomes from management actions and other events become better understood. Careful monitoring of these outcomes both advances scientific understanding and helps adjust policies or operations as part of an iterative learning process. Adaptive management also recognizes the importance of natural variability in contributing to ecological resilience and productivity. It is not a ‘trial and error’ process, but rather emphasizes learning while doing. Adaptive management does not represent an end in itself, but rather a means to more effective decisions and enhanced benefits. Its true measure is in how well it helps meet environmental, social, and economic goals, increases scientific knowledge, and reduces tensions among stakeholders.”

For the purposes of this guide, adaptive management is defined as a formal, science-based, risk management strategy that permits implementation of actions despite uncertainties. Knowledge gained from monitoring and evaluating results is used to adjust and direct future decisions. Simply stated, adaptive management is learning while doing in the face of uncertain outcomes.

Regardless of source, certain characteristics are common to most definitions of adaptive management (Walters 1986, Williams et al. 2009, Fischenich et al. 2012). Adaptive management involves the accumulation of understanding over time (that is, learning) and adjustment of management decisions over time (that is, adaptation) to better achieve project goals and objectives. It demands the clear statement of objectives, identification of management alternatives, predictions of management consequences, and recognition of uncertainties. Stakeholder engagement, monitoring of resource response, and modeling are obligatory, as is a governance process that ensures new knowledge is operationalized through decision making. None of these activities by themselves are sufficient to make a decision process adaptive; all must be present in a framework that is tailored to the decision needs.

Adaptive management is a science-based management approach, and scientific knowledge and methods support adaptive management in several important ways:

- Current scientific understanding can be used to help formulate the initial problem statement and planning alternatives as management-relevant hypotheses that can be evaluated through implementation and monitoring.
- Science can be used to translate conceptual models into operational models that in turn can be used to forecast the expected outcomes (benefits, costs, and less-quantifiable risks and benefits) of planning alternatives.
- Implementing management decisions as scientifically rigorous experiments can generate monitoring data and information that can be used to reduce uncertainties associated with future planning.
- Science-based assessments of sensitivity and uncertainty can be used to design monitoring programs that target key sources of uncertainty to improve management capabilities.

Adaptive management is a forward-looking process that unfolds in an anticipated manner; it is not an ad hoc, trial-and-error, or wait-and-see approach to management. The focus of adaptive management is not research per se. Rather, the primary objective of adaptive management is the accumulation of reliable knowledge toward improved and informed decision making (Lancia et al. 1996). However, research can be an important compliment to adaptive management, offering an efficient, focused means for addressing specific uncertainties (particularly where a large number of variables affect outcomes and controlled experiments in a laboratory or mesocosm are needed to obtain response functions).

1.4 Types of adaptive management

Adaptive management approaches have mainly been classified as either passive or active (Parma et al. 1998). The dichotomy between active and passive adaptive management has been discussed widely in relation to ecosystem management, although not without confusion (Westgate et al. 2013). Either approach may be appropriate; in practice a continuum of strategies involving components of both may be utilized, particularly on large adaptive management programs. This section also introduces “collaborative” adaptive management as an evolving approach that can be employed in conjunction with either active or passive adaptive

management. Contingency planning is also discussed in relation to adaptive management.

1.4.1 Passive adaptive management

Passive adaptive management has been defined in several different ways (e.g. Walters 1981; Parma et al. 1998; Williams 2001; Pearsall et al. 2005) and we use Williams' (2001) definition, where learning is not accounted for explicitly in determining the optimal management strategy. Model updating and learning can occur "passively" as the system is managed and are secondary to the achievement of the fundamental objectives.

Passive adaptive management addresses variability and uncertainty by using historical and existing information to develop cause-and-effect relationships between a management action and anticipated system responses to alternative management scenarios, optimally represented in the conceptual model (see section 3.4.1.2). The approach traditionally leads to selection of what is believed to be the "best" plan and design for achieving desired responses (e.g., ecological, hydrological, flood control). Actual system response is monitored and, if warranted, the management alternative(s) is adjusted to achieve goals and objectives. Knowledge gained from monitoring of the system or management action performance can be applied to other future projects. Many USACE applications of adaptive management conform to the description of passive adaptive management.

Advantages of passive adaptive management include undertaking management actions in light of current understanding, assessing the utility of the management actions in relation to achieving outcomes consistent with management goals and objectives, and learning to manage effectively by monitoring system conditions (including "natural" patterns of environmental variability). One limitation of this approach lies in developing management actions that are effective only within the range of conditions measured during the program or project. The passive approach might provide competent management capability over a reasonable range of system conditions, yet preclude the identification of management actions or decisions necessary to correctly respond to highly unusual or future circumstances that were not encountered during the project period.

In practice, passive adaptive management approaches have seldom demonstrated that learning has occurred. This has less to do with

weaknesses in the passive management strategy than with inadequate monitoring and assessment or a conviction to change when performance lags. Westgate et al. (2012) found that less than five percent of 1,336 articles citing “adaptive” and “management” identified through the ISI web of knowledge explicitly claimed to enact AM. These 61 articles cumulatively described 54 separate projects, but only 13 projects were supported by published monitoring data. Only five projects used the information gained from monitoring to make adjustments to the management actions. An analysis of 217 projects completed under USACE ecosystem restoration authorities from 1986 to 2014 showed results slightly better than found in the general literature; 49 percent had a monitoring plan, 19 percent had collected some data, but only five percent included adaptive management plans (Gardner et al. 2014).

1.4.2 Active adaptive management

In contrast, active adaptive management views management actions as purposeful experimental manipulations of the managed system (e.g., Walters and Holling 1990) designed to increase understanding of system responses in the short term and to increase the chances of achieving management goals and objectives in the long term through improved decision making. Active adaptive management addresses particularly uncertain or risky outcomes by designing management actions (i.e., field tests, physical models) to test multiple hypotheses about system responses to management. Evaluation of these hypotheses can help determine how to efficiently achieve a desired response to management (Gregory et al. 2006). Hypotheses may be tested concurrently, using several designs or operational plans to achieve goals and objectives. This approach requires a more scientifically rigorous experimental design to discriminate cause-and-effect relationships among the management options or questions that are tested. Active adaptive management is often referred to as “hypothesis-driven” or “experimental management” because it treats management actions as actual or de facto experiments.

Active adaptive management is implemented less often than passive adaptive management, but it offers highly reliable information, greater potential for rapid learning, and facilitates acquisition of new management skills (Taylor et al. 1997). Because it emphasizes knowledge as an intermediate objective toward fundamental management objectives, active adaptive management typically forgoes short-term returns for learning, resulting in improved understanding and maximized returns in the long

term (Walters et al. 1993). Active adaptive management is widely thought to be the strategy most likely to resolve situations involving high uncertainty and risk and to maximize returns over time.

Examples of an optimal active adaptive strategy in practice are rare, however, and some examples claiming to be active adaptive management have been similar to passive adaptive management in practice (Hauser and Possingham 2008). Additionally, trade-offs between short-term gains in understanding through system manipulation and experimentation must be weighed against the risk that such manipulations might produce substantial and irreversible (undesirable) changes that reduce the likelihood of achieving objectives or that foreclose on future management options.

1.4.3 Collaborative adaptive management

Collaborative adaptive management has emerged as an approach that combines collaborative planning with either passive or active adaptive management. The Collaborative Adaptive Management Network (Sims and Pratt-Miles 2011) defines collaborative adaptive management as:

... a systematic management paradigm that assumes natural resource management policies and actions are not static, but are adjusted based on the combination of new scientific and socioeconomic information. Management is improved through learning from actions taken on the ecosystem being affected. A collaborative adaptive management approach incorporates and links knowledge and credible science with the experience and values of stakeholders and managers for more effective management decision making.

Ecosystem restoration and resource management projects/programs typically present challenges related to information, coordination, communication, and understanding the results of management actions. Collaborative adaptive management is, in part, a response to these challenges. It seeks to merge science, collaboration, and a focus on outcomes. The emphasis on collaboration acknowledges that uncertainty, complexity, and change pertain not only to physical systems but also to human communities (Scarlett 2013).

While the USACE cannot abdicate its decision-making responsibility for actions within its authority, it routinely collaborates with stakeholders in

order to consider all views and information, improve the quality of decision making, and increase the perceived credibility, relevance, and legitimacy of the science used to inform decisions. Collaboration results in better adaptive management strategies and improves the likelihood of project success.

1.4.4 Contingency plans

A contingency plan is a strategy devised to address an undesirable outcome (or trajectory). Section 1116 of WRDA 2016 specifically addresses the use of contingency plans when describing adaptive management. While some implementation guidance has used the term contingency plan synonymously with adaptive management, they are technically different. In adaptive management, a project's effects are monitored and then a decision is made regarding whether to make an adjustment and what the nature of the adjustment should be. In contingency planning, the need for and nature of adjustments are predetermined.

Developing a contingency plan usually involves scenario analysis to identify potential circumstances and/or outcomes that might warrant a response and exploring potential adjustments to management actions under particular scenarios. Contingency plans are commonly employed for risk management, but can be utilized as part of an adaptive management strategy when decisions can be specified in advance based on measurable outcomes from the actions. This usually involves the application of decision criteria that, when met, trigger the implementation of a contingency plan. Contingency plans can help reduce uncertainty related to the outcome of an adaptive management program.

1.5 Why adaptive management?

Adaptive management provides a precautionary approach to acting in the face of uncertainty and generally improves the probability of project/program success. Love et al. (2018) identified several benefits from adaptive management: reduced long-term cost, decreased risk of failure, strengthened credibility, increased public trust, objective basis for decisions, chance to test before investing in larger projects, and improved restoration outcomes. Importantly, adaptive management helps move the state of science and understanding of ecosystem restoration forward in a deliberate way.

Adaptive management, particularly in its more progressive forms (i.e. active AM with triggers and contingency plans), promotes collaboration and flexible decision making through deliberately designing and implementing management actions to test hypotheses and maximize learning about critical uncertainties to better inform management decisions (Williams and Brown 2012). A collaborative adaptive management approach incorporates and links credible science and knowledge with the experience and values of stakeholders and managers for more effective management decision making (Sims and Pratt-Miles 2011).

2 Adaptive Management Fundamentals

The USACE has employed the passive form of adaptive management in its traditional mission areas – particularly navigation – for decades without explicitly labeling it so. Increased recognition of adaptive management as an effective tool for risk management has led the USACE to embrace adaptive management as an approach to address management challenges accompanied by high uncertainty under its ecosystem restoration authorities. The first section of this chapter outlines the requirements for and applicability of adaptive management to these authorities. The next section describes the adaptive management process and relates it to other important USACE processes. The chapter concludes with considerations for alternative forms of adaptive management and collaborating with stakeholders.

2.1 USACE requirements for adaptive management

Implementation guidance for Sections 2036 and 2039 of WRDA 2007 (31 August 2009) emphasize new monitoring requirements on certain USACE projects and also provide guidance on adaptive management. The guidance uses the term “contingency plan” synonymously with an adaptive management plan. Paragraph (3)(d) in Section 2039 states that “an adaptive management plan will be developed for all ecosystem restoration projects. . . appropriately scoped to the scale of the project.” However, it is recognized that adaptive management may not be warranted in all cases (see Section 2.1.1). The guidance also specifies the following:

- Rationale and cost of adaptive management and anticipated adjustments will be included in and reviewed as part of the decision document.
- Identified physical modifications will be cost-shared and must be agreed upon by the sponsor.
- Changes to the adaptive management plan approved in the decision document must be coordinated with HQ USACE.
- Significant changes needed to achieve ecological success that cannot be addressed through operational changes or the adaptive management plan may be examined under other authorities.
- Costly adaptive management plans may lead to re-evaluation of the project. In other words, if very large uncertainties exist or the potential for very large modifications remain after identification of the initial

selected plan and supporting adaptive management measures, there is the potential that additional planning or evaluation may be required to secure project approval.

Adaptive management might be required by agencies external to the USACE in order to proceed with planned projects (for example, as a condition in a biological opinion). Adaptive management might also be undertaken as part of the operation and maintenance of existing projects. There is also a growing collection of examples for the application of adaptive management for flood risk-management projects, water control and reservoir regulation, water quality, and navigation projects (Davis 2009). Nevertheless, the basic elements and purpose – to increase the likelihood of success – are the same.

2.1.1 Criteria for determining the applicability of adaptive management to a project

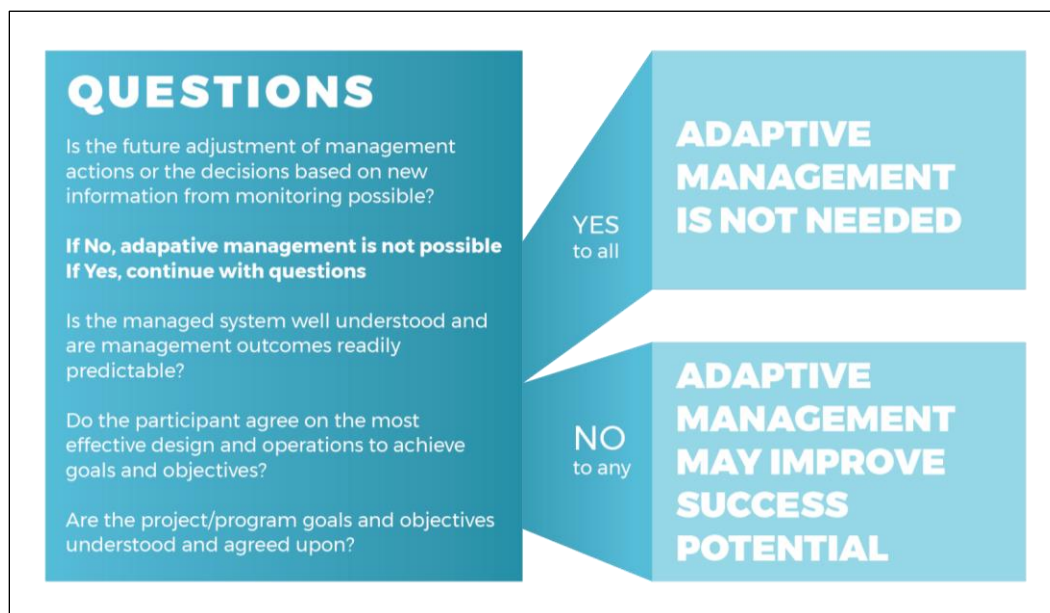
Determining whether a management problem calls for adaptive management, and the complexity and scale of adaptive management, is a crucial step that should be addressed early in project scoping, but that may not be answerable until later in the planning process. While conceptually applicable to almost any problem, there are conditions that favor or hinder adaptive management, and its application to inappropriate contexts will fail to yield expected benefits and likely waste resources (Gregory et al. 2006).

Implementation Guidance for Sections 2036 (Mitigation for Fish, Wildlife, and Wetlands) of 2007 WRDA and Section 1116 of WRDA 2016 (Monitoring for Ecosystem Restoration) require contingency planning (adaptive management planning) and the preparation of adaptive management plans as part of planning for all ecosystem restoration projects. Recognizing that there are cases where adaptive management is unnecessary or even inappropriate, this requirement has been revised in practice to obligate the *consideration* of adaptive management for all ecosystem restoration projects. Projects under related authorities should include adaptive management plans or provide sound justifications for why adaptive management is not warranted.

Four elements must be present for adaptive management to proceed: 1) uncertainty regarding the outcome of a management action, 2) an ability to monitor and evaluate the system response to management actions, 3) capacity to learn from the monitoring, and 4) the ability and will to

apply a decision to change management. Independent of the above requirements, if uncertainties are interfering with project planning or preventing successful implementation, adaptive management is an appropriate strategy. Figure 1 presents a decision rubric to help determine whether adaptive management is warranted. Criteria for the rubric are discussed below.

Figure 1. Decision rubric to assess potential for application of adaptive management.



1. *Are there design, operational, or regulatory impediments to future adjustment of management actions?*

If authorities, funding, or other practical considerations severely limit or prohibit opportunities to adjust a project, it cannot be adaptively managed. For example, a canal intended to alter hydrology and restore ecological function may have been designed to maintain certain minimum and maximum stages to ensure flood control, maintain water supplies or meet water quality standards. Its design constraints may only be minimally changeable under adaptive management, and a small degree of operational flexibility might limit the ability of that project to test different operations to meet a particular goal or objective.

2. *Is the system (or components) to be restored or managed well-understood (hydrologically and ecologically), and are management outcomes accurately predictable?*

Adaptive management is decision making under managed uncertainty.

If the range of potential responses to a proposed management action are known with a high level of confidence and an acceptable degree of accuracy based on well-established science or engineering, the proposed action might not benefit from adaptive management. Such situations are likely where considerable experience exists with a particular technique applied under a particular set of circumstances. Common sources of uncertainty to consider (not a complete list) include (1) incomplete understanding of the system (environmental or engineering) to be managed or restored, (2) imprecise estimates of the outcomes of alternative management actions, and (3) poor understanding of future boundary conditions such as land-use changes and climate change.

3. *Do participants generally agree on the most effective design and operations to achieve program/project goals and objectives?*

Restoration objectives can usually be met by alternative means (different methods, designs, or operations) with varying costs and trade-offs. In some cases, only one approach is feasible or acceptable. In those instances, an alternative management scheme is improbable at best and adjustments under adaptive management equally unlikely.

4. *Are the goals and objectives understood and agreed upon by all parties?*

The primary purpose for adaptive management in the USACE is to ensure a project achieves its goals and objectives. Ecosystem restoration objectives are often poorly defined. The USACE states that

“...the purpose of ecosystem restoration activities is to restore significant ecosystem function, structure, and dynamic processes that have been degraded so as to partially or wholly re-establish the attributes of a naturalistic functioning and self-regulating system” (ER1165-2-501).

For ecosystem restoration projects, the extent to which structure, function, and dynamic processes can be restored and the degree of restoration needed for a system to be naturally functioning and self-regulating may be unknown or highly uncertain. The “vision” for a project may differ among stakeholders, or between the USACE and stakeholders due to different expectations regarding outcomes. Adaptive management is well-suited to this situation.

While the four elements listed above are *requisite* for adaptive management, they are not always *sufficient* to determine that adaptive management is appropriate. While most ecosystem restoration and mitigation projects can benefit from adaptive management, the following three considerations can be important in determining whether adaptive management is feasible or unlikely to add value in the planning and execution for specific USACE programs and projects.

First, if institutional or stakeholder support for adaptive management is lacking, adaptive management will be challenging. Adaptive management is conceptually unpalatable to some; it requires an admittance of uncertainty and willingness to regard projects as “incomplete” following implementation. Stakeholders and managers may lack patience for experimental designs that cannot resolve uncertainties for years or even decades.

Second, adjustments to management actions that are conceptually and even technically feasible may not be practically implementable. Constraints to operational flexibility imposed by stakeholder concerns can be persuasive impediments, particularly for multi-purpose projects involving flood management, water supply, hydropower, etc. Stakeholders may regard adaptive management as an unacceptable trade-off of one form of uncertainty (achieving objectives) for another (future management).

Finally, adaptive management is not without cost. The added monitoring, assessment, and governance costs may themselves be prohibitive, and costs to alter management actions (e.g. physical restoration measures) may be excessive. Uncertainty regarding if and when adjustments might be needed and for the associated cost creates planning and implementation challenges. Return on investment should be considered with the costs of adaptive management weighed against the benefits.

2.1.2 Issues of scale

Adaptive management is most often associated with large-scale applications with a high degree of complexity. Adaptive management is scalable, however, meaning that the approach may be appropriately sized to projects ranging from a single management unit to entire ecosystems (Williams et al. 2009). There likely are many more potential applications of adaptive management at more localized scales, not only because there is

a preponderance of such problems but also because they often can be more easily framed, key uncertainties can be more readily identified, and stakeholder involvement can be more easily facilitated (McConnaha and Paquet 1996).

While many of the examples cited in the literature and lessons learned from application have been derived from the large adaptive management programs, the approaches and key concepts are equally applicable to small projects pursued under continuing authorities' programs. The steps, while the same in both cases, may involve vastly different levels of effort and time. Complexity and scope of uncertainty – not physical scale or cost – may be the best indicator of the appropriate investment needed to develop and implement adaptive management plans for ecosystem restoration and mitigation projects or programs.

Adaptive management as described here applies equally well to local issues and large-scale systems, as long as the basic conditions are met (see Williams et al. 2007 for examples). The specifics of an adaptive management plan will often differ between an ecosystem restoration program and the projects within that program. This is understandable, given that the objectives, uncertainties, and potential adaptive actions at the project scale may be different than those for the overall program of which it is part.

Several USACE comprehensive ecosystem restoration programs (e.g., Upper Mississippi River, Florida Everglades, Coastal Louisiana; see Appendix B) consist of many focused projects directed at incremental environmental improvements that cumulatively improve or restore ecological function at the system scale. Identifying relevant spatial and temporal scales in adaptive management plans for these applications can be challenging. Within these larger, complex programs, adaptive management processes should be developed and applied that simultaneously monitor and evaluate several related individual projects. Insightful planning and organization can reduce duplication in monitoring efforts, increase efficiency, and reduce overall costs of adaptive management.

System-wide implementation of adaptive management might reasonably result in a nested hierarchical approach to adaptive management wherein the objectives and uncertainties for projects are addressed by one plan component, while the system-wide objectives and uncertainties are

addressed by another, with both relying upon the same adaptive management infrastructure (governance, data management, etc.)

Implementation of adaptive management also requires consideration of relevant temporal scales for monitoring, evaluation, and particularly for making adjustments. In some instances (e.g., floodplain forest restoration in the Upper Mississippi River, cypress-tupelo restoration in Coastal Louisiana), the required duration for adaptive management might exceed the USACE authority or funding term, requiring the project sponsor to assume responsibility. Guidance for Section 1116 of WRDA 2016 allows for cost-shared monitoring for up to 10 years; longer periods may be supported by non-Federal sponsors or, in the case of large ongoing programs, through programmatic monitoring activities. The need for adjustment may not be apparent for even longer periods. While this may be accommodated in large programs, it presents challenges to smaller restoration projects.

As noted above, adaptive management expertise and experience in the USACE has been developed mainly from its application to large-scale programs. However, the steps in the process and the underpinning principles are the same, irrespective of scale, and can be applied to smaller projects.

2.2 The adaptive management cycle

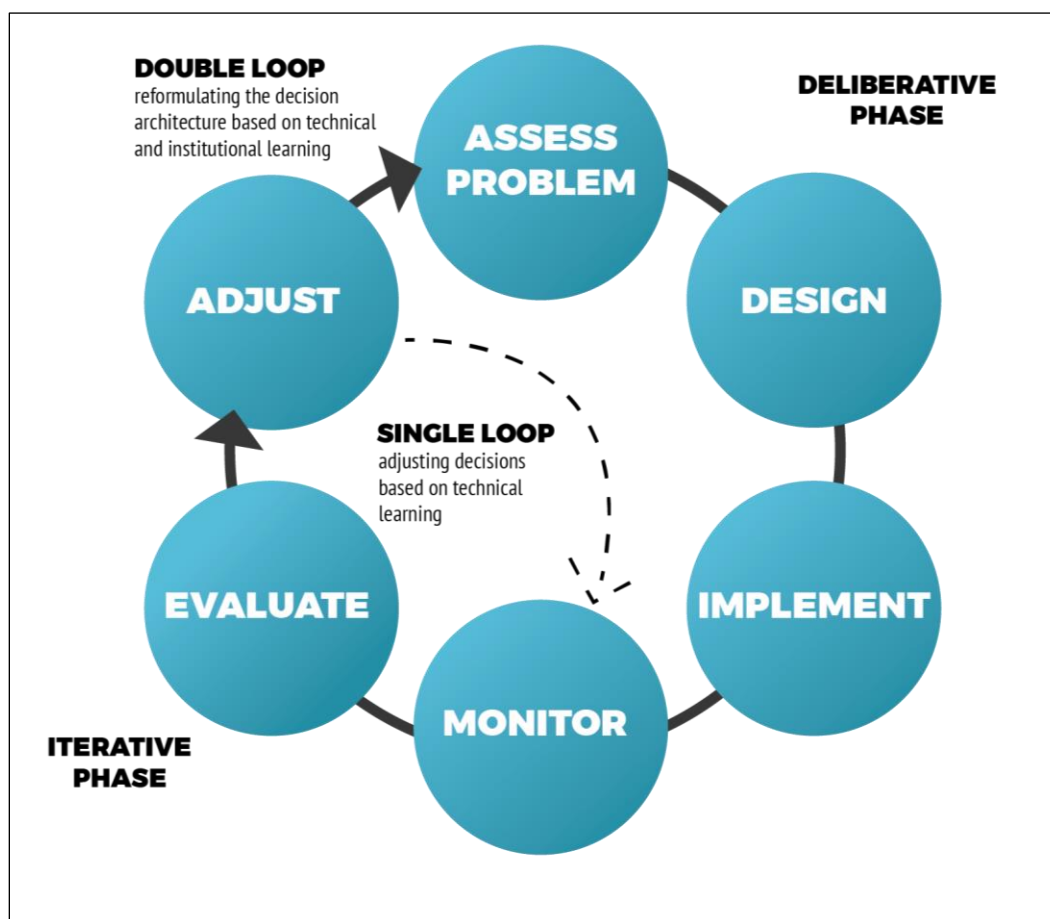
2.2.1 Traditional adaptive management cycle

The basic steps of adaptive management as routinely described include (e.g., Walters 1986):

1. **Assess the problem** by defining the management challenge or opportunity, including the specification of desired goals and objectives and recognition of sources of uncertainty, and formulating a conceptual model incorporating this understanding;
2. Identify or **design** potential management actions to address the challenge or opportunity;
3. **Implement** the selected action according to its design;
4. **Monitor** the results or outcomes of the management action;
5. **Evaluate** the action in relation to specified management goals and objectives and/or assess hypotheses based on the new information; and
6. **Adjust** (adapt) the action(s), conceptual model, or goals and objectives as warranted based on new knowledge.

In this traditional view, the basic steps (and particularly the last four), are performed iteratively until the goals and objectives are achieved, the management action is substantially modified or replaced, or the process is terminated because objectives are met (Figure 2). A development phase includes problem assessment, design of the management action and the decision architecture, and implementation. An implementation phase includes monitoring, evaluation of monitoring results, and adjustment of management strategy.

Figure 2. Basic steps of traditional adaptive management (e.g., Walters 1986). This diagram includes “double-loop” learning reflecting institutional learning, described by Williams and Brown (2018).



Many authors describe this cycle as involving two phases: (1) a deliberative phase involves framing the resource management issue in terms of stakeholders, objectives, management alternatives, predictive models (including measures of the confidence one places in them), and monitoring protocols; and (2) an iterative phase that uses these elements in an ongoing cycle of technical learning about system structure, function,

and management impacts. Williams and Brown (2018) identifies an institutional learning phase that focuses on the decision components themselves by periodically interrupting the iterative cycle of technical learning to reconsider project objectives, management alternatives, stakeholder engagement, and other elements of the deliberative phase.

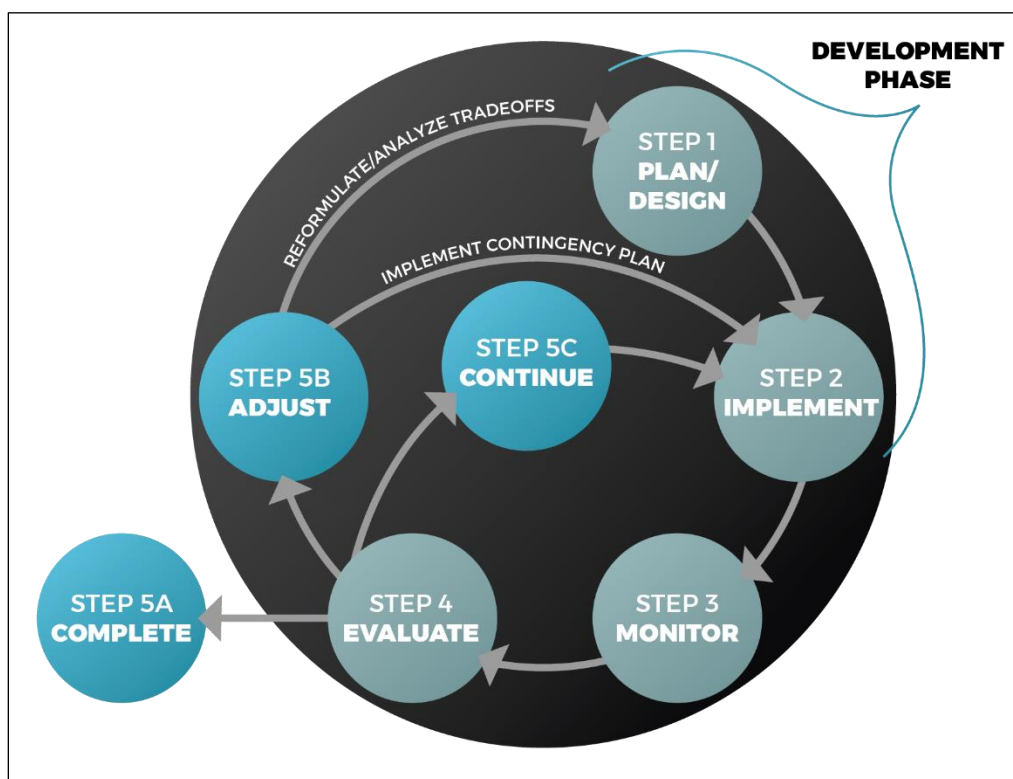
2.2.2 Modification of the adaptive management cycle for the USACE

To support USACE project planning and implementation more effectively, the basic steps of traditional adaptive management have been modified slightly and extended for compatibility with the USACE civil works project life-cycle process and implementation guidance for relevant policies (Figure 3). The elements of the modified cycle parallel the traditional adaptive management process, but the USACE process is more explicit in the assess and design steps, which encompass the Corps' planning process, and in the adjust step, recognizing that the assessment of project performance in relation to desired outcomes can result in decisions to:

- **Continue** project implementation as originally designed or
- **Adjust** the project if goals and objectives are not being achieved or
- Determine that the project has achieved **success** by meeting objectives (or demonstrating a sufficient trajectory toward success), in which case the adaptive management cycle can be regarded as **complete**.

The Adjust step may involve modifications to the current project implementation consistent with the original adaptive management plan (i.e., the alternative remains effectively the same, or a previously evaluated contingency plan is implemented). If adjustments are required beyond the current authority, a new plan might be required (i.e., project reformulation as part of post authorization change process outlined in Appendix G-16 of ER 1105-2-100), potentially involving a new round of scoping and analysis under NEPA). In this regard, the USACE planning cycle is embedded within the adaptive management cycle and may be iteratively addressed.

Figure 3. Adaptive management cycle modified for compatibility with USACE ecosystem restoration and mitigation projects.



The concept of a two-phase approach to adaptive management helps to delineate the steps for the USACE process. The USACE approach considers a “development phase” in which the adaptive management plan is developed and an “implementation phase” wherein the plan is put into practice. These phases can be iterative; that is, the implemented action and/or the adaptive management plan may be revised as a consequence of learning (see the reformulate/analyze tradeoffs arrow in Figure 3).

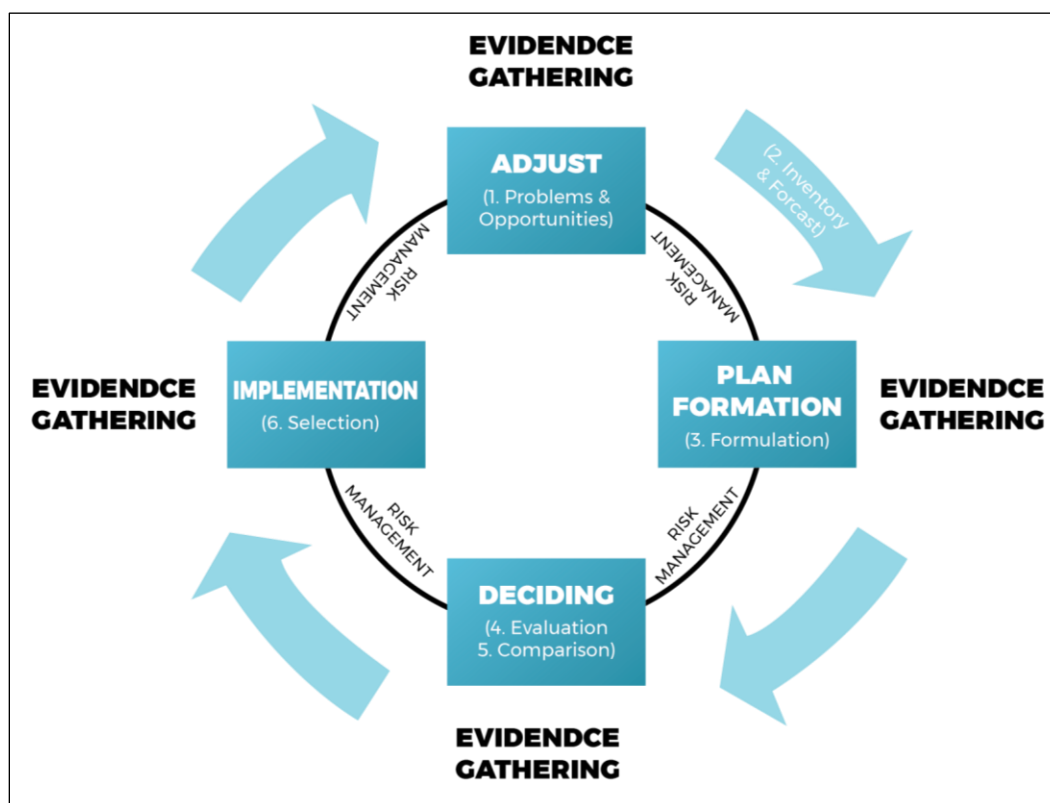
2.2.3 Integration of adaptive management with the USACE planning and project management processes

Risk-based decision making and early vertical team engagement are emphasized in two 2012 USACE planning memoranda. SMART planning is the name given to the initiative that implemented the five pillars outlined in the memoranda. The “R” in SMART refers to “Risk-Informed.” Risk-informed planning pays careful attention to uncertainty, and it uses a set of risk-performance measures, together with other considerations, to inform planning. The iterative analytical steps in risk-informed planning reduce, but cannot eliminate, uncertainty. Adaptive management is the

tool used to address residual uncertainty and is an integral part of the planning process.

SMART planning has evolved under a risk-management paradigm. Figure 4 depicts the risk-informed planning process as an iterative set of four tasks that begins with scoping and ends with implementation. The six “traditional” USACE planning steps are listed in the figure. The data gathering of Step 2 is shown to be ongoing throughout the planning process, not confined to or described by a single step. Evaluation and comparison of alternatives (Steps 4 and 5) are combined into the “Deciding” task.

Figure 4. USACE risk-informed planning process with the six traditional planning steps shown (from Yoe 2017).



The first two steps in the adaptive management cycle encompass the traditional six-step USACE planning process because the need for adaptive management is identified during these steps and the foundational products for adaptive management overlap with those for planning. This part of the adaptive management cycle is regarded as the development phase (Figure 5). The implementation of adaptive management involves iterations through the remaining steps of the adaptive management cycle (see Figure 3 and Table 1) and are part of the broader USACE project

lifecycle management. As such, the planning process -- the first two steps of the adaptive management process -- may be revisited if warranted. Risk management applies to each step of the process, as discussed below. Tasks within each of the steps of the USACE adaptive management cycle are listed in Table 1.

Figure 5. Portion of the adaptive management cycle expanding Steps 1 and 2 to emphasize the USACE planning process.

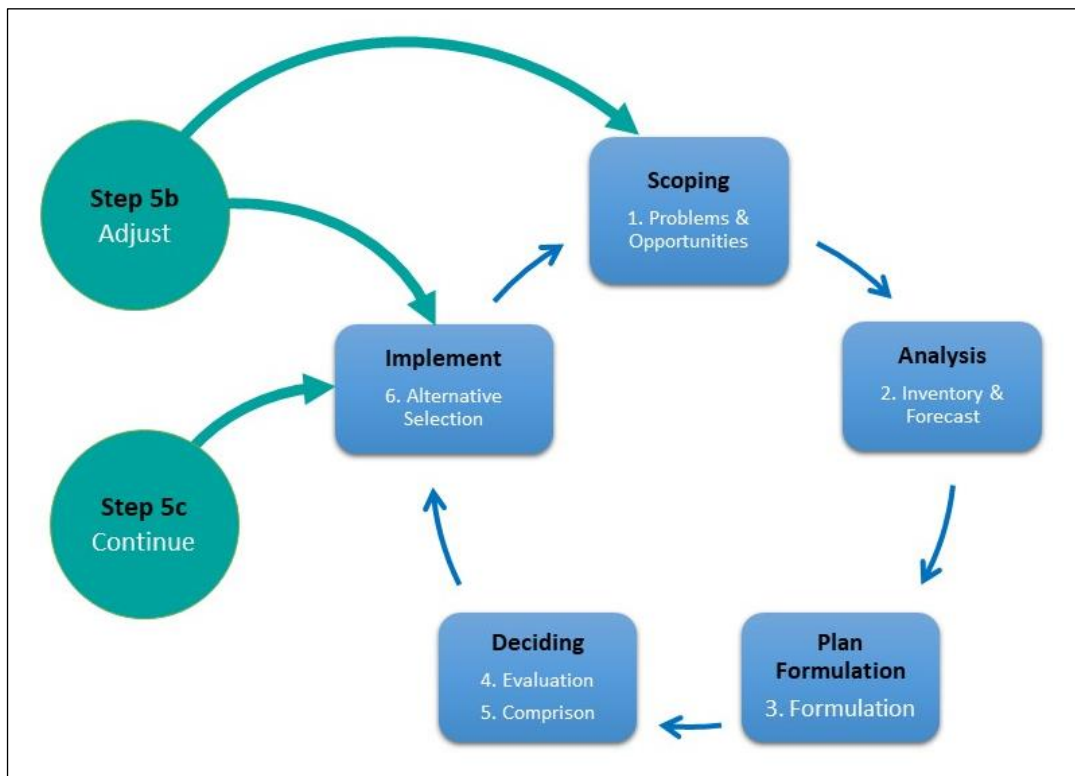


Table 1. Steps and tasks in the USACE adaptive management process¹.

Phase	AM Steps	Tasks within each Step
Development Phase	Step 1: Assess and define the problem	- Clearly state management goals and objectives - Involve scientists, stakeholders, managers - ID spatial/temporal bounds - Build conceptual models - ID key uncertainties (what are the management questions?) - Consider need/potential for AM (three screening criteria) - Articulate hypotheses to be tested - ID relevant metrics and measurable indicators - Explicitly state assumptions - State up front how what's learned will be used
	Step 2: Formulate alternatives and design	- Consider implications of AM to NEPA - Explore alternative management actions (experimental "treatments") - Use active AM when possible; passive AM is OK - Predict outcomes using metrics related to objectives - Estimate costs (including AM costs considering contrasts, replications, controls, monitoring, assessment, and potential remedial actions) - Consider contingency plans and next steps under alternative outcomes - Compare alternatives, contrasting with and without AM - Develop a formal AM plan (determine governance structure, develop a monitoring plan with statistical advice, develop a data management, communications and reporting plan, etc.) - Get the plan peer-reviewed and revise cost estimate as needed
Implementation Phase	Step 3: Implement	- Obtain baseline monitoring (if possible) - Implement contrasting treatments - Implement as designed (or document unavoidable changes)
	Step 4: Monitor	- Obtain and document "as-built" conditions - Conduct training and revisit monitoring protocols as needed - Implement the Monitoring Plan as designed to assess

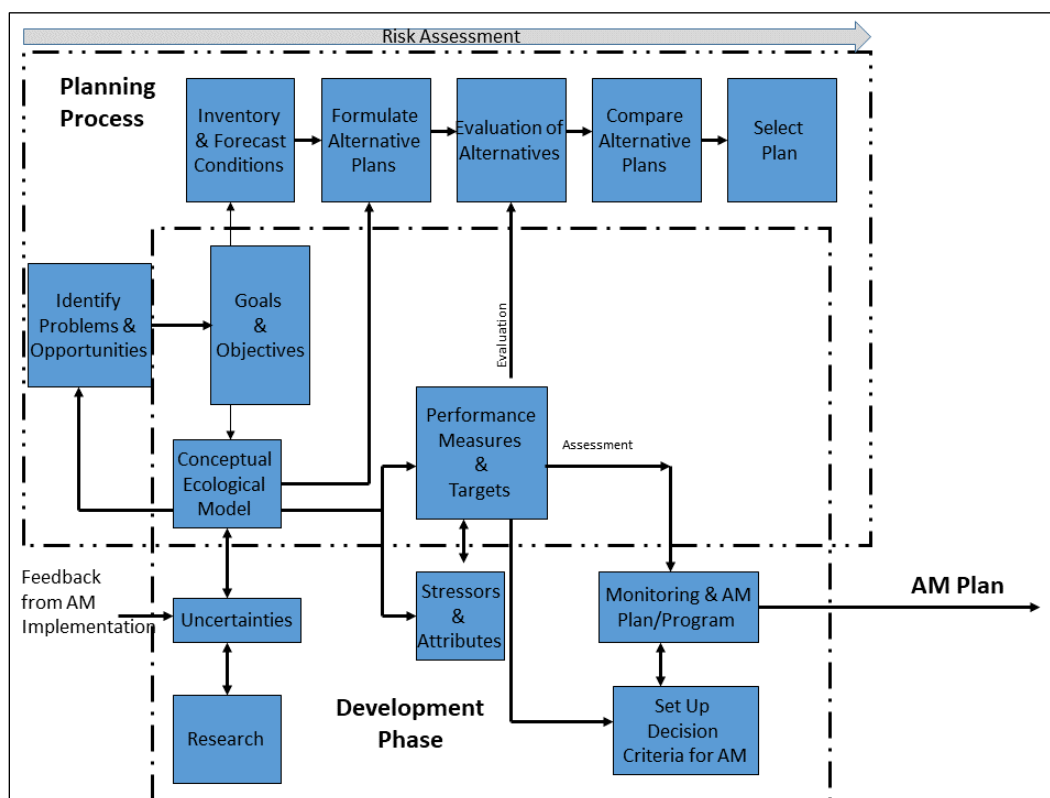
¹ Adapted from Fischenich et al. (2012) and augmented with input from a survey in Fischenich, J. C., K. E. Buenau, J. L. Bonneau, C. A. Fleming, D. R. Marmorek, M. A. Nelitz, C. L. Murphy, G. Long, and C. J. Schwarz. 2018. *Missouri River recovery program science and adaptive management plan*. ERDC EL TR (in preparation). Vicksburg, MS: U.S. Army Engineer Research and Development Center. Note that the tasks may vary depending on the nature of the project and the type of adaptive management employed.

Phase	AM Steps	Tasks within each Step
	Step 5: Evaluate results	• Compare monitoring results against objectives, assumptions, uncertainties, and hypotheses • Compare actual results against model predictions • Consider outside sources of information (e.g. new science) • Ensure data analysis keeps up with data generation • Obtain statistical/analytical assistance and review as needed
	Step 6: Continue/ adjust/ success	• Ensure meaningful learning occurred, was documented, communicated to decision makers (and others as needed), etc. • Decision criteria/triggers indicate need to implement contingency plans • Decision makers consider whether to continue as planned, or

The development phase of adaptive management, described in Chapter 3, proceeds concurrently with the planning process and is managed as part of the Project Management Business Process (PMBP). Project managers should include the adaptive management plan and team as a functional area of the Project Management Plan (PMP). Adaptive management plan tasks and adaptive management team resources need to be identified in the work breakdown structure. Adaptive management tasks will require schedules and budgets to coordinate with management for approval and track implementation.

When there are significant uncertainties about the future or the effects of plans, phased implementation and adaptive management strategies are viable options to consider during the plan formulation. For ecosystem restoration, this means that adaptive management is a consideration from the onset of scoping. Figure 6 shows the tightly integrated steps of the planning process and those of the adaptive management development phase. They rely upon the same fundamental information, processes, and products (e.g. conceptual models, goals and objectives, Risk Register, projected outcomes, and uncertainty analyses, etc.)

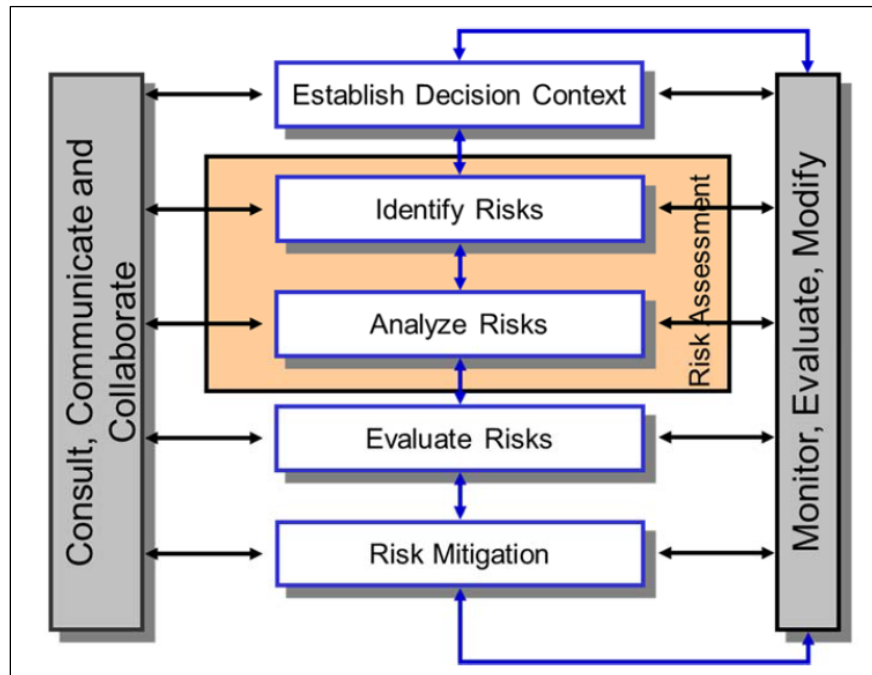
Figure 6. Crosswalk of the six traditional planning steps with the steps in developing the adaptive management plan.



SMART planning and adaptive management are both closely aligned with the USACE risk management strategy. In a risk-informed planning process, risk in some form is a decision criterion and planners must determine what a tolerable level of risk is to the agency and stakeholders. Risk assessment, risk management, and risk communication are components of the USACE risk management model used to support decision-making under uncertainty (Figure 7).

Risk management begins with scoping and the identification of problems and opportunities, each of which have associated uncertainties and risks. It continues throughout the full planning process. A key element of SMART planning is maintaining an appropriate level of detail to make the decision at hand; obtaining additional information is of little use if it is not needed to make a decision or will not improve the decision. Built into this concept of an appropriate level of detail is an implicit notion that the risks associated with not reducing the uncertainty further have been considered. Risk registers, scenario analysis, and uncertainty analysis are all tools to help identify, evaluate, and communicate risks.

Figure 7. The USACE risk management model.



Scenario analysis can be used to consider alternative futures with and without adaptive management. Probing uncertainties and exploring potential outcomes forces the PDT to consider the implications of uncertainties, which helps separate acceptable risks from tolerable risks and unacceptable risks. It also helps the team identify possible risk reduction measures. Broad categories of measures include:

- Eliminating or avoiding the context in which the risk occurs
- Modifying (transforming) the consequences of the risk
- Reducing the likelihood of the risk occurring
- Removing objection to the phenomenon that causes the risk to be perceived as a problem
- Transferring the risk to someone else
- Adaptive management and contingency plans.

SMART planning seeks to reduce uncertainty and associated risks. When the remaining planning uncertainty is not amenable to further reduction through more evidence gathering or where the fundamental direction of the future is in doubt, it is time to consider plans that include adaptive management. Nominally, the Feasibility Report must discuss adaptive management and, if it is not needed or warranted, provide a justification. If adaptive management is justified, a monitoring and adaptive

management plan as well as a cost estimate is required. Chapter 3 provides details regarding the integration of planning and the adaptive management development phase.

2.3 Monitoring in relation to USACE planning guidance

The USACE has historically addressed civil works projects such as flood risk management and navigation by planning, designing, and implementing the project, then turning the project over to the local sponsor with identified requirements for operations and maintenance. In most cases, post-project monitoring or assessment was simply conducted under the periodic inspections program as part of normal operations and maintenance (i.e. compliance monitoring). For cost-shared projects, inspections were the responsibility of the non-Federal sponsor.

Directives for monitoring are provided in the implementation guidance documents pertaining to Sections 2036 and 2039 of WRDA 2007 and Section 1161 of WRDA 2016. These documents require that all mitigation plans and ecosystem restoration projects include a monitoring plan. This monitoring may be as simple as basic post-project inspections. However, in many cases, more detailed performance-based evaluations will be necessary. The guidance specifically includes the following:

- Development of a monitoring plan will be initiated during plan formulation, focusing on key indicators of project performance relative to the goals and objectives.
- The decision document must provide the rationale for monitoring, identify specific monitoring parameters, link those parameters to desired outcomes or decisions (typically through the conceptual models), and describe uses of the information.
- The plan must specify the nature, duration, and periodicity of monitoring; disposition of monitoring and analysis; costs; and responsibilities.
- Pre-project monitoring may be necessary to support alternative formulation and design and establish baselines to measure change. Monitoring in support of adaptive management commences upon completion of construction and continues until “restoration success” is documented by the District Engineer in consultation with Federal and state resource agencies and determined by the Division Commander.
- Success will be determined by an evaluation of predicted outcomes vs. actual results.

- The scope and duration should include the minimum monitoring actions necessary to evaluate success and need not be complex.
- Financial and implementation responsibilities for monitoring will be included in the Project Partnering Agreement (PPA).
- Cost-shared (under Construction) components are not to exceed 10 years. Shared monitoring costs must be included as part of the project cost and cannot increase the Federal cost beyond the authorized dollar limit. Monitoring can end sooner if success is determined. Monitoring beyond 10 years is a 100-percent non-Federal responsibility.
- The monitoring plan will be reviewed during Agency Technical Reviews and Independent External Peer Review as necessary during the planning phase.

2.4 Alternative forms of adaptive management

Much of the adaptive management literature in the past two decades has focused on distinguishing passive and active adaptive management. Both forms of adaptive management utilize learning to inform management interventions. The distinction between the two approaches is the extent to which learning is a specific objective and the degree to which management is used proactively to accelerate the rate of learning (Williams et al. 2009). In practice, a continuum of strategies exists and the appropriate approach is dictated by project or program needs and constraints.

Collaborative adaptive management (CAM), which is the combination of adaptive management and collaborative planning, includes stakeholders in the decision process to build trust, establish legitimacy, and reduce delays (Berkley 2013, Pratt-Miles 2013, Scarlett 2013). Successful implementation of adaptive management is considered unlikely without stakeholder buy-in (Green et al. 2013). Stakeholder inclusion is often seen as the greatest challenge to implementation of CAM projects, however (Monroe et al. 2013), and care is needed in clearly defining roles.

While USACE District and Division Commanders cannot abdicate decision responsibilities, CAM provides a forum for scientists, managers, and stakeholders to raise and explain concerns, articulate management goals, and suggest strategies to address concerns and management actions to achieve goals. In contrast with the type of engagement that occurs as part of the NEPA process, CAM involves collaboration in each of the steps of the adaptive management cycle.

The USACE Engineer Pamphlet EP 1105-2-57 (USACE 2019) provides the requirements and guidelines for stakeholder engagement, collaboration and coordination. Early engagement is essential to scoping and the development of goals and objectives. Opinions about these foundational considerations are likely to be diverse at the outset and, while there may be lingering disagreement about their construct, a common and clear understanding of the scope and objectives is essential. Documenting the issues, questions, agreements, and points of view throughout the process helps to build understanding and trust among parties and provides an important record for future use. Other principles for CAM are listed in the text box.

**PRINCIPLES FOR DESIGNING
COLLABORATIVE PROCESS IN AN
ADAPTIVE MANAGEMENT CONTEXT
(ADAPTED FROM PRATT MILES 2013).**

- Provide forums for interaction between managers, scientists, and other stakeholders
- Invite and document input from affected stakeholders at key junctures in the adaptive management process
- Share data and information with stakeholders
- Identify in advance triggers or points in the process when monitoring results and new information will be evaluated to enable changes in management, if warranted
- Design decision-making structures to incorporate and act on new information

Collaborative processes should be designed to fit the specific needs and circumstances of a project or program. Structures that have been used by other adaptive management programs to collaborate with affected stakeholders can offer insights into possible approaches. The Comprehensive Everglades Restoration Program (CERP) and the Missouri River Recovery Program (MRRP) offer two such examples for large USACE programs (see Appendix B).

Adaptive management programs involving one or more federal agencies and projects on public lands are subject to the provisions of the Federal Advisory Committee Act (FACA). This law requires that federal agencies seeking collective advice or recommendations from individuals or organizations outside government form advisory committees that are diverse and balanced in their makeup and operate in an open and transparent manner (Public Law 92-463 1972).

FACA can present challenges to CAM. While it lays out clear, established guidelines for the establishment of a committee, the creation of a charter, training, and participation in meetings, conducting meetings and getting consensus advice from a diverse array of stakeholders is demanding and

often difficult. Certain bodies are FACA exempt, including scientific bodies convened by the National Academy of Sciences, ESA recovery teams, and groups exempted from the act by statute (Public Law 105-153 1997). The collaborative bodies working with the USACE on the CERP and MRRP are FACA exempt. A FACA exemption offers flexibility to tailor process and structure to meet the needs of specific circumstances, but also requires time to develop a customized structure and process.

CAM is not required in every situation and alternative forms of decision making are preferred in many cases. A collaborative approach should be considered when there are multiple jurisdictions, resource users, and viewpoints about the best way to manage a system, and where complexity and uncertainty are high.

3 Developing an Adaptive Management Plan

Adaptive management is foremost and fundamentally a planning process and, as practiced in the USACE, fully symbiotic with SMART planning (see Appendix C). This chapter identifies the critical parts of an adaptive management plan – the product of the development phase of the adaptive management cycle (see Figure 3) – and describes a process for developing plans for USACE ecosystem restoration projects. The approach emphasizes establishing the necessary feedback relationships between management actions (i.e., decision making) and monitored outcomes, central to adaptive management. This approach to planning adaptive management was designed with an emphasis on environmental management and ecosystem restoration. However, the overall approach to adaptive management applies to other USACE mission areas, such as engineering construction projects, or to the operation and maintenance of existing projects. In particular, the approach described in this guide is well-suited to the fish and wildlife compliance concerns associated with conventional USACE projects.

3.1 The Adaptive Management Team

CREATING THE ADAPTIVE MANAGEMENT TEAM

- Identify individuals to serve on the Team
- Determine policies for terms of service, substitution of members, and selection of new members
- Plan for adequate technical and logistical support services

Those individuals responsible for developing and implementing adaptive management are referred to as the Adaptive Management Team (AMT) in this Technical Guide. These individuals will play an instrumental role in developing the adaptive management and monitoring plans and overseeing their implementation. In most cases, the AMT will be responsible for assessing the need for adaptive management, development of the AM Plan, managing data, assessing monitoring results, making recommendations to decision makers, identifying adjustments to actions or the plan, and reporting and communicating results.

The composition of the AMT will be dictated by project complexity and scale, is usually a reflection of the PDT, and will logically consist of USACE planners, scientists, engineers, and decision makers who can add expertise to the mission, program, or project planning and implementation process. For more complex plans with higher degrees of uncertainty about the historic or desired restoration conditions, experts on environmental history and statistics may be needed to better define restoration success criteria and monitoring plan design.

Depending on the nature and complexity of the management or restoration action, the AMT might range from a few USACE staff to a large number of individuals, including from other participating federal (e.g., NMFS, FWS) or state resource or regulatory agencies, as well as stakeholder organizations. It is likely that participating individuals will have other duties. Therefore, the formal invitation should be accompanied by a list of AMT commitments and schedules so that participants' time can be prioritized to support the effort. It should be understood that adaptive management can only be effectively executed if it is based on a formal association of individuals who contribute directly and regularly to adaptive management. Appointment of an individual to serve as an Adaptive Management Project/Program Manager may be necessary for larger or more complex projects.

Provisions should be developed for terms of service, substitution of members, and selection of new AMT members. The AMT might be augmented during the adaptive management process by individuals who possess special technical skills or unique management experience. In addition, the adaptive management and monitoring plans should be reviewed at a minimum as part of agency technical review and as part of an independent external peer review for complex actions. Provisions should be made within the operating procedures of the adaptive management plan that permit the AMT to secure such support as needed. The important point is that the individuals responsible for developing and performing adaptive management are clearly identified at the outset and throughout the course of adaptive management. The members and organizations that constitute the AMT should be identified in the adaptive management plan.

Adaptive management plan tasks and AMT resources need to be included in project management plan (PMP) work breakdown structures. Project

managers working with AMT members can identify appropriate schedules and budgets for adaptive management plan tasks. These tasks become part of the approved PMP by USACE and sponsor agency to approve, fund, and track progress. In addition, the schedule needs to be coordinated with external AMT members to ensure their commitment to accomplishing key tasks.

Given the importance of conserving endangered and listed species, the complexity associated with protecting these imperiled species, and the impacts the ESA may have on society and agency decision making, any adaptive management program that may affect listed species or critical habitat is more likely to be successful if it involves FWS and/or NOAA early in the process. Key to efficient species and effective consultation is an initial description of the range of potential adaptations and effects of those actions on listed species and their designated critical habitats.

3.2 Outside expertise and facilitation

There is often value in engaging individuals from outside the organization to provide subject-matter expertise or to facilitate engagements, particularly with the stakeholder community. Outside experts can be used to augment the AMT, providing insights on critical issues such as experimental designs, monitoring strategies, and governance structures. Facilitators can offer novel insights while assisting with stakeholder interactions and are particularly helpful on complex projects or where contentious issues affect stakeholder interactions. Technical experts and facilitators with experience from other adaptive management projects can relate important lessons from those experiences.

3.3 Independent external review

Government-wide standards for the peer-review requirements of scientific information outline the types of peer review that should be considered (OMB 2005). The USACE employs robust, multi-level product review and quality assurance processes and the traditional independent external product review (IEPR) process will be sufficient to assess products of many adaptive management efforts. However, any adaptive management effort could benefit from an independent science panel (ISP) that provides objective input throughout the adaptive management process and the use of such a panel is especially important for complex or contentious problems.

The subject of an ISP should be introduced early in the discussion of adaptive management planning because the expert advice such a panel can provide is particularly useful in the initial stages of adaptive management because it can advise and assess the clarity of hypotheses, the validity of any experimental design, the quality of data collection procedures, the appropriateness and robustness of the methods employed, and the extent to which conclusions follow from the analyses.

Murphy and Weiland (2019) discuss the attributes of successful science review and advice in the context of the Endangered Species Act (ESA). Their recommendations are applicable to the adaptive management of USACE ecosystem restoration projects as well and include the following:

- A deliberative panel of three or more professionals free of conflicts with the skills, expertise, and experience dictated by the project's technical needs.
- A charge or task statement to query the fundamental approaches taken, the pertinence and quality of data and analyses employed, and the conceptual and quantitative models used.
- Direct interaction between the ISP and agency (and sometimes sponsor) subject-area experts and decision makers early and often in the process, emphasizing both advice and review of roles as appropriate.
- Agencies must show their work, allow adequate time and resources for review, and provide responses to review comments and questions. Reviews should occur early enough in the process that changes can be made to products or decisions based upon the review.
- A substantive review panel needs to be availed of the analyses of effects of the action, supporting/justifying documentation, and other scientific information in addition to the AM plan.

3.4 Development phase

Planning for adaptive management consists of an initial comprehensive development phase that is concurrent with project planning and addresses all fundamental components of an adaptive management plan (see Table 6). There are clear linkages between planning for adaptive management and the traditional USACE six-step planning process (see Section 2.6). The feasibility study includes an initial determination of whether adaptive management is required for the project based on the problem identification, conceptual ecological model development, and risk and

uncertainty assessment given the restoration goals and objectives. Sections 2.1 through 2.3 address factors in determining the need for adaptive management.

If adaptive management is determined to be necessary, successful completion of the development phase includes the development of a draft adaptive management plan. The plan should sufficiently characterize adaptive management associated with different project planning alternatives that the requirements and preliminary cost estimates for monitoring and implementing adaptive management can be developed.

The development phase of adaptive management is discussed in the following sections. The development phase culminates in the preparation of an adaptive management plan. The process is described in the context of planning for an ecosystem restoration project. However, the process and steps are effectively the same for addressing existing USACE projects in pre-construction engineering and design, operations and maintenance of existing project, or adaptive management mandated external to the USACE for project approval (e.g., Biological Opinions, Terms and Conditions), although the options to adjust may be more limited.

KEY ELEMENTS OF THE AM PLAN:

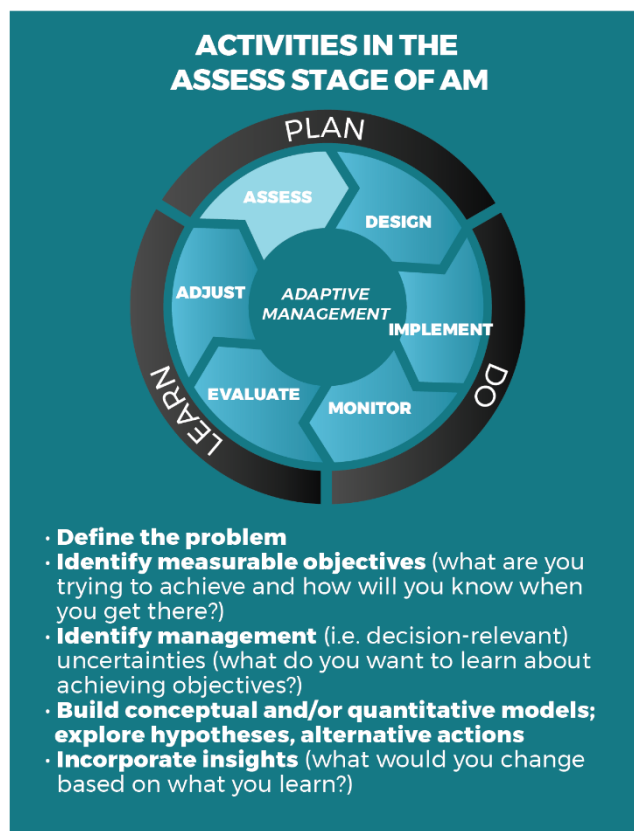
- Goals and objectives
- Uncertainties
- Hypotheses
- Management actions
- Model predictions
- Decision criteria
- Monitoring program
- Analytical requirements
- Decision-making process and roles
- Contingency actions
- Reporting and communications
- Process and timeline for modification

3.4.1 Assess

The assess stage of the traditional adaptive management cycle – often glossed over in discussions of adaptive management – incorporates much of USACE’s planning process and is crucial to effective adaptive management planning. In this stage, the PDT/AMT defines the scope of the management problem, identifies project goals and objectives (Step 1 of the Six-Step Planning Process), synthesizes existing knowledge about the system (Step 2: Inventory and forecast conditions), and explores the potential outcomes of alternative management actions (Steps 3-6: Formulate, evaluate, compare,

and select management alternatives). Explicit forecasts are made about outcomes to assess which actions are most likely to achieve management objectives.

During this exploration and forecasting process, conceptual ecosystem models are developed and key gaps in understanding of the system (i.e., uncertainties that limit the ability to predict outcomes) are identified. Risks associated with uncertainties are identified and categorized in a Risk Register (see an example of a Risk Register in Appendix E). Goals and objectives are identified and decision criteria for each performance measure that defines project success are also defined. Monitoring and adaptive management needs are explored through scenario analyses for each alternative. Risk management strategies are considered and risk reduction measures incorporated into the alternative formulation, as warranted.



The activities in this step are the equivalent of the “effects analysis” called for by Murphy and Weiland (2011) as a requisite for establishing the best available science when evaluating the effects that actions proposed by federal agencies may have on threatened or endangered species. Best available science should underpin adaptive management, and the principles and practices embodied in an effects analysis are as relevant to AM planning as to ESA compliance. The ESA’s best available science mandate reflects a Congressional mandate to ensure that decisions are informed by reliable knowledge using a structured approach.

3.4.1.1 Problems and opportunities

The specific water resource problems and opportunities are identified at the beginning of the six-step planning process. While seemingly straight-

forward, a clear, evidence-based definition of the problem(s) is challenging. Conceptual ecological models (CEMs) can be used to organize available data and promote a better understanding of potential ecosystem restoration opportunities or potential environmental impacts from water resource projects. CEMs can help expand the problem definition to identify the nature, cause, location, dimensions, origin, time frame, and importance of the problem, as well as an indication of who considers this a problem. An opportunity can be defined the same way.

3.4.1.2 *Conceptual models*

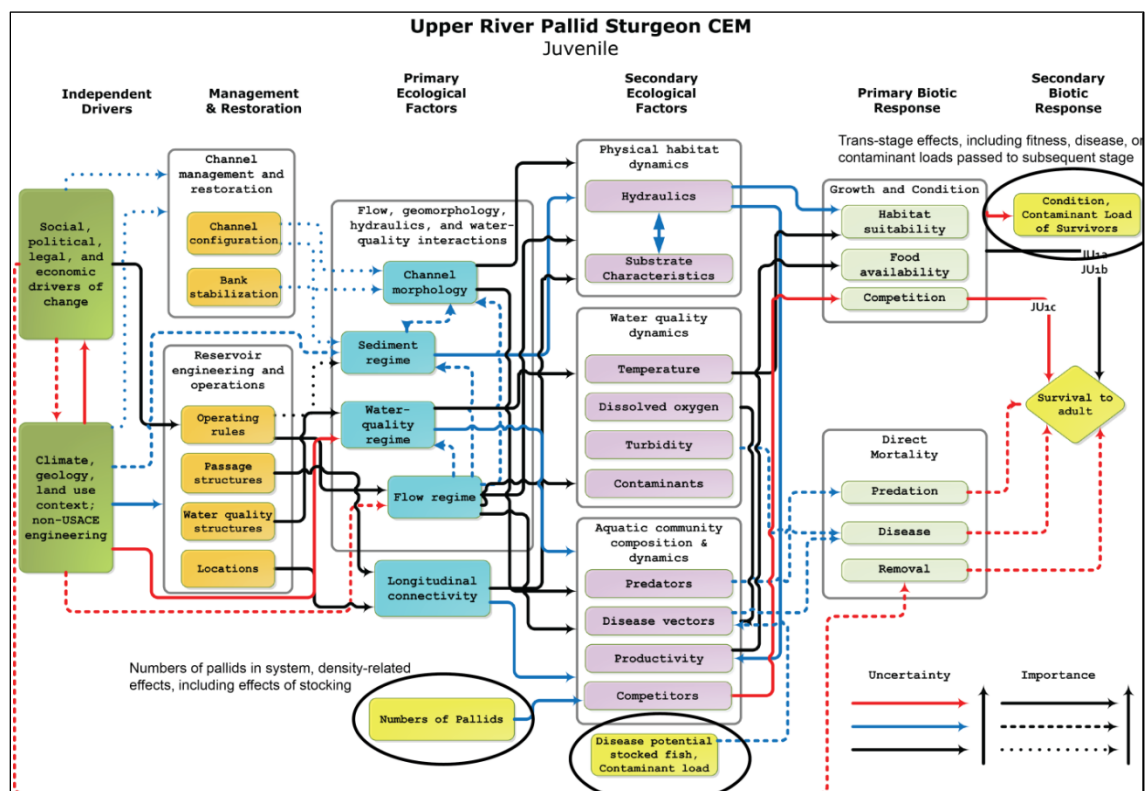
Conceptual models identify the key components and processes of the managed system, their interrelationships, and their expected responses to proposed management actions (Galat et al. 2007). The development and use of conceptual models is recommended at the feasibility study level for ecosystem restoration projects. Because it is a crucial planning tool for adaptive management, ensuring an appropriate level of effort for product development - including obtaining seasoned assistance if needed – is recommended. Guidance on the development of conceptual models for ecosystem restoration can be found in Fischenich (2008).

DEVELOP CONCEPTUAL MODELS TO SUPPORT THE ADAPTIVE MANAGEMENT PLANNING

- Identify key components of system to be managed or restored
- Identify and describe important interrelationships among key model components
- Construct the conceptual model(s)
- Use the model(s) to help evaluate alternative management and restoration actions
- Identify sources of variability and uncertainty

Conceptual models can take the form of flowcharts, matrices, contributing factors diagrams, or narrative descriptions. Figure 8 provides an example of a conceptual model developed to support adaptive management of a set of actions required for compliance with a biological opinion on the Missouri River. The model explicitly identifies the effects of management actions on pallid sturgeon and includes representation of the uncertainty in the model relationships. These uncertainties form the basis for the adaptive management program.

Figure 8. Example of a conceptual ecological model (note that this is just the graphical depiction of the model – an accompanying narrative describes the components and linking processes).



Conceptual models of ecological systems can help identify and describe the resources of concern (ecological attributes) that might benefit or be placed at risk as a result of proposed management actions affecting stressors in the system. The functional interrelationships among the ecological attributes and stressors included in the conceptual model can help managers understand the potential direct and indirect effects of management actions and help anticipate the effects of management actions that can propagate through complex ecological systems in the face of incomplete knowledge. Similar conceptual models are also an essential tool for engineering projects, operations and maintenance actions, or construction in relation to adaptive management planning.

Once drivers and outcomes have been identified, the cause-and-effect linkages between these two groups can be explored and described (Fischenich 2008). Specific attributes of each linkage should be defined, including:

- Nature and direction of the effect – positive/negative effect: +/-/0 (0 means no effect).
- Importance or magnitude of the effect – displayed using width of line.
- Understanding underlying the effect (degree of uncertainty) – displayed using color/shading of line.
- Predictability of the effect – displayed using solid, dashed, or dotted line.

The more specific indicators of goals and objectives can be used to define performance measures or risk endpoints to use in evaluating benefits for restoration alternatives and monitoring actual restoration success. The level of understanding of the driver and ecological attribute response relationships can be used to identify uncertainties and hypotheses, as well as help inform the type of adaptive management approach needed and the design of monitoring programs for specific management and restoration actions.

Maddox et al. (1999) suggested that conceptual ecological models play three significant roles in monitoring. First, models summarize the most important ecosystem descriptors, spatial and temporal scales of critical processes, and current and potential threats to the system. They provide feedback to and help formulate goals and objectives, indicators, management strategies, results, and research needs. They also facilitate open discussion and debate about the nature of the system and important management issues.

Second, a model plays an important role in determining indicators for monitoring. Because the model is a statement of important physical, chemical, or biological processes, it identifies aspects of the ecosystem that should be measured. If the model is a good reflection of current understanding, but the measurement indicators cannot be seen in the model, then the measurements have little to do with the ecosystem.

Third, a model is an invaluable tool to help interpret monitoring results and explore alternative courses of management. An explicitly stated model is a summary of current understanding of and assumptions about the ecosystem. As such, it can motivate and organize discussion and serve as a “memory” of the ideas that inspired the management and monitoring plan.

3.4.1.3 Goals, objectives, and constraints

The goal for projects pursued under the USACE ecosystem restoration mission has been defined as “to restore significant ecosystem function, structure, and dynamic processes that have been lost or degraded” with the intent of partially or fully re-establishing the attributes of a naturalistic, functioning, and self-sustaining system (USACE 1999). This stated purpose

provides context for the establishment of more specific planning objectives. The objectives state what planners intend to do about the problems and opportunities they face. Done well, objectives reflect the most important values in the decision process. Constraints should also be identified and, like objectives, are unique to each planning study.

A GOOD OBJECTIVE/ CONSTRAINT IS:

- Specific; i.e., it is clear and free from ambiguity
- Flexible; it can be adapted to new or changing requirements
- Measurable by some objective means
- Attainable; plans can reach the objective.
- Acceptable; welcomed by key stakeholders

The objectives established for the project planning serve as the objectives for adaptive management as well, noting that some additional objectives and constraints may apply to adaptive management. Assuring success is a primary purpose of adaptive management, so metrics associated with specific, measurable, and attainable objectives are the focus of monitoring efforts that inform the adaptive management process and guide decision making for the project.

As a result of the USACE’s risk-informed planning process, the USACE identifies environmental conditions that it wishes to achieve, risk and uncertainty associated with achieving those conditions, as well as risks and uncertainty to be avoided, minimized, or mitigated. The AMT will generally need to evaluate proposed project alternatives from the perspectives of likely success, level of uncertainties and risks, and suitability for adaptive management. It is possible that much of this evaluation will have been completed by the planning team (e.g., plan formulators, scientists, engineers) during the traditional planning process. Some of those planning team members will also be part of the AMT that will include additional technical skills and/or management experience and will ultimately continue their support beyond the planning phase. Importantly, the planning phase of adaptive management provides

additional opportunities for interaction among USACE planners, stakeholders, and the AMT in developing viable management and restoration alternatives to achieve desired future conditions and/or reduce risks. PDTs should consider the use of workshops focused on adaptive management planning that include AMT members. In addition, PDTs should refer to Appendix D for USACE AM support and training of planning and AMT members.

The development phase in planning for adaptive management also provides the AMT with the opportunity to review the goals and objectives for feasibility and compatibility with possible adaptive management actions (e.g., feasibility planning, engineering projects, O&M). There might be instances where a planning alternative has been previously selected or in operation prior to consideration of adaptive management. In this situation, the AMT should interact with the planning team to determine the efficacy of developing a corresponding plan for adaptive management, monitoring, and assessment that is compatible with the construction or ongoing operation and maintenance of an existing or selected project. In any case, it is necessary to determine whether modifications or adaptations can be made after project implementation. If not, then opportunities for adaptive management might be limited to implementing a monitoring plan to obtain data and knowledge that can be applied to other future similar projects. If the proposed management actions are inflexible or incompatible with the fundamental aspects of adaptive management, the AMT can advise managers that adaptive management is not advisable and activities should be limited to monitoring to assess success.

3.4.1.4 Risk and uncertainty

Risk, over a given time, is a product of likelihoods and consequences of adverse outcomes. This definition implies that four aspects are involved in considering risk—a time scale, scenarios, relevant consequences, and corresponding likelihoods or probabilities (Beer 2006). In a typical risk assessment, the questions below are addressed as part of the overall risk management process (after Suedel et al. [2012]). For simple projects, the PDT can address these informally with sponsor input. For larger, more complicated, and collaborative efforts, use of a professional facilitator in a workshop setting is advised.

1. What can go wrong?
2. What is the likelihood that it will go wrong?
3. What are the consequences?
4. What can be done to mitigate the risks?

Uncertainty is a lack of knowledge. This Technical Guide focuses on two types of uncertainty: natural variability and scientific bias. “Variability” refers to natural patterns of spatial and temporal heterogeneity that cannot be reduced by additional sampling or data collection. Variability reflects the dynamic nature of ecological, environmental, and engineered systems. Sampling methods and designs should accurately and precisely quantify variability. Importantly, methods have been developed that use relationships between sample variance and frequency and location of sampling to identify the relevant scale in assessing many ecological performance measures that might be important in planning for monitoring and adaptive management (e.g., Gardner et al. 2001). Thus, variability and scale are interrelated; monitoring and adaptive management plans should characterize the scale dependence of these relationships for the selected performance measures and risk endpoints.

“Scientific Bias” refers to bias and imprecision introduced into monitoring and adaptive management planning from several sources, including inadequate sampling designs, improper methodologies in sample collection, errors in sample processing or data analysis, errors in data management and communication, and incomplete scientific understanding of the managed system. The implications of these uncertainties on the overall effectiveness of the adaptive management

RISK & UNCERTAINTY ASSESSMENT

- Identify uncertainties early in planning
- Residual sources of uncertainty should be classified as to type, analyzed and documented, and then addressed iteratively throughout the planning process.
- Quantify uncertainty where possible, using confidence intervals or probability distributions as opposed to point estimates when describing predicted outcomes.
- The relative uncertainty of alternative plans should be presented, as uncertainty in outcomes may be considered during plan comparison and is an important part of an overall risk management/communication strategy.
- If the recommended plan has uncertainty that can be practically reduced through post-construction monitoring, assessment and adjustment, an adaptive management plan should be developed to manage risks and maximize realized benefits.

process will be described and quantified to the extent possible as part of the adaptive management plan outlined in this section.

All restoration projects face uncertainties, and identifying the likely sources is the first step in managing uncertainty. Corps policy requires that uncertainty in water resource planning be evaluated and communicated. Methods for evaluating uncertainty in ecosystem restoration projects continue to evolve, but include sensitivity analyses, scenario planning, and parametric uncertainty analysis. These and other means of identifying, quantifying, evaluating, and otherwise considering uncertainties as part of the planning process provide important information that assists decision making. Although uncertainties can arise at any point in a study, the identification, classification, and documentation of uncertainties is critical during the development of a CEM (note the solid red lines in Figure 8), during modeling and forecasting, and during formulation of the monitoring and adaptive management plan.

Linkages between drivers that are modified by restoration actions are often the factors that pose the most risk to achieving success. Higher-risk links between restoration actions and ecosystem outcomes, where uncertainty may also be moderate to high, are more likely to benefit from adaptive management as a risk management strategy if actions can be adjusted. Assessing risk early on in project planning can help inform project planning to design alternative plans that can be adjusted based on actual performance when implemented. High-risk and uncertainty relationships might indicate the need for an active adaptive management approach that tests multiple competing restoration designs before implementing the best design at full scale.

Importantly, adaptive management will generate data and information from monitoring. This information can be used not only to guide future management and decision making, but also to reduce uncertainties inherent in managing and restoring complex ecological and engineered systems. Adaptive management establishes the critical feedback mechanisms that interject the results of monitoring and assessment into decision making, reduces uncertainties, and increases the likelihood that management goals and objectives will be achieved (risk reduction).

3.4.1.5 *Performance measures, targets, and decision criteria*

An important part of planning for adaptive management is the translation of the management and goals and objectives into specific performance measures (or metrics), targets, and decision criteria. During the development phase, the AMT should work from the Conceptual Model(s) and with the project planning team and stakeholders to define the physical, chemical, biological, and ecological stressors and attributes that will be evaluated to assess project performance. Specification of the mechanism by which performance will be measured will also require delineation of the spatial and temporal scales relevant to project implementation and management, which might differ among the measures.¹ Target values for success should be identified, but there may also be constraints (sometimes called risk endpoints) for which specific, quantifiable targets that trigger a decision exist.

The term “decision criteria” refers to pre-determined conditions that trigger or guide a decision or the implementation of a contingency plan. They can be qualitative or quantitative based on the nature of the performance metric and the available information. A recent study of judicial decisions on adaptive management programs cited the lack of decision criteria as one of three key deficiencies leading to possible overturning by the courts of agency practice (Fischman and Ruhl 2016).

Decision criteria can play several roles in adaptive management, including:

- defining requirements for success or other compliance purposes (e.g., ESA, NEPA, USACE’s policies)
- facilitating complex decisions, or decisions that must be made quickly during implementation
- providing a roadmap for participants (i.e., they define the decision space)
- ensuring that decisions are based upon best available science.

¹ Performance measures and risk endpoints can also be defined for engineering projects or operations. Performance measures might simply pertain to successful construction per engineering specifications. Risk endpoints can be identified as undesired changes in conditions, for example, declines in levels of protection through structure depreciation, changes in land use and other actions that make structures inadequate for protecting habitats, or establishment of invasive species that requires changes in operation.

Decision criteria can come in various forms, including quantitative values that serve as triggers, decision trees structured in IF / THEN form that address various scenarios, and planning rubrics or heuristics that help with decision making when multiple lines of evidence are needed to establish a decision. Criteria cannot be developed for every decision. Some decision criteria may not be evident during the initial planning stages; useful criteria cannot be developed until details of actions are known in some cases. As knowledge grows, it will likely become apparent that some criteria need to be changed. To address these situations, the adaptive management plan should include a process to guide the development and/or revision of decision criteria.

The specification of performance measures and target values provides the necessary focus in designing a monitoring plan that will provide the critical information needed for adaptive decision making. Properly executed, there should be a clear connection between the project's goals and objectives, the metrics, decision criteria and (if applicable) contingency actions taken. Table 2 presents an example from the Louisiana Coastal Area (LCA) showing how one objective with two associated performance measures links to the targets, decision criteria and contingency plans. Table 3 provides another example from the science and adaptive management plan for the MRRP showing the links among hypotheses, experimental design, study questions and methods for evaluation for one management action – interception and rearing complexes (IRCs).

Table 2. Example linking objectives, metrics, targets, decision criteria (triggers), and contingency plans (adapted from the Blind River Project for LCA).

Objective 3: Establish swamp hydroperiod with dry period of sufficient length to improve baldcypress and tupelo productivity, seed germination and survival.
Performance Measure 3a: Depth, duration, and frequency of flooding in the swamp.
Targeted Outcome: Maintain dry periods (moist soils) in the swamp for a minimum 7-35 days during summer and early fall for seed germination and maintain water levels below seedling height to promote seedling survival.
Monitoring Design: Hourly hydrologic recorders will be deployed to measure stage/depth.
Trigger: Depth of inundation fails to drop below target levels for less than 7 days in any one year or less than 10 days for two successive years.
Contingency Action: Modify gate operation to reduce inflow to project area.
Performance Measure 3b: Number of baldcypress and tupelo seedlings and saplings.
Targeted Outcome: A 25% increase in the number of baldcypress and tupelo saplings per acre five years after project implementation and 50% increase after 10 years.
Monitoring Design: Understory vegetation will be measured to determine numbers of baldcypress seedlings and saplings in order to assess regeneration.
Trigger: No measurable increase in baldcypress and tupelo saplings after 5 years.
Contingency Action: None specified. Will evaluate conditions and determine appropriate course of action, if any.

Table 3. Example linking management actions, hypotheses, metrics, and decision criteria (adapted from the science and adaptive management plan for the MRRP¹).

Action	Question	Method for Evaluating
Interception and Rearing Complexes (IRCs) <u>Associated hypotheses</u> - Re-engineering of channel morphology will increase channel complexity and: - bioenergetic conditions to increase prey density abundance (invertebrates and native prey fish) for exogenously feeding larvae and juveniles. - minimize bioenergetic requirements for resting and foraging of exogenously feeding larvae and juveniles. - serve specifically to intercept and retain drifting free embryos in areas with sufficient prey for first feeding and for growth through juvenile stages. Experimental design: AM plan sections 4.2.6.3.4 4.2.6.4.4	Do free embryos and exogenously feeding larvae leave the thalweg and enter IRCs? Is there sufficient food in IRCs for exogenously feeding larvae to grow better and maintain a healthier condition than reference areas and times? Do age-0 fish that occupy IRCs survive better than age-0 fish in reference areas and times? What's the population-level effect of improved survival of age-0 fish in IRCs? Is food limiting outside of IRC habitats	Predicted fate of free embryos from advection/dispersion models. Testing of these predictions with field monitoring (see below). Staircase design comparisons of IRC habitat sites with reference areas and times, using the metrics listed in Table 9, section 4.4 (e.g., CPUE, probability of apparent presence, food production/area, condition, growth and survival of age-0 fish), and applying covariates to help explain year to year variation (e.g., index of upstream spawning success). Population model projections of the consequences of improved age-0 survival rates.

3.4.2 Design

The Design stage finalizes the specifications of a selected alternative to ensure a robust project capable of performing under extreme system conditions. Such design ensures the necessary flexibility to adjust management actions in the face of uncertain future conditions. More than

¹ Fischenich, J. C., K. E. Buenau, J. L. Bonneau, C. A. Fleming, D. R. Marmorek, M. A. Nelitz, C. L. Murphy, G. Long, and C. J. Schwarz. 2018. *Missouri River recovery program science and adaptive management plan*. ERDC EL TR (in preparation). Vicksburg, MS: U.S. Army Engineer Research and Development Center.

one proposed plan or design should be evaluated in relation to costs, risks, information, and ability to meet management objectives. The design step can be used to iteratively refine the preliminary monitoring plan and adaptive management plan.

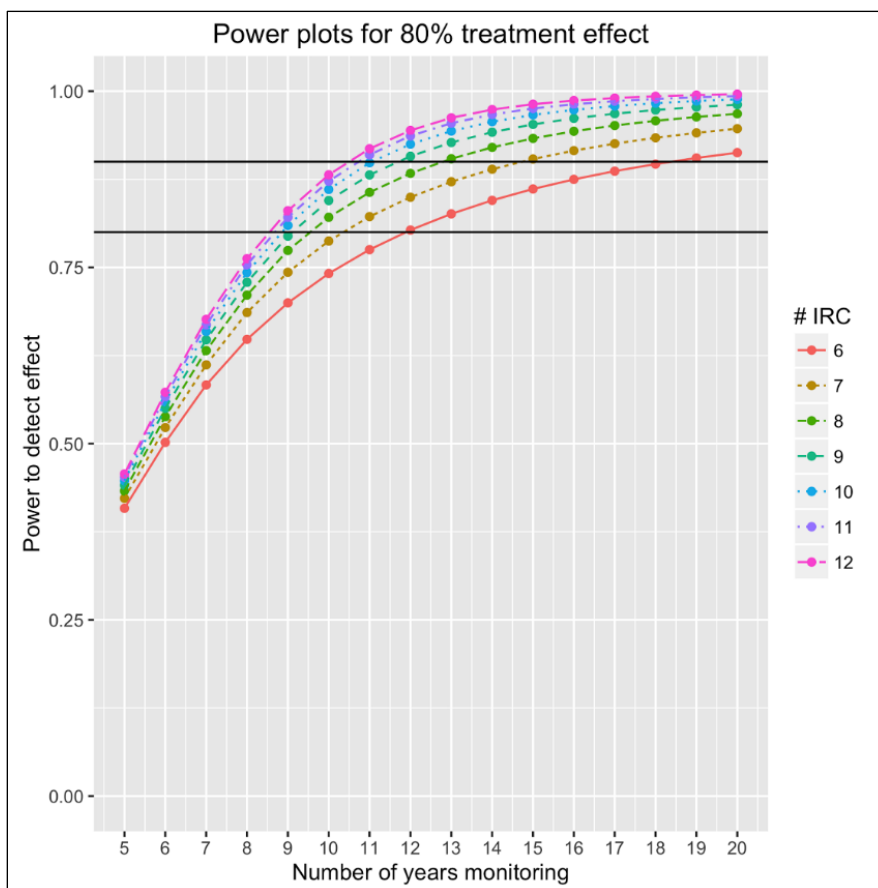
In the context of the adaptive management cycle, the Design stage deals with the identification and detailed development of management actions and, in particular, with the complexities of experimental design when the active form of adaptive management is practiced (see Section 4.1 for more detail). Models quantifying outcomes of potential management actions in terms of resource response play an important role in the design stage. Decision making is based on a comparison of management alternatives in terms of their costs and resource consequences.

Models also play a major role in representing uncertainty.

Structural and functional uncertainty can be expressed through contrasting hypotheses about system structure and functions as represented by different models (Figure 9). Evidence from monitoring is used to assess the adequacy of each model (i.e., validation analysis) in characterizing resource dynamics. As evidence accumulates, confidence in each model (and its associated hypothesis) evolves, through a comparison of model predictions with actual data from monitoring. Data acquired through monitoring, research or outside sources can be used to re-parameterize models, improving predictions.



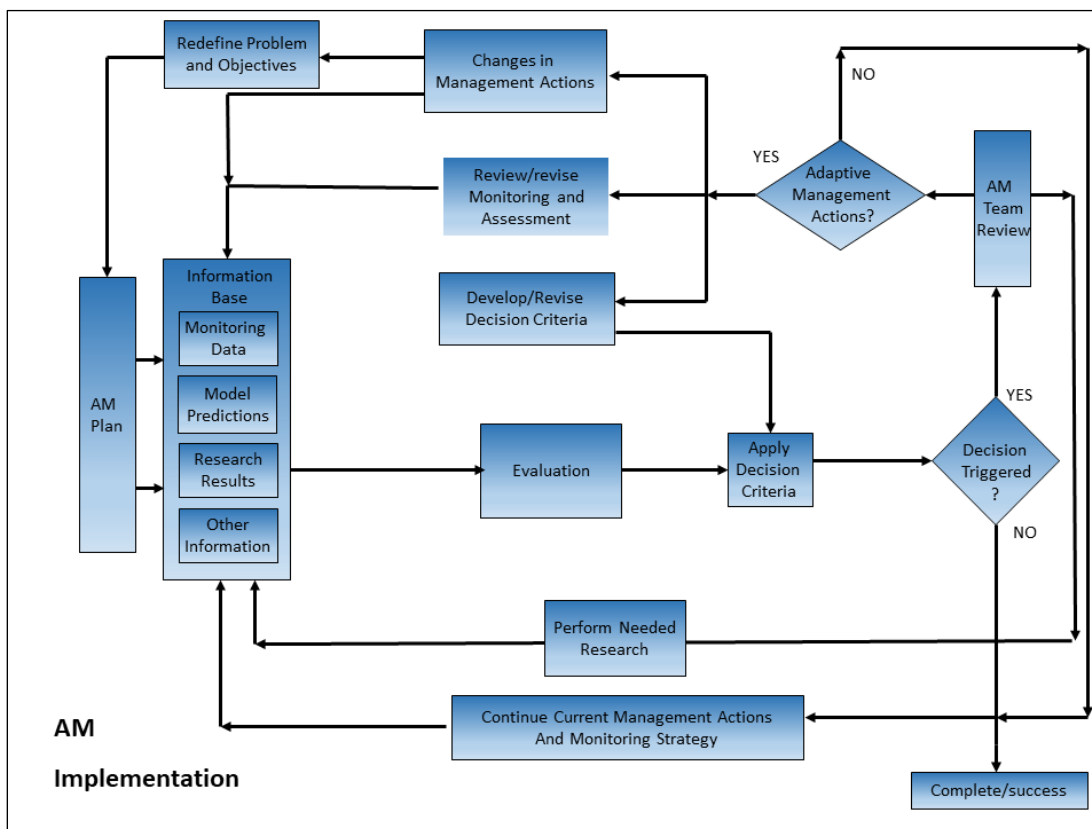
Figure 9. The design stage often involves development of experimental designs. In this example, the number of years of monitoring required as a function of the number of project/control pairs implemented (i.e. # of Randomized Control Trials [RCT]) in order to achieve a 0.8 and a 0.9 probability of detection is computed.



3.5 Planning for the implementation phase of adaptive management

Implementation describes how the adaptive management plan developed for a specific application will be put into action. During the adaptive management development phase, the AMT should determine how the proposed adaptive management plan will be implemented and describe implementation in the adaptive management plan. Monitoring plans, assessment methods, a governance structure, other adaptive management procedures, and data management, communications, and reporting should all be addressed to a sufficient level of detail so as to set expectations and identify costs. Development of schematics, as shown in Figure 10, can help orient the team, USACE management, and sponsors to the tasks required. Assignment of responsibilities, development of a timeline for the activities, and an estimation of the associated costs should also be developed and identified in the plan.

Figure 10. Schematic of the Implementation Phase for USACE adaptive management.



3.5.1 Monitoring

Effective monitoring is central to the adaptive management process and, whereas adaptive management is an intuitive concept that most grasp, monitoring is inherently complex, widely misunderstood, and rarely practiced in ecosystem restoration and adaptive management (e.g. Bernhardt et al. 2007; Brierley et al. 2010; Chapman 1998; Downs and Kondolf 2002; Walters 2007). The development of a monitoring plan to collect the data and information needed to reduce uncertainties, test hypotheses, and track progress relative to goals, objectives, and decision criteria will likely equal the level of effort needed to formulate all remaining elements of an adaptive management plan.

PROJECT MONITORING

"...includes the systematic collection and analysis of data that provides information useful for assessing project performance, determining whether ecological success has been achieved, or whether adaptive management may be needed to attain project benefits."

USACE CECW-PB, 8/31/09

Monitoring is not surveillance and it is not counting things; it is the purposeful gathering of precisely the data needed to support decisions. Depending upon the application, monitoring under adaptive management supports one or more of the following purposes (adapted from Williams and Brown 2018): (1) to evaluate progress toward achieving objectives; (2) to determine resource status, in order to identify appropriate management actions; (3) to increase understanding of resource dynamics by comparing predictions with actual monitoring data; and, (4) to develop and refine conceptual and numerical models. Monitoring should be designed to meet at least one of these purposes.

Monitoring is conducted according to protocols assembled in the development phase of adaptive management, but is not simply after-the-fact tracking in the absence of any capacity to contrast actual results with predicted responses (Nichols and Williams 2006). Monitoring is a form of applied research, which in service to adaptive management must be approached much as a laboratory experiment is approached—with a rigorous design and application of the scientific method (Noon 2003).

3.5.1.1 Steps in monitoring design

A monitoring scheme must have explicit goals and objectives, direct the gathering of data in a framework adequate to detect meaningful changes in the conditions of ecological resources, and develop reliable, scientifically defensible indicators for measuring change. Development of monitoring schema includes identification and characterization of the complement of environmental attributes and ecological processes that directly and indirectly affect the system of interest. The level of monitoring effort should be scaled to the risks and the needs of management and decision making.

Direct measures and environmental-condition indicators that are efficient at detecting effects of management actions should be identified. Where monitoring uses surrogate or proxy measures, those indicators should be subject to a validation process describing the similarities in responses of the surrogate and target measures to the same environmental phenomena, and describing the accompanying uncertainties (Murphy and Weiland 2014b). In addition, it is necessary to establish detection limits for the variables to be measured and condition indicators that are employed, and contingent decision values must be identified (thresholds or trigger points) for direct measures or indicators that have been validated.

1. *Specify the monitoring purpose and objectives and define the hypotheses to be tested and/or key management questions.*

Monitoring purposes should align with one or more of those listed in Section 3.5.1. Objectives should be closely aligned and reconciled with the project/program objectives. To the extent possible, objectives should be expressed in numeric terms.

2. *State the spatial and temporal domain (the sampling frame) of the ecosystem or the population of interest.*

The domain for management/conservation actions and policies needs to be clearly bound in space and in time. Monitoring results, and inference to restoration results or population state, are limited to this domain.

3. *Identify the monitoring state variables and indicators; describe why they were selected.* Appropriate state variables will depend on the nature of the project/program, and whether biotic or abiotic objectives have been defined. Selection of the state variable(s) should be based on the information content of the variable(s) (e.g., based on a life-history sensitivity analysis).

Monitoring data are not gathered with the hope that they will somehow prove useful. A frequent justification for monitoring additional variables is that more information about a system must be useful to its management. Although this premise is true to some degree, it does not address the key issues of effectiveness and efficiency (Nichols and Williams 2006).



The feedback required to evaluate and adapt management experiments requires leading indicators, metrics that provide information about the drivers/causal factors shaping future conditions and outcomes, rather than lagging indicators, which mainly provide information about past developments and effects. Leading indicators need to be defined on the basis of detailed change hypotheses showing how management actions are expected to lead to particular outcomes (Margoluis et al. 2013).

4. *Specify the type(s) and magnitude of change to be detected through monitoring.* The nature of the state variable(s) dictates the type of change(s) to be estimated. For example, if the area of a particular habitat type is the state variable, change in the habitat acreage over time is measured. The magnitude of change required in order to detect effect size is essential for sample design decisions. This may be the single most challenging element in the design of a monitoring scheme.
5. *Following (4) specify desired precision for the trend estimate; this uses available (pilot) data and a components-of-variance analysis.* Only after Step 4 is completed can the actual design phase of monitoring begin. Design components include, for example, plot size, number of plots, spatial distribution of plots, and sampling frequency essential for reliable statistical inference.
6. *Generate estimates of uncertainty.* Attributes of an ecosystem or population cannot be thoroughly sampled in most cases. Inference to the target is always subject to sampling variation and frequently to measurement error. Such inferences need to be accompanied by measures of estimation uncertainty.
7. *Optimize the monitoring design for obtaining data.* Develop and evaluate different monitoring designs, examining their ability to meet the required levels of precision at an acceptable cost. Optimization of the design may involve considerable work, including various efforts to refine methods before finalizing the design, which leads to the following principles.
 - a. Ensure that important time series are maintained if monitoring protocols are being improved.
 - b. Use past data and possibly intensive pilot sampling to gain insight into spatial and temporal variability of key metrics.

- c. Perform statistical power analyses to determine how false positives and false negatives vary with sampling effort, number of treatment (management action) and reference sites, the staging of implementation of management actions, and the number of years of monitoring before and after the action is implemented.
 - d. Allow for an adjustment period with new monitoring needs, and use pilot approaches to discover bugs and solve initial problems.
 - e. Complete laboratory and mesocosm work as needed to define biological/ecological effect sizes of interest, clarify mechanisms of impact, assess measurement errors, and refine monitoring protocols.
 - f. Complete modeling studies to simulate different M&E strategies.
8. *Specify the monitoring experimental design and protocols.* A monitoring design describes the combination of logical, statistical, field/logistical, and cost strategies to answer one or more management questions that feed into a management decision. Components of an M&E strategy can include (modified from Hillman 2006¹):
- a. a “statistical” design, which provides the logical structure for testing hypotheses, using spatial and temporal contrasts, and identifying the minimum requirements for implementation monitoring, process/effectiveness monitoring, and population monitoring;
 - b. a “sampling” design that describes the process for selecting sampling sites and sampling times and lays out the details of the work, gear, etc., needed to accomplish the sampling;
 - c. a “measurement” design outlining the specific performance measures and the protocols used to monitor them at the chosen sites and times; and
 - d. a “response” design that explains how the monitoring data will be analyzed to make inferences in the adaptive management evaluation step.

¹ Hillman, T. W. 2006. *Monitoring strategy for the Upper Columbia basin*. Second draft report. Prepared for Upper Columbia Salmon Recovery Board, Bonneville Power Administration, and National Marine Fisheries Service. Boise, ID.

9. *Update design as needed—make sure objectives, actions, and metrics align (adaptive monitoring).* Decision-relevance and the evolving tradeoffs between monitoring cost and precision can motivate revisions in an experimental design or monitoring protocols. It may become apparent that previously unmonitored system attributes are crucial to decision making, or that some monitoring results have marginal value. Advances in technology, changes in the spatial extent of the monitoring effort, increases or decreases in per-unit monitoring costs, and the perceived value of having more (or less) precision can lead to a reconsideration of monitoring protocols (Williams and Brown 2018).

3.5.1.2 *Monitored parameters*

The initial set of performance measures, risk endpoints (constraints such as water quality limits), and associated decision criteria, including triggers, will have been defined as part of the adaptive planning step and should be evident in the supporting conceptual models. However, the design of a monitoring plan provides an opportunity to review and revise these measures and endpoints. It is highly desirable that the selected measures and endpoints be uniquely and unequivocally affected by the management or restoration action. In other words, observed changes in the measures or endpoints should be able to be traced unambiguously to specific management or restoration actions.

The monitoring program should identify one or more direct measures (i.e., monitored parameters or data) that apply to each project performance measure. The level of detail for any selected parameter to be monitored can be reasonably guided by its contribution to assessment and decision making. For example, if a risk endpoint is to minimize the probability of increased algal abundance (i.e., blooms), measures of total chlorophyll might be considered sufficient for decision making. Alternatively, if impacts on algal community structure (e.g., diversity) define the risk endpoint, then more intensive sampling and expensive enumeration of individual algal taxa would be required.

Parameters that provide direct measures of performance are generally preferred for monitoring. However, environmental variability and uncertainties associated with project performance or anticipated management outcomes might limit the degree to which observed changes can be directly related to a specific management or restoration action. Additionally, monitoring of direct measures of performance might be

impractical or too costly. In these instances, the use of surrogate or proxy measures might be required.

A validation procedure should clearly articulate the reasoning behind the selection of the surrogate. It should explicitly describe the similarities in ecological responses by the surrogate and target to the same environmental phenomena, link demographic responses to habitat extent and condition, and clearly describe the uncertainties that accompany the relationship between the status and trends of the surrogate and those of the target under common circumstances (Murphy and Weiland 2014b).

3.5.1.3 *Methods and protocols*

The monitoring plan should identify the technical methods used to obtain the specified data for each of the monitored measures and endpoints. Included are methods for sample collection, sample processing, data management, and communication of monitoring results to decision makers. The methods should be incorporated into a Standard Operating Procedure (SOP) that can be followed by any institution and should include descriptions of sampling designs (i.e., locations, frequency), sampling procedures, sample storage and preservation, and processing of samples to generate data. Scientifically recognized and generally accepted standard methods should be used whenever possible. Novel performance measures might require innovations in methodology. New methods should be rigorously evaluated and offered for appropriate technical review prior to incorporation in the monitoring program. Quality assurance and quality control (QA/QC) protocols should be identified.

If different monitoring plans are implemented for separate but related projects, performance measures or risk endpoints common to the projects should be measured using the same or easily compared methodologies. Opportunities to economize should also be pursued in the design of monitoring for multiple projects. Redundant monitoring can be useful where significant uncertainty is involved and common monitoring across multiple projects would provide valuable information about causes of variable responses; in other cases, it may be avoided or minimized by design. In some cases, resources from multiple projects may be combined to incorporate monitoring measures that are generally desirable and informative but not affordable by the individual projects.

3.5.1.4 *Statistical power*

The monitoring plan should define the sampling methods and procedures required to develop data of sufficient quality (i.e., accuracy, precision, statistical power) for use in decision making. To achieve high-quality data, the number of sample locations and frequency of sampling should be determined for each measure and endpoint. Given an initial estimate of sample variance, standard statistical procedures are available to calculate the number of samples required to obtain a specified level of performance for hypothesis testing (e.g., Cohen 1988, Thomas 1997).

The decision-making process should estimate the desired statistical power for each monitored parameter. Power analysis is a useful tool in the planning of monitoring schemes and can be used after data analysis to improve the interpretation of non-significant results. Unfortunately, the definition of adequate statistical power in the ecological literature often appears arbitrary with minimal attention to the decision context of the study, and a convention has evolved where significance and power levels are set at 0.05 and 0.80, respectively (Di Stefano 2003). Instead, the relative costs of both Type I and Type II statistical errors need to be considered for each situation (i.e. a Type I error isn't always four times costlier than a Type II error).

The accuracy and precision necessary for an individual measure will depend in part on the ability and cost to obtain quality data, the importance of the measure in the overall assessment, the sensitivity of the measured parameter to the proposed management action(s), the level of uncertainty to be resolved, the level of risk and the nature of the decision-making process, including the consequences of ill-advised decisions. For example, demonstrating simple presence-absence of a species might reasonably require less of a monitoring investment than determining quantitative changes in the abundance of an existing species. Data demonstrating that a population is increasing can be less accurate or precise than data required to demonstrate that a population is increasing by some specified percentage or rate. The necessary result of this activity is the specification and documentation of data quality objectives for each of the performance measures and risk endpoints included in the assessment. The recognition that different data quality objectives can be justified for adaptive management can guide the development of efficient and economical monitoring plans.

3.5.1.5 *Monitoring plan and costs*

The key product of the monitoring step is a detailed monitoring plan, with an associated data management plan, QA/QC procedures, and a cost estimate for these activities. The monitoring plan should identify what will be measured in relation to the goals and objectives and the relevant methodologies to be used in acquiring the necessary data and information. The frequency and intensity of sampling should be specified for each performance measure and risk endpoint. Units of measure and degrees of required accuracy and precision (i.e., data quality objectives) should be defined initially for each performance measure and endpoint. A system for data management and quality assurance and control should be provided. Finally, expectations regarding the term, roles and responsibilities, and costs for monitoring must be described.

Iteration through development of the monitoring plan is to be expected, and the level of detail at the feasibility stage of a project is usually much lower than is needed for a final plan (which must provide specific protocols, for example). Optimal monitoring may also require iteration following implementation – an adaptable monitoring scheme. Field values are typically required for estimating statistical parameters. Absent such data, preliminary estimates are used for an initial monitoring design. After some monitoring, the AMT should review their initial estimates of the statistical parameters, and update them using the newly obtained data if warranted. These new estimates can then be used to re-evaluate and update the monitoring design.

Depending on the complexity, monitoring plans might be more usefully developed as separate appendices to the adaptive management plan. Tabular descriptions and summaries of the monitoring and information management strategies in the plan can be used to orient the parties to the needs and help ensure that the plan addresses the intended purposes (e.g., Table 4). The monitoring plan should include a discussion of duration for monitoring and supporting data management activities and should describe the roles and responsibilities for the USACE, sponsors, and others.

COMPONENTS OF A MONITORING PLAN

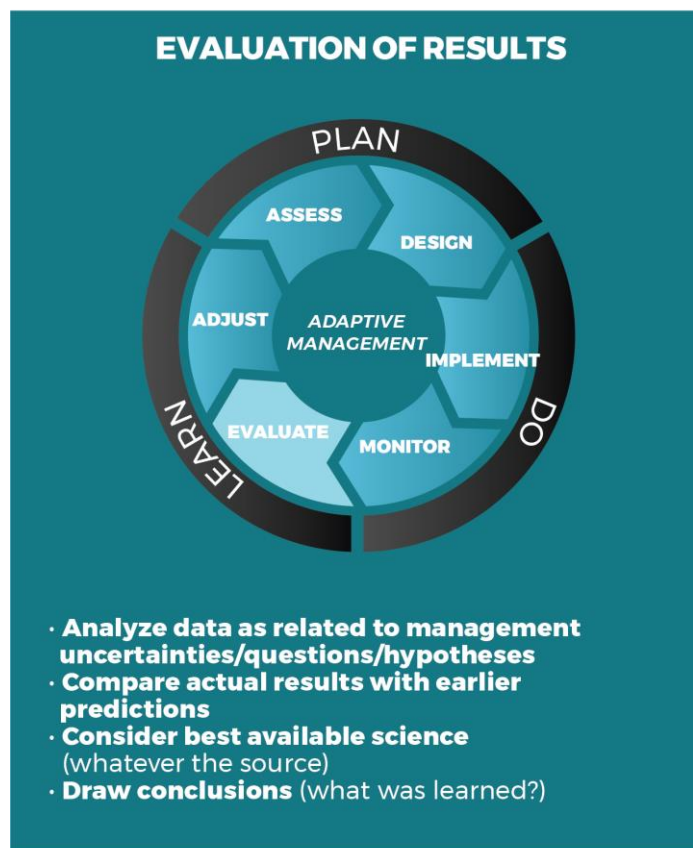
- Monitoring objectives
- Parameter identification
- Field protocols for data acquisition
- Sampling frequency and intensity
- Required accuracy and precision
- Sample and data management plan
- QA/QC procedures
- Cost estimates

Table 4. Example table of information to guide development of a monitoring and data management plan.

Goals and objectives	Data quality objectives			Monitoring program – sampling design				Data management			Decision making
Monitored parameter	Units	Data quality	Method	Number of samples	Sample locations	Sampling frequency	Sample processing	Data analysis	Data storage	Data reporting	Decision criteria
Performance measures (examples)											
Restored wetlands	Habitat units	N/A	Aerial imagery	10	UTM coordinates	End of project	Spatial analysis	GIS	GIS files	Maps, statistics	100 HUs
Population size of desired species	Individuals or biomass	25% coefficient of variation (CV)	Permanent quadrats	75	Stratified random samples	Once per month	Individual counts, biomass weighed	Univariate statistical analysis	Spreadsheet database	Simple statistical summaries	50% incremental increase
Plant community diversity	Simpson diversity	15% CV	Field transects	10 transects; 20 samples each	Stratified random locations	Before and after project construction	Individual species counts	Calculation of diversity index	Relational database	Simple statistical summaries	15% incremental increase
Establishment of an invasive species	Presence/absence	N/A	Standard field sampling	100 random samples	Random quadrats	One sample per year during project	Field data sheets	Simple recording of presence/absence	Spreadsheet database	Maps, statistics	Eliminate invasive species
Bluegreen algae biomass	Individuals and g/m3	75% CV	Filtered water samples	50 locations; 1 sample per location	Stratified random samples	Monthly Sampling	Species counts, total biomass as carbon	Univariate statistical analysis	Spreadsheet database	Simple statistical summaries	Minimize blooms
Dissolved oxygen	mg/L	2% CV	Standard sampling methods	100 locations; 1 sample per meter	Regular grid over project area	Daily sampling	Standard chemistry methods	Univariate statistical analysis	Spreadsheet database	Simple statistical summaries	Avoid hypoxia

3.5.2 Evaluation

The assessment process compares the results of the monitoring efforts to the model predictions and decision criteria defined as the desired values of project performance measures and/or acceptable risk endpoints (Figure 6). The assessment step defines the frequency and timing for such comparisons of monitoring results to the selected measures and endpoints. Methods for data analysis and summarization should also be identified in developing the assessment process. The nature and format (e.g., qualitative, quantitative) of these comparisons are defined in this step. The resulting assessment methods should be documented as part of the overall adaptive management plan. It is important that the adaptive management plan identify those individuals or organizations that will perform or otherwise be responsible for the assessment. The procedures for documenting and communicating the results of each assessment to managers and decision makers as well as to stakeholders should be described as part of the assessment step.



3.5.2.1 Modeling in support of adaptive management

Modeling plays a central role in adaptive management. As already mentioned, CEMs developed early in the planning process guide the identification of management actions, metrics for assessing performance, and hypotheses regarding key (decision-relevant) uncertainties. They also serve as a basis for the development of numerical models used to assess the effects of alternative management actions and to predict ecosystem response to drivers of change. Management decisions and operations are driven by scenario analyses and model projections based upon changes in the system state. Models are often required to help interpret the

implications of data acquired through monitoring as they help us project changes in system state and processes to estimate future conditions. Modeling during adaptive management planning is used to help understand sensitivity and focus management experiments, avoiding the need for management learning by trial and error.

The models developed and applied to effects analysis during the planning stages are indispensable to the implementation under adaptive management. The models are again applied in the evaluation phase to assess the implications of observed performance (e.g. population response due to monitored habitat changes) and determine management needs (using model projections of habitat and population for alternative management actions, for example). The models are used to consolidate information, predict outcomes, quantify performance, and provide information needed by decision makers to determine the best course of action under adaptive management.

Adaptive management recognizes the need for action in the face of uncertainty, and complete or perfect ecosystem models (which are not likely to be perfected in any case) do not need to be crafted in order to support decisions (Walters 1997). A primary mechanism for capturing and applying knowledge is incorporating relevant information into model improvements. Information sources include a) assessments based on monitoring data updated on an annual basis, b) information from research studies or short-term additional monitoring and c) information from external studies deemed to be of sufficient quality and relevance.

Information may support structural changes to the models — adding new mechanisms or changing the scale, for example. These changes require additional time to develop, code, and test. Comparison of old and new model results (using the same parameters) can provide understanding of the consequences of the changes to model structure and function and the decisions informed by modeling.

Model validation procedures test model accuracy and precision by comparing model predictions with observations that were not used to parameterize the model. Model accuracy can be statistically assessed by identifying the percentile of the model distribution at which the observed value falls. Results near the 50th percentile indicate high accuracy, while results near the 0 or 100th percentile indicate low accuracy. Results from

model validation may be used to interpret projections, adjust management decisions (to accommodate systematic over- or under-prediction) and to identify information and model development priorities.

3.5.2.2 *Frequency of assessment*

The implementation plan should specify the frequency and scheduling of assessments. This specification should address:

- Relevant temporal scales of the performance measures and risk endpoints,
- The time required to obtain sufficient monitoring results and analysis for meaningful comparisons with the decision criteria,
- The consequences (ecological, socioeconomic, political, stakeholder) of variances¹ with decision criteria,
- The logistical requirements to perform the assessment,
- The availability of the adaptive management personnel, and
- Funding.

The adaptive management plan should describe procedures for documenting the assessments. Such documentation might include summaries of meetings in which assessments were performed. The results of monitoring and their comparisons with decision criteria should be preserved, for example, in the form of tables, figures, and supporting text for each assessment. Variances determined for any of the performance measures or risk endpoints should be recorded along with suggested actions to address variances (i.e., to adaptively manage or continue the status quo).

3.5.2.3 *Actionable science*

The term “actionable science,” coined by the Department of Interior’s Advisory Committee on Climate Change and Natural Resource Science (ACCCNRS 2015), serves as a useful concept for guiding the information necessary to support adaptive management decision making while fulfilling the best-available science mandate. Actionable science provides data, analyses, projections, or tools that can support decisions regarding management of the risks and impacts of operations on the Missouri River.

¹ For the purposes of adaptive management, a variance is defined as the difference between a monitored value of a performance measure or risk endpoint and its corresponding decision criterion used in decision making.

Ideally co-produced by scientists and decision makers, actionable science creates rigorous and accessible products to meet the needs of stakeholders.

The following principles, adapted from ACCCNRS (2015), are presented to guide efforts for producing actionable science and are entirely consistent with principles for monitoring and evaluation:

- Scientists, decision makers, and stakeholders working in concert are more likely to arrive at actionable science than scientists acting alone.
- Start with a decision that needs to be made. Research needs are rarely precisely known (and seldom clearly specified) in advance, so they must be identified collaboratively and iteratively.
- Give priority to processes and outcomes over products, and use the process to build connections across disciplines and organizations and among scientists, decision makers, and stakeholders.
- Periodically evaluate the utility of products and processes and the ability to take actions based on the science developed by the program. Use the lessons learned to adjust products and processes as needed and to refine the definition of “actionable” based on evolving views of risk.

This approach recognizes that actionable science is not only actionable information, but also includes longer-term processes and relationship-building to help ensure the appropriate use of that information. Time and resources will be required to develop and maintain interpersonal interactions among scientists, decision makers, stakeholders, and other users of the scientific information. Deploying these services efficiently and effectively also requires building connections across disciplines and among the organizations engaged in the effort. The budgets for the program and individual projects, project evaluations, and staff incentives and evaluations should reflect commitment to this need.

3.5.3 Governance

Governance of an adaptive management plan includes the approach for converting knowledge into improved management through decision making, identifying:

- **what** decisions need to be made
- **who** is involved in the decision process
- **how** decisions are made
- **when** decisions are required.

The adaptive management plan should describe the process whereby the results from monitoring and assessment will be used to make decisions concerning project management. This includes identifying who is responsible for making the decisions, how the decision-making group operates, how they report their decisions, and provisions for the resolution of conflicts. The governance process should: (1) comply with all pertinent legal requirements; (2) maintain transparency and involve all relevant entities in the adaptive management learning process and in the formation of recommendations for decisions; and, (3) help efficiently achieve the project or program's goals and objectives.



There is no “one-size-fits-all” approach to effective governance. An effective governance structure and process will depend on the purpose and needs and will have clear expectations around outcomes (Rijke et al. 2012). Functions served by governance include: (1) trust-building, (2) knowledge generation, (3) collaborative learning, (4) preference formation, and (5) conflict resolution (Green et al. 2013). Although lessons can be learned from other adaptive management programs, an effective system of governance for any application requires consideration of how the above functions apply within the context of the unique ecological and social conditions for that application.

The concept of “adaptive governance” has emerged as an important component of an adaptive management strategy, adding the need for organizational and institutional flexibility to change as a consideration in the decision process. Recognizing that the adaptive management plan

itself may need to evolve and providing a process for that change is a key consideration in the development phase.

3.5.3.1 *Decision makers*

The composition of individuals and organizations making adaptive management decisions for specific USACE applications may differ depending upon the authority, sponsor and scope, and complexity of the project or program. Decisions are typically made by the Corps' Division and District Commanders — subject to their authorities and appropriations — with input from sponsors and the public, as appropriate. Corps commanders cannot abdicate their responsibilities but will often delegate some decisions to other management levels within the organization. The AMT (and sometimes other entities) typically inform decision makers and may make recommendations.

Some decisions should be a joint consideration of USACE leadership and the sponsor or other federal agencies (e.g., changes to targets, decision criteria, or the governance process itself). Joint decisions may be possible in some cases; more often, existing authorities and jurisdictions establish that certain entities are responsible for particular decisions and the governance process is structured to ensure those decisions are informed by the partners. The adaptive management plan should clearly identify the roles and responsibilities of the decision makers in these circumstances. Figures 11 and 12 provide examples of governance structures for a project and program, respectively, where some shared decision responsibilities exist.

Figure 11. Example governance structure for the Poplar Island Environmental Restoration Project (PIERP) (USACE 2005).

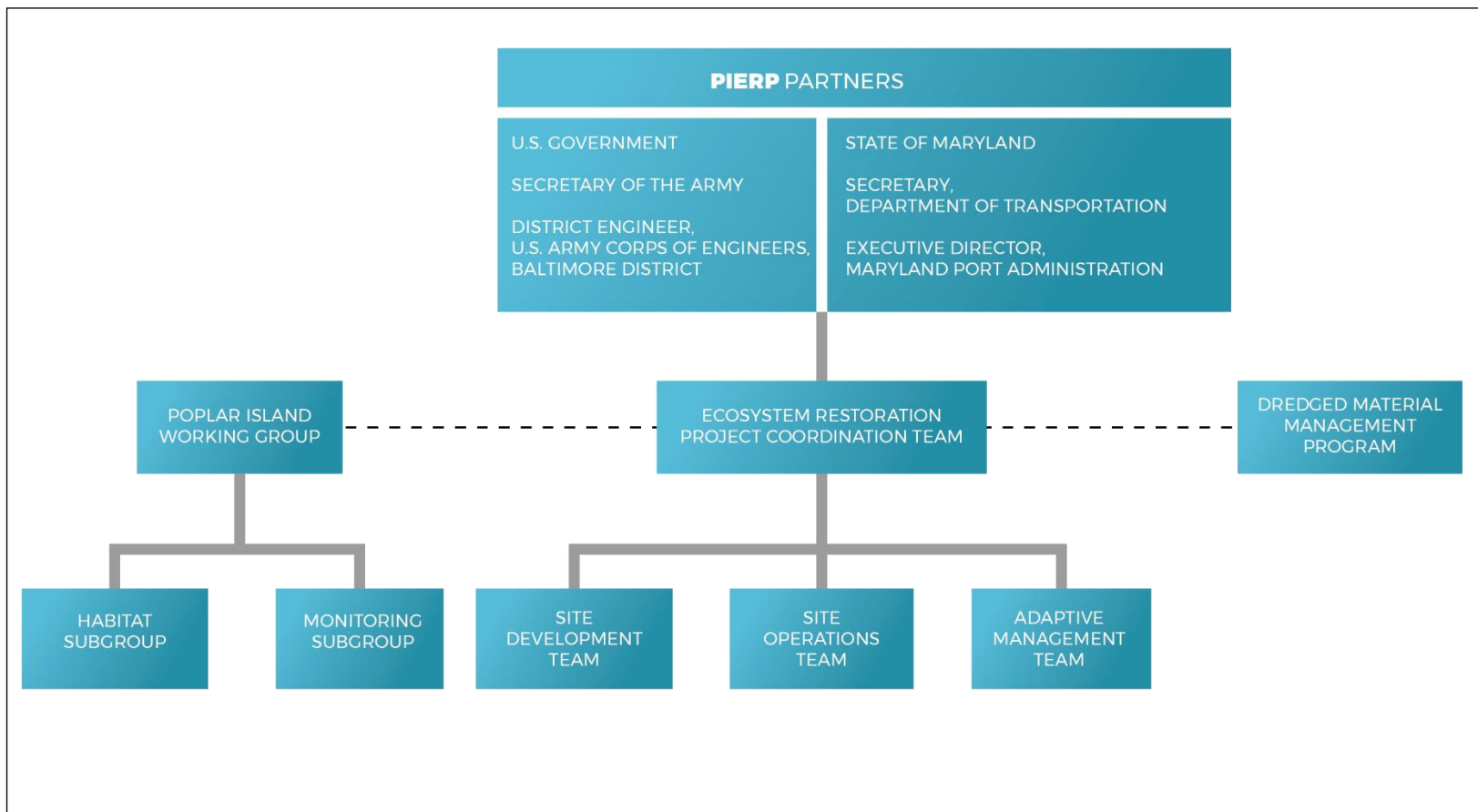
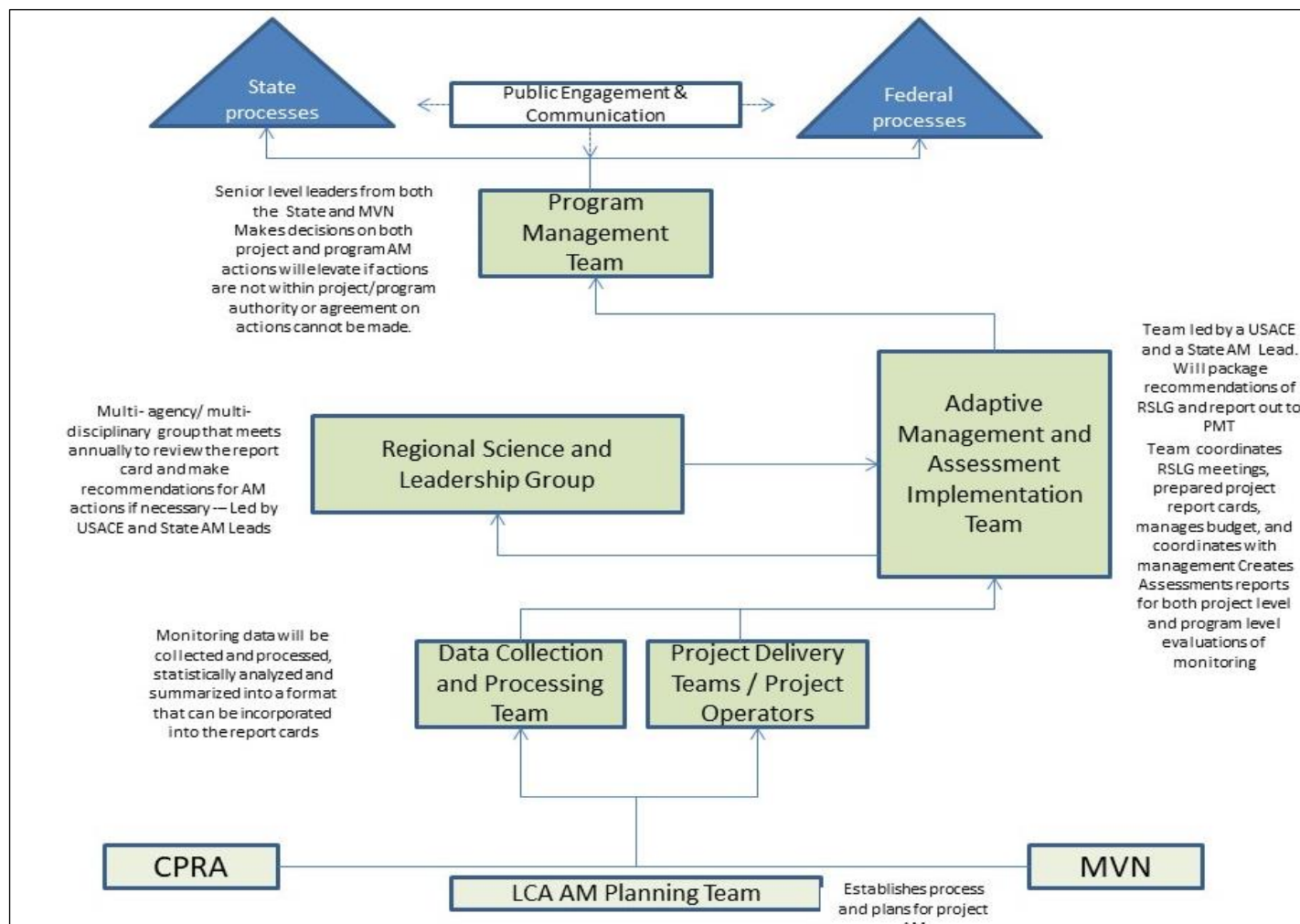


Figure 12. Example governance process for a large program, drawn from Louisiana Coastal Authorities.



3.5.3.2 *Decision making*

The most evident and essential function of governance for adaptive management is to facilitate effective, transparent decision making. However, decisions may be complicated by several important legal, social, political, and economic dimensions. Therefore, the design of the governance structure and processes must anticipate the range of decisions needed to translate knowledge gained into effective and acceptable management and promote decision making at the lowest practicable level.

Various decision-support frameworks can be used to support adaptive management. Schwartz et al. (2017) discussed five frameworks with broad recognition and applicability: (1) strategic foresight; (2) systematic conservation planning; (3) structured decision making; (4) open standards for the practice of conservation; and (5) evidence-based practice. They emphasize the value of using these decision tools and note that using any framework in isolation may diminish benefits since no one framework covers the full spectrum of potential decision challenges.

Scenario analysis (a strategic foresight tool) can be used in the planning (i.e., development) phase to explore the range of decisions that might be needed and how they will be addressed. The following types of questions can be used to explore situations that might arise and help the team to identify associated governance needs (these exercises often lead the team to revisit objectives, metrics, monitoring strategies, etc., improving the planning process):

- How will project success be determined and what steps are needed to “close out” a project?
- What circumstances might arise that could cause the system response to differ from desired or anticipated response? What could/should be done if this were to occur?
- How much time should it take for a response to be evident or quantifiable?
- Can response be determined directly from monitored data, or will interpretation from multiple lines of evidence be required?
- What role will sponsors and other stakeholders play in the decision process? How will disputes be resolved if there is disagreement over decisions?

- How will interruptions in funding or other impediments to implementation be addressed?

The above list is a sampling of the scenarios and considerations that might be explored. In practice, dozens of similar questions will arise, and it is important that the AMT fully explore these issues with USACE leadership, sponsors, and stakeholders to ensure the decision structure and process are capable of addressing needs. Adaptive management decisions that will be required on a routine (typically annual) basis include selecting from the following:

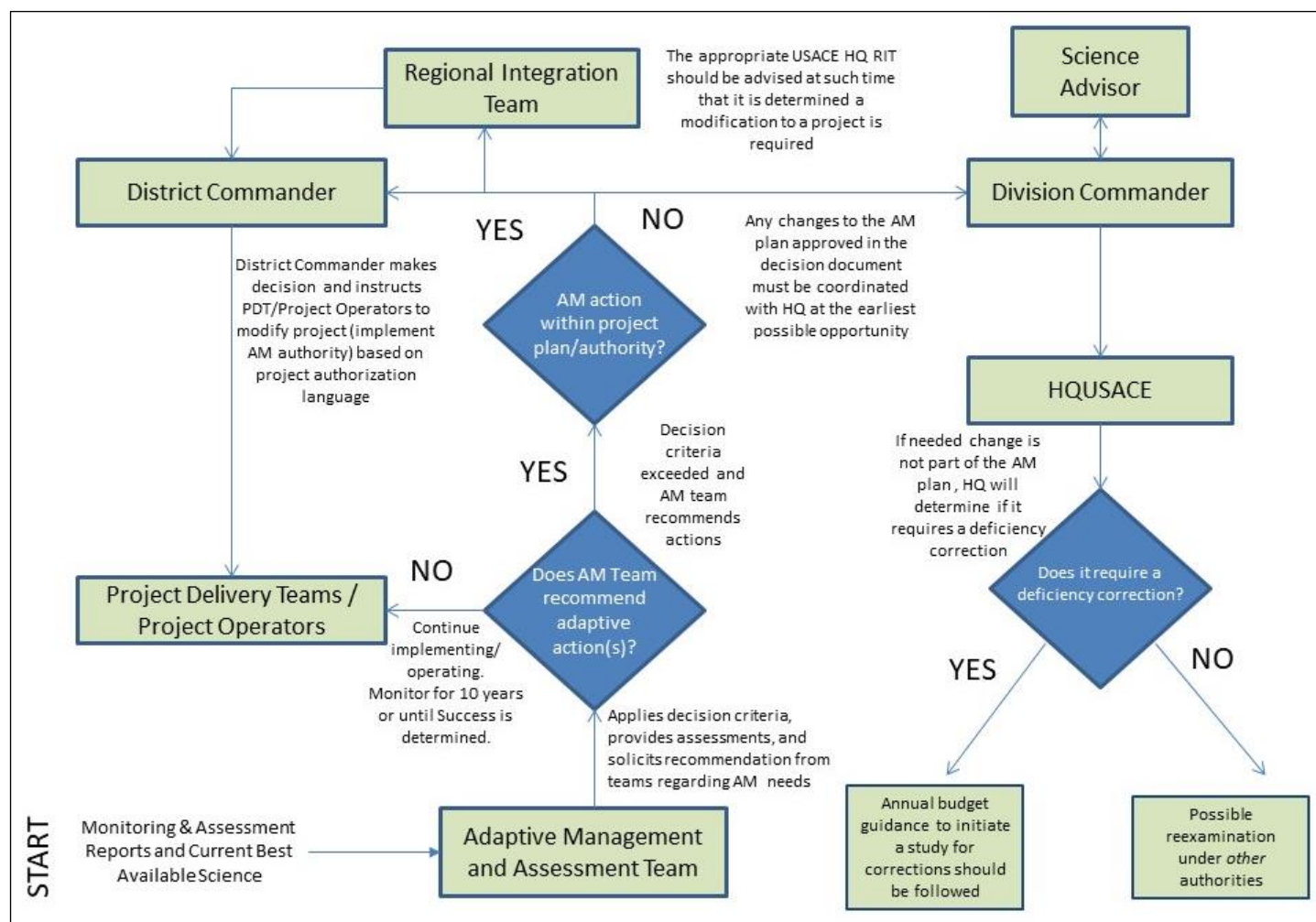
- To continue the current management or restoration action without modification. This decision would be warranted if monitoring results demonstrate that the response to management is as expected or acceptable, if it is too soon to conclude whether response is as anticipated, or if, despite unexpected or unacceptable response, no other option is currently available.
- To modify the implementation of the management or restoration action, if the current implementation is not achieving management or restoration goals, or if risks are not being effectively avoided, minimized, or managed.
- To implement an alternative management or restoration action to more effectively achieve the originally specified management goals and objectives or to minimize or avoid risks. If such actions exceed the scope of the current authorization, it may prove necessary to return to the reformulation stage of the adaptive management process.
- To adjust components of the plan. It may become apparent from monitoring that the initial goals and objectives were unreasonable, and a decision may be made to adjust the goals and/or objectives. Other components of the adaptive management process might also require adjustment, such as monitoring protocols, analysis techniques, and the governance structure or process. Provisions for such change should be anticipated in the adaptive management plan and decision makers should have a mechanism to implement these changes when needed.
- To halt adjustment and prepare a post-authorization change report, general re-evaluation report, or seek new authorization to remediate the problems if the restoration action is not achieving goals or objectives or successfully addressing risks. Such a decision may require informing HQUSACE and sponsors. De-authorization may also be an option in rare cases.

- To declare success and stop federal funding for monitoring and adaptive management if the goals and objectives have been demonstrably achieved or a trajectory to success is assured.

The complexity of the decision-making process can be influenced by the number of performance measures included in the assessment, as well as the rigor of the assessments (Figure 13). Methods of structured decision making supported by multi-criteria decision analysis (e.g., El-Swaify and Yakowitz 1998, Linkov et al. 2006, Andrew et al. 2008), meta-analysis (e.g., Wolf 1986, van den Bergh et al. 1997), or other multi-variate approach can support decision making in adaptive management applications characterized by multiple performance measures and complicated assessment methods.

The adaptive management plan should address the number of variances in any single assessment that would trigger any of the decisions just outlined. It is possible that a single measure or endpoint (e.g., impacts to an endangered species) may be sufficiently important (e.g., human safety, dam failure, impacts to an endangered species) that a demonstrated variance would require a decision other than to continue the current management action. Alternatively, and again depending on their associated consequences, a larger number of variances of lesser impact might be required to change an ongoing management action.

Figure 13. Example of a general decision process for USACE adaptive management projects.



A detailed description of the process whereby results of the project monitoring and assessment are evaluated in relation to the decision criteria and decisions are made is required. The decision-making process can be disaggregated into the components described in Table 5.

Table 5. Components of a decision-making process (Rubenstein 1975).

Goals and Objectives	What the USACE planners and decision makers desire to achieve. Explicit statements of anticipated desired outcomes or performance, as well as risks to be avoided, minimized, or mitigated.
Decision Alternatives	Alternative actions that the managers and decision makers control and select among; for example, proposed planning alternatives developed during a feasibility study.
States of Nature	The broader environmental context wherein the selected alternatives or management actions manifest themselves; for example, climate change, stakeholder values, business cycles, and USACE policy.
Outcome	The results from a combination of a management alternative or management action and states of nature; for example, the acreage of wetlands restored by river diversions during a drought period or in relation to sea level rise or regional subsidence.
Utility	The value of an outcome in relation to achieving the goals and objectives.

3.5.3.3 *Conflict resolution*

Management and restoration in the public sector often require decisions that involve choosing among alternative actions. The choices can be perceived as competing, incompatible, or even exclusive, but inevitably are a matter of weighing tradeoffs. Decisions can become controversial, and conflicts can arise when participants and/or affected parties (stakeholders) have different philosophies, risk tolerance, values, or goals (Shields et al. 1999).

There are several approaches to conflict resolution (e.g., see Mostert 1998). The decision-making process should include methods for minimizing and resolving conflicts that might arise during implementation of adaptive management. It is important that the process be defined before conflicts arise to ensure the efficient and continued operation of the adaptive management process; clearly describing the approach in the adaptive management plan is important. While intervention or mediation by higher-level authorities in the participating organizations may be needed, it is best if issues can be resolved at lower management or technical levels.

3.5.3.4 *Procedures for implementation*

Implementation requires the formulation of standard procedures and a governance process that documents how decisions under adaptive management will occur. Practicality suggests that the procedures be neither so formal as to pre-empt action nor sufficiently informal that consistent and productive activity proves impossible. Consensus-based procedures may prove workable and efficient, depending on the makeup of the AMT. Majority-rule or more autocratic approaches to executing an adaptive management program might also be considered, depending on the nature and authorization of the management mission, program, or project. The standard operating procedures should be described as part of the adaptive management plan.

The documented procedures for carrying out the adaptive management plan should include, but not be limited to:

- Specifying the mechanisms for responsible personnel to execute the adaptive management plan and process. These mechanisms might include meetings, teleconferences, web meetings, and electronic or written correspondence.
- Delineating the location and frequency of such interactions, as well as logistic responsibilities necessary for implementing the adaptive management plan.
- Formulating rules or policies that stipulate how the members will interact to conduct business (e.g., evaluation of monitoring results in relation to decision criteria). These interactions might reasonably include provisions for the participation of technical support personnel or stakeholders.
- Communicating the deliberations of the adaptive management team to decision makers.
- Making or participating in adaptive management decisions.
- Providing guidance and assurance for monitoring, analysis, and data management supporting the decision process.

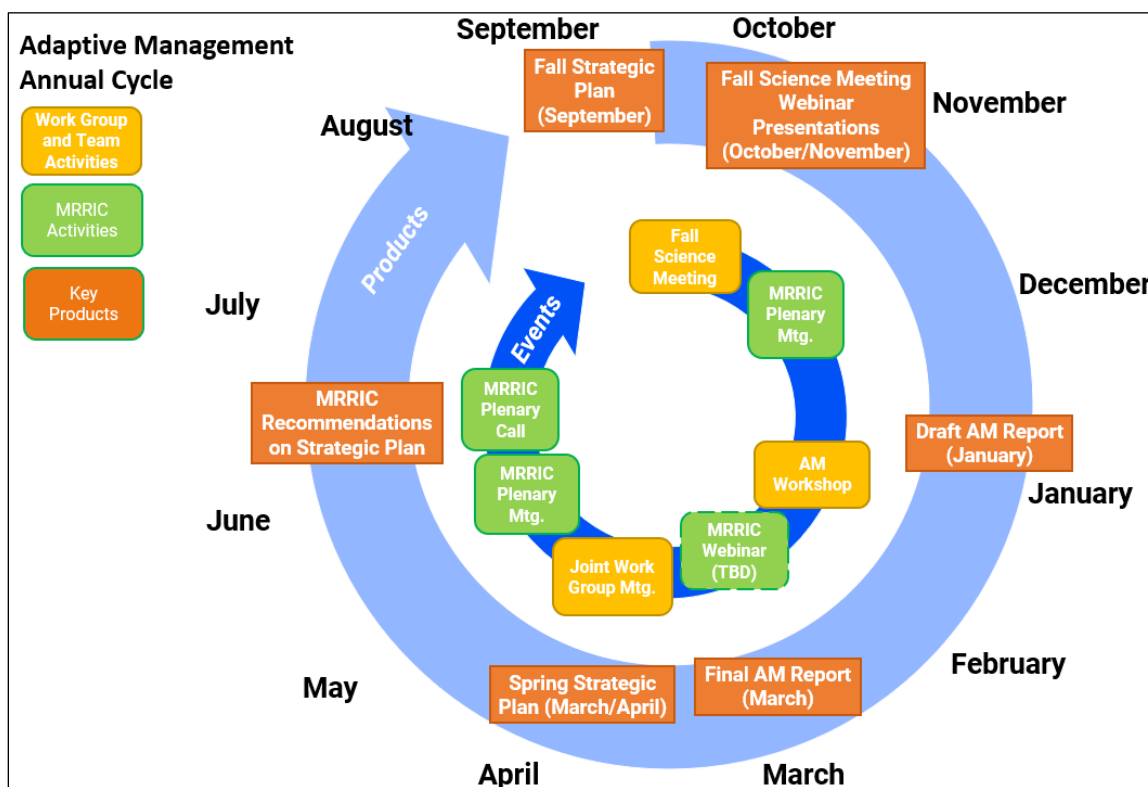
The intent in developing and documenting operating procedures is to produce a coherent process that can be carried forward in a consistent and productive manner independent of changes in the composition of the AMT. Operating procedures can be modified during the course of implementing adaptive management. Understanding the operating

procedures is also necessary to establish reasonable cost estimates for the implementation of adaptive management programs.

Development of a timeline – usually on an annual cycle basis – is recommended to set expectations, to help ensure that the necessary time and resources are available to implement adaptive management, and to structure details of the process. Monitoring needs are often seasonal, which provides a convenient basis for establishing a time table. A certain amount of time may be required for QA/QC of monitoring data before analysis can begin. Analysis, reporting and communication of the data will require time, as will any model updates and projections of future conditions that decision makers may require. Decisions must be timely in order to mesh with USACE budgeting processes. The annual cycle may be further complicated if significant engagement with sponsors or other agencies is necessary. Figure 14 shows an example of a timeline involving stakeholder and product development on a recurring annual basis involving engagement with agencies and stakeholders (adapted from the science and adaptive management plan for the MRRP)¹.

¹ Fischenich, J. C., K. E. Buenau, J. L. Bonneau, C. A. Fleming, D. R. Marmorek, M. A. Nelitz, C. L. Murphy, G. Long, and C. J. Schwarz. 2018. *Missouri River recovery program science and adaptive management plan*. ERDC EL TR (in preparation). Vicksburg, MS: U.S. Army Engineer Research and Development Center.

Figure 14. Example of a recurring annual timeline involving engagement with agencies and stakeholders (adapted from the science and adaptive management plan for the MRRP¹).



3.5.4 Data management, communications and reporting

A critical component of adaptive management is accurately transforming the best available science into actionable and accessible information and communicating information in the right format and in a timely manner to support decisions regarding implementation of the program. Data management, reporting and communication needs and strategies should be identified in the adaptive management plan, and be developed to a sufficient level of detail to permit assessment of associated costs. Data management includes the collation, storage/retrieval, analysis, summarization, and communication of monitoring results and related information (e.g., published information, model results) used in support of adaptive management. This is typically a task of the AMT. The data management plan should identify the computing hardware and any specialized or custom software used in data management for an adaptive

¹ Fischenich, J. C., K. E. Buenau, J. L. Bonneau, C. A. Fleming, D. R. Marmorek, M. A. Nelitz, C. L. Murphy, G. Long, and C. J. Schwarz. 2018. *Missouri River recovery program science and adaptive management plan*. ERDC EL TR (in preparation). Vicksburg, MS: U.S. Army Engineer Research and Development Center.

management program. The AMT should collaborate with the data managers to identify the types of data and information to be included in the data management system, establish convenient formats for storing and retrieving data, and guarantee the preservation of the data (i.e., backup versions, electronic and/or hard copy).

Adaptive management benefits from an open and transparent management practice wherein the results of monitoring, assessment, and decision making are routinely and consistently documented and communicated. It will be important to develop, implement, and periodically re-evaluate a communication plan that considers all of the different audiences, and the diverse forms of reporting that are most appropriate to each audience (e.g., decision-oriented syntheses, annual reports, reporting sessions, science workshops, peer-reviewed reports and journal articles, fact sheets, videos, presentation summaries).

These topics are discussed further in Appendix E, which describes adaptive management implementation.

4 Summary and Key Take-Away Points

Implementation guidance for Sections 2036 and 2039 of WRDA 2007 and Section 1161 of WRDA 2016 provide monitoring requirements for certain USACE projects and require that either ecosystem restoration projects include appropriately scoped adaptive management plans or provide sound justification for why adaptive management is not warranted. Criteria in Section 2.1.1 define the circumstances when adaptive management is not needed.

Adaptive management is an iterative process for managing natural resources (Gunderson and Holling 2002, Gray 2000, Walters 1986, Holling 1978). Under adaptive management, decisions are based on the best available (yet often incomplete and imperfect) scientific data, information, and understanding, recognizing uncertainties that introduce risks to the achievement of goals and objectives.

Adaptive management aims to overcome the limitations of static management approaches by institutionalizing cycles of evaluation and subsequent change. A management plan is considered temporary, with revision based upon information garnered from ongoing monitoring and evaluation possible. The emphasis is on learning by doing and being responsive to new information and system feedback. This requires new approaches to management and decision making that are flexible and support ongoing learning.

Adaptive management should not be mistaken as a “trial-and-error” management approach. Adaptive management uses performance-related hypotheses, conceptual or other causal models, and directed monitoring and assessment to confirm and improve understanding of ecological processes and help explain why the goals and objectives were or were not achieved. The active form of adaptive management, which is generally preferred, treats projects as experiments and applies the scientific process to their evaluation.

Adaptive management’s true measure is in how well it helps meet environmental, social, and economic goals, increases scientific knowledge, and reduces tensions among stakeholders (NRC 2004). These benefits come with added costs from the monitoring, assessment, and governance that accompany adaptive management.

Adaptive management can be regarded in terms of two principal phases; the development phase wherein the adaptive management strategy is developed, the plan prepared concurrently with traditional Corps' planning activities, and an implementation phase during which the strategy is executed. Adaptive management adds several considerations to the traditional planning process, but is harmonious with SMART planning.

Adaptive management planning requires consideration of the flexibility and reversibility of alternatives and a determination of what adjustments to the project restoration actions may be needed. Plans must also be made for the acquisition and management of data, as well as the analysis and decision making required to implement management decisions. These requirements force planning teams to contemplate objectives and project performance at a high level of detail, and the resulting plans inevitably benefit from this additional degree of thought.

The explicit treatment of uncertainty as part of planning, the development of conceptual and numerical models to evaluate management actions, and the treatment of management decisions as experiments with monitoring to assess performance are at the core of adaptive management. Decisions are based on the current best available scientific information, overlaid with other relevant policy and socio-economic considerations following a governance process laid out in the plan. If the adaptive management is collaborative, sponsor and stakeholder engagement occur as part of the process. In any case, objectivity, transparency, and effective communication are used.

Current guidance provides for federal funding of monitoring and adaptive management for up to ten years, or until the project has been deemed successful. Success for ecosystem restoration projects occurs when decision criteria suggest that the objectives have been met, or that specific thresholds have been crossed and the ecosystem is on a recovery trajectory that will result in the achievement of the objectives.

4.1 Key points

Adaptive management works best when: (1) management flexibility is incorporated into the design and implementation of programs or projects; (2) projects and programs can be implemented in phases to allow for course corrections based on new information; (3) interagency collaboration and productive stakeholder participation are fostered; and,

(4) scientific information is introduced into the decision-making process and guides managers not only during planning, but also after project implementation (Fischenich 2012).

Projects planned under ecosystem restoration authorities must include adaptive management plans or sound justifications for why adaptive management is not warranted. For programs and projects not subject to these requirements (e.g., certain environmental management actions and engineering projects), application of adaptive management should be evaluated on a case-by-case basis.

To be effective, adaptive management nominally requires 1) one or more critical uncertainties affecting outcomes; 2) the ability to monitor and assess the effects of management; and, 3) the ability and will to change management decisions based on new knowledge. Absent any of these attributes, a decision process and risk management strategy other than adaptive management is required. Even if the above criteria are met, the decision to employ adaptive management should be made with the understanding of the limitations and costs of adaptive management.

Adaptive management has a critical planning component that requires careful consideration of uncertainties and outcomes. It is not strictly a post-construction consideration, but instead is foremost a planning activity that integrates fully with other USACE planning activities.

The site specificity of environmental and natural resource management problems and the diversity of authorities, scales, stakeholder interests, etc., means that there is no one-size-fits-all prescription or blueprint for adaptive management. The adaptive management plan, implementation strategy, and governance structure must be adapted to the needs of each situation.

Despite the unique attributes of individual projects, the basic process, underpinning principles, and aims of adaptive management remain the same and provide a foundation for developing and implementing effective adaptive management plans that meet USACE needs.

Adaptive management is most effective when it is collaborative in nature, engaging stakeholders early and at all stages. Failure to keep stakeholders involved, and their interests accounted for, can lead to loss of support for

necessary decisions. Adaptive management can only be successful when decisions are grounded both in good science, and political and practical realities. Engagement of external expertise and facilitation services can help with any adaptive management effort and may be crucial for establishing trust with stakeholders. Use of independent science panels are encouraged for the same reasons.

Monitoring and adaptive management plans should be scoped to match the level of assessed risk and the needs of management and decision making. Up-front investment in the development of sound experimental designs for project implementation and monitoring may be the best hedge against excessive project costs. This may require the engagement of expertise not commonly found in Corps districts.

The aspects of adaptive management discussed in the development phase and implementation phase should be integrated and documented in the form of an adaptive management plan. The adaptive management plan should serve as an open (i.e., generally available) and transparent document that describes the basis for the plan, roles, and responsibilities of those involved with its execution, the governance structure, monitoring and assessment requirements, and any relevant metrics and decision criteria. The adaptive management plan should clearly describe the objectives, hypotheses, metrics, monitoring, and assessment strategies that will be used to assess the restoration or mitigation actions (Figure 15).

Figure 15. A well-constructed adaptive management plan should make a clear connection between the plan components.

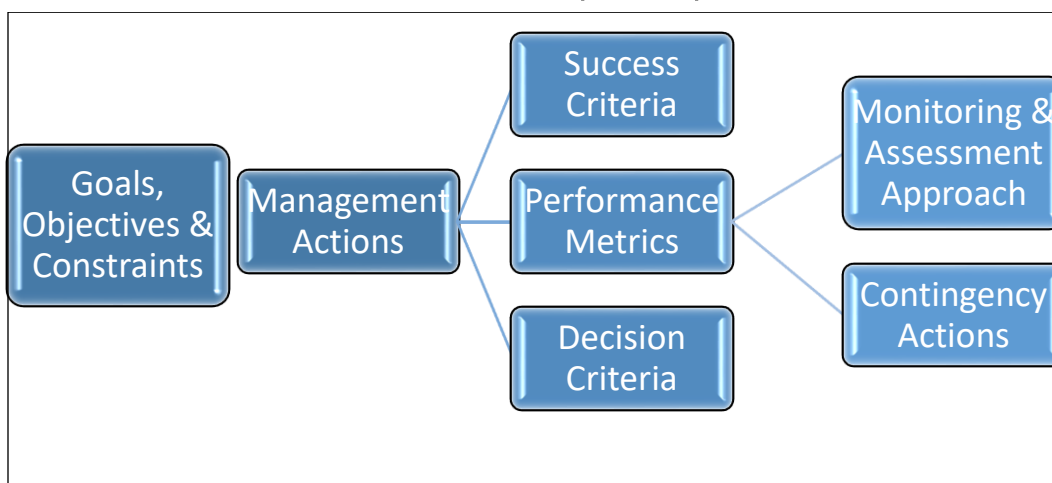


Figure 16 provides an example outline for an adaptive management plan that includes the essential components. For relatively simple ecosystem restoration projects where other planning documents are referenced, the adaptive management plan may be described in a few dozen pages. Large programs with many diverse projects and complicated governance structures may require considerable documentation (see the adaptive management plan for the MRRP¹).

¹ Fischenich, J. C., K. E. Buenau, J. L. Bonneau, C. A. Fleming, D. R. Marmorek, M. A. Nelitz, C. L. Murphy, G. Long, and C. J. Schwarz. 2018. *Missouri River recovery program science and adaptive management plan*. ERDC EL TR (in preparation). Vicksburg, MS: U.S. Army Engineer Research and Development Center.

Figure 16. Example for an outline for an adaptive management plan.

EXAMPLE ADAPTIVE MANAGEMENT TABLE OF CONTENTS

1.0 INTRODUCTION

- 1.1 Authorization for Adaptive Management
- 1.2 Procedure for Drafting Adaptive Management Plan
- 1.3 Communication Structure for Implementation of Adaptive Management

2.0 PROJECT ADAPTIVE MANAGEMENT PLANNING

- 2.1 Project Goals and Objectives
- 2.2 Conceptual Ecological Model for Monitoring and Adaptive Management
- 2.3 Sources of Uncertainty

3.0 RATIONALE FOR ADAPTIVE MANAGEMENT

- 3.1 Adaptive Management Program for Project

4.0 MONITORING

- 4.1 Rationale for Monitoring
- 4.2 Project Monitoring Plan
- 4.3 Analysis and Use of Monitoring Results

5.0 DATABASE MANAGEMENT

- 5.1 Description and Location
- 5.2 Data Storage and Retrieval
- 5.3 Analysis, Summarization, and Reporting

6.0 ASSESSMENT

- 6.1 Assessment Process
- 6.2 Frequency of Assessments
- 6.3 Variances and Success
- 6.4 Documentation and Reporting

7.0 DECISION-MAKING

- 7.1 Decision Process
- 7.2 Decision Criteria
- 7.3 Potential Adaptive Management Decisions
- 7.4 Project Close Out

8.0 COSTS FOR ADAPTIVE MANAGEMENT

- 8.1 Adaptive Management Planning Costs
- 8.2 Monitoring Costs
- 8.3 Adaptive Management Implementation Costs

9.0 LITERATURE CITED

SUPPORTING APPENDICES

4.2 Enabling characteristics for effective adaptive management

Following is a set of ten enabling characteristics for effective adaptive management summarized from a more comprehensive treatment by Fischenich and Murphy (2019¹).

1. Clear articulation of adaptive management objectives and program scope. Objectives set expectations and guide decisions. Objectives can be expressed in either aspirational or operational terms, where the former generally reflect ethical, cultural, and ideological values and the latter are intended to guide management decisions and therefore must be linked to feasible and measurable metrics that serve as performance indicators for management. Adaptive management cannot simultaneously maximize all the objectives and, as a practical matter, focuses on those objectives for which uncertainty and operational flexibility are greatest.
2. Documentation of the best available science. A formal, quantitative analysis of the effects of an action is an obligatory step in the planning process. A crucial component of an effects analysis is the development of an analytical framework that supports quantification of the effects of alternative actions and management responses (Murphy and Weiland 2011). A thorough effects analysis, and particularly a conceptual ecological model, provides the information base and template for the monitoring that is required to assess the effectiveness and efficacy of the adaptive management framework.
3. Monitoring in an experimental framework. Best available science has a second portal into adaptive management through the design and implementation of monitoring and the interpretation and assessment of data that is summarily gathered. Monitoring is a form of applied research, which in service to adaptive management must be approached much as a laboratory experiment is approached — with a rigorous design and application of the scientific method (Noon 2003). A monitoring scheme must have explicit programmatic goals and objectives, direct the gathering of data in a framework adequate to detect meaningful changes in the conditions of ecological resources, and develop reliable, scientifically defensible indicators for measuring change.

¹ Fischenich, J. C., and D. D. Murphy. 2019. *The enabling characteristics of adaptive management on big landscapes: observations from implementing the Endangered Species Act in the Missouri River Restoration Management Program*. Draft. Prepared for Journal of Environmental Management.

4. Identifying appropriate metrics and contingent decision criteria. Performance measures derived from project objectives should: 1) be measurable; 2) have a relatively strong degree of predictability (i.e., targets specified by predictive models); 3) change in response to project implementation; and 4) help verify progress and evaluate hypotheses through monitoring and assessment. Decision criteria presented in the form of targets and decision triggers directly related to program/project objectives should be established prior to implementation to assist with governance.
5. Modeling to forecast outcomes from proposed management actions. Models linking potential management actions to resource consequences play a decision-support role in virtually all adaptive management applications. They also play a key role in representing uncertainty, with hypotheses imbedded in different models forecasting resource changes through time. As evidence accumulates over time, the confidence placed in each model (and its associated hypothesis) evolves, through a comparison of model predictions against monitoring data.
6. Applying structured decision-making strategies to acknowledged trade-offs. Structured decision-making approaches aid in the implementation of key elements of an adaptive management plan by (1) identifying a range of conservation, economic, and social objectives and linking them to management alternatives, (2) making key decision tradeoffs explicit, and (3) highlighting considerations that are and are not important in the selecting of management actions from among alternatives.
7. Integrating human considerations into all aspects of risk assessment. There are socio-economic ramifications – and hence tradeoffs – to most decisions on restoration and mitigation projects. Related considerations should be woven into all facets of adaptive management, from the objectives through monitoring and the analysis and forecasting that supports governance efforts.
8. Adaptive management governance structure and process. Governance structures and processes should be symbiotic with existing organizational realities and tailored to the specific needs of an adaptive management project or program so as to be efficient and effective. Use of decision criteria, triggers and contingency plans promote decision making at the lowest effective administrative level, permitting senior leaders to focus on only the most contentious decisions.

9. *Independent scientific advice and review.* A standing panel of “outside experts” engaged during development of an adaptive management plan and extending into its implementation can provide critical insights on conceptual models, effects analyses, hypotheses, monitoring designs, and other key products as well as provide perspective on the adaptive management process. The panel can help build trust within and between agencies and stakeholders.
10. *Stakeholder engagement in adaptive resource management.* Stakeholder involvement from the point of project initiation through implementation facilitates mutual learning, provides alternative insights and competing management hypotheses, and is the most effective route to avoiding litigation that can delay the resolution of environmental challenges.

4.3 Benefits of adaptive management

Adaptive management promotes collaboration, flexible decision making through deliberately designing and implementing management actions to test hypotheses and maximize learning about critical uncertainties to better inform management decisions (Williams and Brown 2012). A collaborative adaptive management approach incorporates and links credible science and knowledge with the experience and values of stakeholders and managers for more effective management decision making (Sims and Pratt-Miles 2011).

Adaptive management plans developed as part of a feasibility study add thoroughness to traditional planning and increase the likelihood of success in USACE management and restoration. The adaptive management process requires planners and stakeholders to consider a range of potential problems and outcomes at a level of detail not required in more traditional USACE feasibility studies. Such in-depth examination leads to improvements in the statement of management objectives, formulation of planning alternatives, and analysis of the implications of uncertain outcomes on management decisions.

Adaptive management has been shown to reduce long-term costs, decrease risk of failure, strengthen credibility, increase public trust, and improve restoration outcomes (Love et al. 2018). It helps move the state of science and understanding of ecosystem restoration forward in a deliberate way. Table 6 briefly outlines characteristics of adaptive management and corresponding benefits.

Table 6. Characteristics of an adaptive management strategy and associated benefits.

Characteristic	Associated Benefits
Management flexibility is incorporated in the design and implementation of programs or projects	Flexibility to address uncertainty through monitoring, assessment, and adjustments to management actions increases the robustness of a project and its effectiveness under future scenarios, improving the likelihood of success across a broad range of future conditions.
Scientific processes are used to support project planning, implementation, assessment, and management.	Adaptive management tests hypotheses identified in conceptual models to address the uncertainties inherent in project implementation. Information learned from this process is conveyed to managers and stakeholders to support decision making and evaluate progress toward achieving goals and objectives. This provides a forum for dialogue between scientists and managers to interpret monitoring results, allowing managers to seek clarification about scientific and technical questions that may affect implementation. The process also reduces costly delays from legal actions and policy clarifications by effectively addressing uncertainties and promoting stakeholder engagement and interagency collaboration.
Interagency and stakeholder participation and collaboration occur as part of the AM forum	An open and inclusive atmosphere facilitates interagency participation, aids in acknowledging the full range of stakeholder interests and values, and ensures that new ideas are considered in the decision-making process. This builds trust and increases the likelihood of support for the restoration process by providing a common vision of success and effective and timely conflict resolution.

Glossary

Accounts – Objectives and performance criteria are organized into four accounts in accordance with U.S. Army Corps of Engineers Planning Guidelines. The four accounts are as follows:

- Environmental Quality (EQ)
- National Economic Development (NED)
- Regional Economic Development (RED)
- Other Social Effects (OSE)

Active adaptive management – An adaptive management approach that reduces uncertainty by using multiple designs or operational criteria as management experiments (i.e., field tests, physical models) to test hypotheses about system responses to management. Active adaptive management allows rigorous assessment of the cause-and-effect relationships between management actions and environmental responses, generally providing more comprehensive and rapid knowledge than can be obtained through passive adaptive management. Learning to support future decisions is an explicit objective.

Adaptive action – A course of action to be implemented as defined in the Adjust step (Step 5b of the adaptive management process; see Figure 3) if the performance of a particular management action is not as anticipated and requires correction. In cases where the action is pre-defined, it is referred to as a “contingency action.”

Adaptive Management (AM) – A decision process that promotes action in the face of uncertainties and adjustment as outcomes from management actions and other events are better understood. Careful monitoring of these outcomes advances scientific understanding and helps adjust policies or operations as part of an iterative learning process.

Adaptive Management Team (AMT) – Individuals who will be responsible for developing and implementing adaptive management.

Alternatives – A specified combination of management actions that collectively are deemed to meet the goals and objectives. In the Problem Definition, Objectives, Alternatives, Consequences, Tradeoffs (PrOACT) process, the trade-offs associated with various alternatives on multiple

interests are explored in order to find the alternative(s) that minimize unnecessary negative impacts and is/are otherwise thought to be the “best balance” of impacts on a wide range of interests. Alternatives are used to address the objectives.

AM report – Annual or periodic report that documents new learning based on monitoring results, evaluates progress towards meeting species objectives, and contains recommendations for adjustments to management actions.

Annual Work Plan (AWP) – A document that includes real estate actions, habitat creation actions, monitoring of physical and biological responses to actions, and research activities for a particular fiscal year (FY). It is used by project delivery teams to budget and implement management actions annually.

Assessment – Process by which the results of the monitoring efforts will be compared to the project performance measures and/or acceptable risk endpoints (i.e., decision criteria).

Biological Assessment (BA) – Information prepared by, or under the direction of, a Federal agency regarding listed and proposed species and designated and proposed critical habitat that may be present in the action area and the evaluation of potential effects of the action on such species and habitat.

Biological Opinion (BiOp) – Document stating the opinion of the U.S. Fish and Wildlife Service (USFWS) or the National Marine Fisheries Service (NMFS) as to whether a Federal action is likely to jeopardize the continued existence of a threatened or endangered species or result in the destruction or adverse modification of critical habitat.

Collaboration – Working together to define and solve problems to achieve common goals.

Conceptual Ecological Models (CEMs) – Depictions of an ecosystem used to communicate the important components of the system and their relationships. They are a representation of the current scientific understanding of how the system works, often presented in graphical form with accompanying descriptions of the system components and processes.

Conflict resolution – The methods and process of negotiation, arbitration, and institution-building for alleviating or eliminating sources of conflict.

Contingency action – A pre-evaluated adaptive action that is implemented when triggered by defined decision criteria without the need for further deliberation or decision.

Critical uncertainties – Uncertainties that impede the identification of a preferred alternative management action.

Critical Engagement Point (CEP) – Specific points in the development or implementation phases of adaptive management when the agencies engage for input.

Data management – Development, execution, and supervision of plans, policies, programs, and practices that control, protect, deliver, and enhance the value of data and information.

Data quality objectives – Values of acceptable bias and precision specified for performance measures and risk endpoints.

Decision context – Involves defining what decision (question or problem) is being made, why it is being made, and also describing the scope of the playing field (bounds) for the management decision as well as its relationship to other decisions previously made or anticipated.

Decision criteria – A broad reference to the set of pre-determined criteria used to make adaptive management decisions. Performance metrics, targets, and decision triggers are considered to be different types of decision criteria. They can be qualitative or quantitative based on the nature of the performance metric and the level of information necessary to make a decision.

Decision space – A term used to characterize a range of operational discretion for flows (or potentially other actions) that is “acceptable” to stakeholders, effective in achieving objectives, and within the bounds of actions evaluated under NEPA. Management actions would generally occur within this region, and any operation outside this decision space would require further coordination and approval.

Decision trigger – A pre-defined commitment (population or habitat metric for a specific objective) that triggers a change in a management action. Decision triggers are addressed in the Evaluate step (Step 4 of the AM process) and specify the metrics and actions that will be taken if monitoring indicates performance metrics are or are not reaching target values. In some cases, a decision trigger may be learning a new piece of information that triggers the Continue/Adjust/Complete step (Step 5 of the AM process).

Delphi process – A method of eliciting expert opinion (Normand et al. 1998). While many variations of the process exist, there are generally three common features: (1) qualified experts provide their responses to a set of questions in a structured format; (2) the answers to these questions are synthesized across all respondents and presented back to the same set of experts; and (3) the experts jointly discuss the reasons for variation in the first set of responses (or lack thereof) and, through dialogue, potentially revise their opinions. A modified Delphi process was applied by Jacobson et al. (2016) to prioritize candidate hypotheses.

Design – Plans and specifications of a selected planning alternative.

Ecosystem – The complex of a community of organisms and its environment functioning as an ecological unit.

Ecosystem restoration – Active human intervention that initiates or accelerates the recovery of an ecosystem with respect to its health, integrity, and sustainability.

Effects Analysis (EA) – This effort's purpose is to conceptually and quantifiably make explicit the effects of proposed actions on a resource or species by specifically evaluating the effects of management actions on the ecosystem or the status and trends of the listed species and their habitats.

Environmental Impact Statement (EIS) and Environmental Assessment (EA) – An EIS is a detailed document pursuant to the National Environmental Policy Act that describes and analyzes the environmental effects of the alternatives for a proposed major Federal action; the decision document for an EIS is a Record of Decision. Refer to 40 CFR 1502.4 for examples of major Federal actions that require the preparation of an EIS. An Environmental Assessment is a less detailed

document pursuant to the National Environmental Policy Act that describes and analyzes the effects of a project that is not deemed to be a major Federal action; the decision document for an EA is a Finding of No Significant Impact.

Evaluation – Conduct analyses to compare measured results with anticipated outcomes related to decision criteria for specific management actions to determine whether the implementation should be continued, adjusted, or completed.

Event-driven reporting cycle – In addition to the annual and periodic AM reports (on a routine reporting schedule), reporting may also be event-driven, where new observations or data resulting from an unforeseen event suggest a decision trigger or targets have been reached.

Feasibility study – The project formulation phase during which all planning activities are performed that are required to demonstrate that Federal participation in a specific project is warranted, culminating in approval of the decision document. All plan formulation must be completed during this phase, including all technical analyses, policy compliance determinations, and Federal and non-Federal environmental and regulatory compliance activities required for approval of the decision document.

Flood risk management – Actions to reduce the likelihood and/or the impact of floods.

Formal consultation -- A process between the USFWS or NMFS and a Federal agency that commences with the Federal agency's written request for consultation under Section 7(a)(2) of the Act and concludes with the USFWS/NMFS issuance of the biological opinion under Section 7(b)(3) of the Act.

Fundamental objectives – Objectives used to formalize the desired outcome the program or project is seeking to achieve. They are distinct from means objectives.

Global hypotheses – Set of possible, biologically important hypotheses, relevant to population dynamics that are derived from conceptual ecological models.

Human Considerations (HCs) – A set of objectives with associated metrics addressing the wide array of uses and stakeholder interests for a project or program.

Hypothesis – An idea or explanation that is tested through study and experimentation. A hypothesis is usually based on evidence, making it more than a wild guess but less than a well-established theory.

Investigations – Planning or research activities intended to generate information that will fill the key gaps in understanding and reduce uncertainty associated with implementation of management actions.

Jeopardy – As defined by the Endangered Species Act (ESA), jeopardy occurs when there is an action that reasonably would be expected, directly or indirectly, to reduce appreciably the likelihood of both the survival and recovery of a listed species in the wild by reducing the reproduction, numbers, or distribution of that species.

Limiting factor – A factor that controls the growth, abundance, or distribution of an organism.

Management actions – Proposed or potential actions to be taken by the USACE that contribute to meeting objectives; one or more management actions constitute an alternative.

Management hypotheses – Statements (in affirmative hypothesis form) that a specific management action will be effective in achieving objectives.

Means objectives – Describe ways of achieving the fundamental objectives and specify the way and degree to which the fundamental objectives can be achieved. They are used to further develop management actions and alternatives and are potentially useful in tracking progress towards fundamental objectives in the near-term when a response in the fundamental objectives may not be detectable in shorter time frames due to a delayed species response to management actions or other reasons.

Monitoring – The process of measuring attributes of the ecological, social, or economic system. Monitoring has many potential purposes, including: to provide a better understanding of spatial and temporal

variability, to confirm the status of a system component, to assess trends in a system component, to improve models, to confirm that an action was implemented as planned, to provide the data used to test a hypothesis or evaluate the effects of a management action, and to provide an understanding of a system attribute that could potentially confound the evaluation of action effectiveness.

Multi-criteria decision analysis – A comprehensive, structured process for selecting the optimal alternative in any given situation, drawing from stakeholder preferences and value judgments as well as scientific modeling and risk analysis.

National Environmental Policy Act (NEPA) – Requires Federal agencies to integrate environmental effects and values into their decision-making processes by considering the environmental impacts of their proposed actions and reasonable alternatives to those actions. To meet NEPA requirements, Federal agencies prepare an Environmental Impact Statement or Environmental Assessment.

No-action alternative – The Council on Environmental Quality defines no action as “no change” from current management direction or level of management intensity. The no action alternative is required in all NEPA documents pursuant to 40 CFR 1502.14

Objectives – Concise statements of the interests that could be affected by a decision – the “things that matter” to people. Objectives define an endpoint of concern and the direction of change that is preferred. In PrOACT, objectives typically take a simple form such as minimize costs and increase population number, increase habitat availability.

Passive adaptive management – An adaptive management approach that reduces uncertainty by using a single design or operational plan to test hypotheses about system responses to a management action. The management hypotheses are modified and tested iteratively by adjusting the project design or operations, using built-in flexibility. Passive adaptive management reduces uncertainty over time, but it does not permit the kind of rigorous testing of the cause-and-effect relationship between management actions and environmental responses obtained with active adaptive management. In passive AM, management actions are focused on

achieving resource objectives; development of knowledge through monitoring and assessment for improved decision making is secondary.

Performance measure – A physical, chemical, biological, or ecological measure used to assess progress towards achieving project/program goals and objectives. Performance measures can be used to help determine whether project response (e.g., slow, no, or decreasing performance trends) require adjustments through adaptive management to improve success.

Performance metric – A specific metric or quantitative indicator that is monitored and can be used to estimate and report consequences of management alternatives with respect to a particular objective.

Preferred alternative – The alternative that the agency believes would best fulfill its statutory mission and responsibilities, giving consideration to economic, environmental, technical, and other factors.

PrOACT decision-making model – An organized, structured decision-making approach to identifying and evaluating creative options and making choices in complex decision situations. PrOACT is a decision analysis approach used to provide analytical structure and rigor to values-based questions by clarifying the consequences of alternate solutions, including the impacts on multiple objectives. The unifying features of PrOACT analyses are that they involve: (1) clarifying the Problem to be solved, (2) listing Objectives to be considered (usually with associated performance metrics), (3) developing Alternative solutions to the problem as stated, (4) estimating the Consequences of each of the alternatives on each of the objectives in terms of the metrics (usually in the form of a consequence table of alternatives vs. objectives) and (5) explicitly evaluating the Trade-offs that are revealed to exist between the alternatives, usually in a discursive setting.

Problem – A question or concern that is being addressed in the decision-making process.

Program – Refers to USACE activities involving the implementation of multiple projects over time. Examples include the Comprehensive Everglades Restoration Program and the Missouri River Recovery Program.

Project Implementation Report (PIR) – Contains site-specific information, alternative designs and project features, the anticipated benefits of the project, and documentation for compliance with the National Environmental Policy Act (NEPA) disclosing the potential affects to the quality of the human environment from project implementation.

Project Management Business Process (PMBP) – USACE approach for the planning, development, and management of projects and programs.

Proxy metric – Type of performance metric. Generally, a proxy metric is an indirect metric used to represent a natural metric like population number (e.g., number of boat ramp days). Proxy criteria are those that correlate well with objectives that are otherwise difficult to measure or estimate.

Quantitative predictive models – Numerical models used to predict biological and ecological responses as a function of management or restoration actions.

Recovery plan – A document drafted by the USFWS or NMFS that serves as a guide for activities to be undertaken by Federal and state agencies or other entities in helping to recover and conserve species listed under the Endangered Species Act.

Risk – An uncertainty coupled with an adverse consequence, ideally expressed as the product of the two components, with uncertainty represented as a probability.

Risk endpoint – Measure of an undesirable outcome of a management or restoration action.

Robustness – The quality of being able to withstand stresses, pressures, or changes in procedure or circumstance and still maintain function and desired performance.

Scenario Analysis – A process used in Contingency Planning to identify potential circumstances and/or outcomes that might warrant a response, and exploring potential adjustments to management actions under particular scenarios.

Section 7 – The section of the Endangered Species Act that requires all Federal agencies, in "consultation" with the Service, to ensure that their actions are not likely to jeopardize the continued existence of listed species or result in destruction or adverse modification of critical habitat.

Selected alternative – The alternative identified in a Record of Decision that the agency intends to implement.

SMART Planning – A modernization to the Corps of Engineers' feasibility study process that improves efficiency and effectiveness in considering risk in making study decisions.

Stakeholder – One who is affected by a management action.

Structured Decision Making (SDM) – Organized approach to identifying and evaluating creative options and making choices in complex decision situations. It is used to inform difficult choices and to make them more transparent and efficient. PrOACT is a specific application of SDM to collaborative problem solving.

Sub-objectives – Sub-objectives are aspects of the fundamental objective described in more detail that need to be addressed to achieve the fundamental objective. They are intended to provide direction in the short term, provide objectives meaningful for AM, and focus efforts on the desired short-term outcomes while contributing to the fundamental objective.

Success – Achievement of goals and objectives.

Success criteria – A qualitative or (preferably) quantitative description of the conditions for which the parties agree that the objectives have been sufficiently met. Usually expressed in terms of the performance metrics.

Target – A specific value or range of performance metric that defines success. Targets can be quantitative values or overall trends (directional or trajectory).

Trade-offs (also Trade-off analysis) – A trade-off occurs when one alternative performs well on one metric but poorly on another relative to another alternative. Reasonable people may disagree about which is the

best alternative because they value the two metrics differently; thus, value trade-offs involve making judgments about how much you would give up on one objective in order to achieve gains on another objective. By analyzing trade-offs, the PrOACT process tries to help find the alternative that (1) eliminates unnecessary trade-offs and (2) that people agree is the “best balance” of trade-offs possible.

Trigger – A form of decision criteria serving as a threshold or condition that, when met, initiates some action or decision.

Uncertainty – Circumstances in which information is deficient. Learning while doing under the adaptive management process provides a framework for reducing program uncertainties over time.

Variability – A measure of how much a set of conditions differs from the mean or median state.

Variance – The difference between a monitored value of a performance measure or risk endpoint and its corresponding value used in decision making.

Water Resources Development Acts (WRDA) – Public laws enacted by Congress to manage aspects of water resources such as navigation, flood risk management, coastal storm risk management, and environmental restoration. The most recent Water Resources Development provisions are included in Title I of the Water Infrastructure Improvements for the Nation Act (WIIN 2016; Public Law 114-322 2016), which amends relevant sections of previous WRDAs. Section 1161 of WRDA 2016 (Completion of Ecosystem Restoration Projects) amends Section 2039 of WRDA 2007 (Monitoring Ecosystem Restoration), for example. The USACE develops and maintains Implementation Guidance for Sections of these authorizations in coordination with the Assistant Secretary of the Army (Civil Works).

References

- ACCCNRS (Advisory Committee on Climate Change and Natural Resource Science). 2015. *Report to the Secretary of the Interior*. https://nccwsc.usgs.gov/sites/default/files/files/ACCCNRS_Report_2015.pdf. Washington, DC: Department of the Interior.
- Andrew, J. H., H. Stefan, and B. Elisabeth. 2008. A multi-objective model for environmental investment decision making. *Computers and Operations Research* 35:253-266.
- Beer, T. 2006. Ecological risk assessment and quantitative consequence analysis. *Human and Ecological Risk Assessment* 12(1):51-65.
- Berkley, J. 2013. Opportunities for collaborative adaptive management progress: integrating stakeholder assessments into progress measurement. *Ecology and Society* 18(4):69. <http://dx.doi.org/10.5751/ES-05988-180469>
- Bernhardt, E. S., E. B. Sudduth, M. A. Palmer, J. D. Allan, J. L. Meyer, G. Alexander, et al. 2007. Restoring rivers one reach at a time: results from a survey of U.S. river restoration practitioners. *Restoration Ecology* 15:482-493.
- Brierley, G., H. Reid, K. Fryirs, and N. Trahan. 2010. What are we monitoring and why? Using geomorphic principles to frame eco-hydrological assessments of river condition. *The Science of the Total Environment* 408(9):2025-2033.
- Chapman, M. G. 1998. Improving sampling designs for measuring restoration in aquatic habitats. *Journal of Aquatic Ecosystem Stress and Recovery* 6(3):235-251.
- Cohen, J. 1988. *Statistical power analysis for the behavioral sciences*. Second edition. Hillsdale, NJ: Lawrence Erlbaum Associates. ISBN 0-8058-0283-5.
- Conroy, M. J., and J. Peterson, 2013. *Decision making in natural resource management: A structured, adaptive approach*. Hoboken, NJ: Wiley-Blackwell. 10.1002/9781118506196.
- Council on Environmental Quality (CEQ). 2007. Handbook for integrating NEPA and adaptive management. <http://www.whitehouse.gov/administration/eop/ceq/>.
- Davis, D. W. 2009. *Flexibility for USACE in reservoir regulation - Is it there?* Institute for Water Resources. Washington, DC: U.S. Army Corps of Engineers.
- Di Stefano, J. 2003. How much power is enough? Against the development of an arbitrary convention for statistical power calculations. *Functional Ecology* 2003(17):707-709.
- Downs, P. W., and G. M. Kondolf. 2002. Post-project appraisals in adaptive management of river channel restoration. *Environmental Management* 29(4):477-496.

- El-Swaify, S. A., and D. S. Yakowitz. 1998. Multiple objective decision making for land, water, and environmental management. In *Proceedings of the First International Conference on Multiple Objective Decision Support Systems (MODSS) for Land, Water, and Environmental Management: Concepts, Approaches, and Applications, 1996, Honolulu*. Boca Raton, FL: Lewis Publishers.
- Federal Advisory Committee Act (FACA). Pub. L. No. 92-463. (1972).
- Federal Advisory Committee Act (FACA). Pub. L. No. 105-153. (1997).
- Fischenich, C. 2008. *The application of conceptual models to ecosystem restoration*. EBA Technical Notes Collection. ERDC/EBA TN-o8-1. Vicksburg, MS: U.S. Army Engineer Research and Development Center.
- Fischenich, C., et al. 2012. *The application of adaptive management to ecosystem restoration projects*. EBA Technical Notes Collection. ERDC TN-EMRRP-EBA-10. Vicksburg, MS: U.S. Army Engineer Research and Development Center.
- Fischman, R. L., and J. B. Ruhl. 2016. Judging adaptive management practices of U.S. agencies. *Conservation Biology* 30(2):268-75. doi: 10.1111/cobi.12616.
- Fish and Wildlife Service and the National Marine Fisheries Service. 1998. *Endangered Species Act section 7 consultation handbook*. Washington, DC: Fish and Wildlife Service and the National Marine Fisheries Service.
- Galat, D. L., J. W. Barko, S. M. Bartell, M. Davis, B. J. Johnson, K. S. Lubinski, J. M. Nestler, and D. B. Wilcox. 2007. *Environmental science panel report: Establishing system-wide goals and objectives for the Upper Mississippi River system*. Upper Mississippi River System Navigation and Ecosystem Sustainability Program, NESP ENV Report 6. Washington, DC: U.S. Army Corps of Engineers, Rock Island, St. Louis, and St. Paul Districts.
- Gardner, R. H., W. M. Kemp, V. S. Kennedy, and J. E. Petersen (ed.). 2001. *Scaling relations in experimental ecology*. New York: Columbia University Press.
- Gardner, J. S., E. E. Maynard, D. L. Price, and J. C. Fischenich. 2014. *Retrospective evaluation of Corps aquatic ecosystem restoration projects protocol part 1: Project overview*. EMRRP Technical Notes Collection. ERDC TNEMRRP-ER-20. Vicksburg, MS: U.S. Army Engineer Research and Development Center. <http://el.erdcl.usace.army.mil/emrrp/emrrp.html>
- Gray, A. N. 2000. Adaptive ecosystem management in the Pacific Northwest: A case study from coastal Oregon. *Conservation Ecology* 4(2):6.
- Green, O. O., B. A. Cosens, and A. S. Garmestani. 2013. Resilience in transboundary water governance: The Okavango River Basin. *Ecology and Society* 18(2):23.
- Gregory, R., D. Ohlson, and J. Arvai. 2006. Deconstructing adaptive management: Criteria for applications to environmental management. *Ecological Applications* 16:2411-2425.

- Gregory, R., L. Failing, M. Harstone, G. Long, T. McDaniels, and D. Ohlson. 2012. *Structured decision making: a practical guide to environmental management choices*. Hoboken, NJ: John Wiley & Sons.
- Greig, L. A., D. R. Marmorek, C. Murray, and D. C. E. Robinson. 2013. Insight into enabling adaptive management. *Ecology and Society* 18(3):24.
- Gunderson and Light. 2006. Adaptive management and adaptive governance in the everglades ecosystem. *Policy Science* 39:323-334.
- Gunderson, L., and C. S. Holling, 2002. *Panarchy synopsis: understanding transformations in human and natural systems*. Washington, DC: Island Press.
- Hammond, John S., Ralph L. Keeney, and Howard Raiffa. 1999. *Smart choices: A practical guide to making better decisions*. Brighton, MA: Harvard Business School Press.
- Hauser, C. E., and H. P. Possingham. 2008. Experimental or precautionary? Adaptive management over a range of time horizons. *Journal of Applied Ecology* 45:72-81. doi: 10.1111/j.1365-2664.2007.01395.x.
- Holling, C. S. 1978. Myths of ecological stability: Resilience and the problem of failure. In *Studies in crisis management*, ed. C. F. Smart and W. T. Stanbury. Montreal: Butterworth.
- Jacobson, R. B., M. L. Annis, M. E. Colvin, D. James, T. L. Welker, and M. J. Parsley. 2016. *Missouri River Scaphirhynchus albus (pallid sturgeon) effects analysis—integrative report*. U.S. Geological Survey, Scientific Investigations Report. Reston, VA: U.S. Geological Survey.
- Keeney, R. L. 1998. *Value-focused thinking: a path to creative decision making*. Brighton, MA: Harvard University Press.
- Lancia, R. A., C. E. Braun, M. W. Collopy, R. D. Dueser, J. G. Kie, C. J. Martinka, J. D. Nichols, T. D. Nudds, W. R. Porath, and N. G. Tilghman. 1996. ARM! For the future: adaptive resource management in the wildlife profession. *Wildlife Society Bulletin* 24:436-442.
- Linkov, I., F. K. Satterstrom, G. Kiker, C. Batchelor, T. Bridges, and E. Ferguson. 2006. From comparative risk assessment to multi-criteria decision analysis and adaptive management: Recent developments and applications. *Environment International* 32:1072-1093.
- Love, M., A. Baldera, and C. Robbins. 2018. *The benefits of adaptive management: Three case studies from ecosystem restoration programs around the U.S. Ocean Conservancy*. Austin, TX: Ocean Conservancy.
- Maddox, G. D., K. E. Poiani, and R. E. Unnasch. 1999. Evaluating management success: Using ecological models to ask the right monitoring questions. In *The Ecological Stewardship Project: A Common Reference for Ecosystem Management*, ed. N. Johnson, 563-84. Oxford: Elsevier Science.

- Margoluis, R., Stem, C., Swaminathan, V., Brown, M., Johnson, A., Placci, G., and I. Tilders. 2013. Results chains: a tool for conservation action design, management, and evaluation. *Ecology and Society* 18(3).
- Marmorek, D. R., D. C. E. Robinson, C. Murray and L. Greig. 2006. *Enabling adaptive forest management – final report*. Prepared for the National Commission on Science for Sustainable Forestry by ESSA Technologies Ltd. Vancouver, B.C.
- McConnaha, W. E., and P. J. Paquet. 1996. *Adaptive strategies for the management of ecosystems: The Columbia River experience*. American Fisheries Society Symposium. Dearborn, MI.
- Monroe, M. C., R. Plate, and A. Oxarart. 2013. Intermediate collaborative adaptive management strategies build stakeholder capacity. *Ecology and Society* 18(2):24.
- Mostert, E. 1998. A framework for conflict resolution. *Water International* 23(4):206-215.
- Murphy, D. D., and P. S. Weiland. 2011. The route to best science in implementation of the Endangered Species Act's consultation mandate: the benefits of structured effects analysis. *Environmental Management* 47:161-72.
- Murphy, D. D., and P. S. Weiland. 2014a. Science and structured decision making: fulfilling the promise of adaptive management for imperiled species. *Journal of Environmental Studies and Sciences* 4:200-207.
- Murphy, D. D., and P. S. Weiland. 2014b. The use of surrogates in implementation of the Federal Endangered Species Act—proposed fixes to a proposed rule. *Journal of Environmental Studies and Sciences* 4:156-62.
- Murphy, D. D., and P. S. Weiland. 2019. Independent Scientific Review under the Endangered Species Act. *BioScience* 69:198-208.
- National Research Council (NRC). 2004. *Adaptive management for water resource planning*. Washington, DC: National Academies Press.
- Nichols, J. D., and B. K. Williams. 2006. Monitoring for conservation. *Trends in Ecology and Evolution* 21:668-673.
- Noon, B. R. 2003. Conceptual issues in monitoring ecological resources. In *Monitoring ecosystems: interdisciplinary approaches for evaluating ecoregional initiatives*, ed. D. E. Busch and J. C. Trexler, 27-72. Washington, DC: Island Press.
- Normand, S. L., B. J. McNeil, L. E. Peterson, and R. H. Palmer. 1998. Eliciting expert opinion using the Delphi technique: identifying performance indicators for cardiovascular disease. *International Journal for Quality in Health Care* 10(3):247-260.
- Office of Management Budget (OMB). “Final Information Quality Bulletin for Peer Review,” 70 Federal Register Volume (14 January 2005).
- Orth, K. D., & Yoe, C. E. 1997. *Planning Primer* (No. IWR-97-R-15). US Army Corps of Engineers Institute for Water Resources, Fort Belvoir, VA.

- Parma, A. M., and the NCEAS Working Group on Population Management. 1998. What can adaptive management do for our fish, forests, food, and biodiversity? *Integrative Biology* 1:16–26.
- Pearsall, S.H., McCrodden, B.J. & Townsend, P.A. (2005) Adaptive management of flows in the Lower Roanoke River, North Carolina, USA. *Environmental Management* 35:353–367.
- Pratt-Miles, J. D. 2013. Designing collaborative processes for adaptive management: four structures for multi-stakeholder collaboration. *Ecology and Society* 18(4):5.
- Rijke, J., R. Brown, C. Zevenbergen, R. Ashley, M. Farrelly, P. Morison, and S. van Herk. 2012. Fit-for-purpose governance: A framework to make adaptive governance operational. *Environmental Science and Policy* 22:73-84.
- Rubenstein, M. F., and I. R. Firstenberg. 1975. *Patterns of problem solving*. Englewood Cliffs, NJ: Prentice Hall.
- Runge M. C. 2011. Adaptive management for threatened and endangered species. *Journal of Fish and Wildlife Management* 2(2):220-233; e1944-687X. doi: 10.3996/082011-JFWM-045
- Scarlett, L. 2013. Collaborative adaptive management challenges and opportunities. *Ecology and Society* 18(3):26.
- Schwartz, Mark W., Carly N. Cook, Robert L. Pressey, Andrew S. Pullin, Michael C. Runge, Nick Salafsky, William J. Sutherland, and Matthew A. Williamson. 2017. Decision support frameworks and tools for conservation. *Conservation Letters* June:1-12.
- Shields, D. J., B. Tolwinski, and B. M. Kent. 1999. Models for conflict resolution in ecosystem management. *Socio-Economic Planning Sciences* 33(1):61-84.
- Sims, S. A., and J. Pratt-Miles, ed. 2011. Adaptive governance in the face of environmental and social change. *CAMNet fifth annual rendezvous, 16-17 April, Antioch University, Keene, NH*. Dillon, OH: Collaborative Adaptive Management Network.
- Suedel, B. C., L. J. Valverde, J. Vogel, I. Linkov, J. C. Fischenich, T. Bridges, and M. Plumley. 2012. *Application of risk management and uncertainty concepts and methods for ecosystem restoration: principles and best practice*. ERDC TN-EMRRP-EBA-15. Vicksburg, MS: U.S. Army Engineer Research and Development Center.
- Taylor, B., L. Kremsater, and R. Ellis. 1997. *Adaptive management of forests in British Columbia*. Victoria, British Columbia, Canada: BC Ministry of Forests.
- Taylor, F. 1911. *The principles of scientific management*. New York and London: Harper & Brothers.
- Thomas, L. 1997. Retrospective power analysis. *Conservation Biology* 11:276-280.
- USACE. 1999. *Civil works restoration policy*. ER 1165-2-501. Washington, D.C.: U.S. Army Corps of Engineers.

- USACE. 2004. *Upper Mississippi River-Illinois Waterway System Navigation Feasibility Study with Integrated Programmatic Environmental Impact Statement*. Rock Island, Illinois: U. S. Army Corps of Engineers, St. Paul, Rock Island, and St. Louis Districts.
- USACE. 2005. *Poplar Island environmental restoration project September 2005 general reevaluation report (GRR) and supplemental environmental impact statement (SEIS) 8-1*. September: 1-19. Washington, DC: U.S. Army Corps of Engineers.
- USACE. 2009. *Planning guidance notebook*. ER 1105-2-100. Washington, DC: U.S. Army Corps of Engineers.
- USACE. 2019. *Stakeholder engagement, collaboration and coordination*. EP 1105-2-57. Washington, DC: U.S. Army Corps of Engineers.
- Van den Bergh, J. C., J. M. van den Bergh, and K. J. Button. 1997. Meta-analysis of environmental issues in regional, urban, and transport economics. *Urban Studies* 34:927-944.
- Walters, C. J. 1981. Optimum escapements in the face of alternative recruitment hypotheses. *Canadian Journal of Fisheries and Aquatic Sciences* 38(6):678-689.
- Walters, C. J. 1986. *Adaptive management of renewable resources*. New York: Macmillan.
- Walters, C. J. 1997. Challenges in adaptive management of riparian and coastal ecosystems. *Conservation Ecology* 1(2).
- Walters, C. J. (2007). Is adaptive management helping to solve fisheries problems? *AMBIO: A Journal of the Human Environment* 36(4):304-308.
- Walters, C. J., and R. Hilborn. 1978. Ecological optimization and adaptive management. *Annual Review of Ecology and Systematics* 9: 157-188.
- Walters, C. J., and C. S. Holling. 1990. Large-scale management experiments and learning by doing. *Ecology* 7(6):2060-2068.
- Walters, C. J., R. D. Goruk and D. Radford. 1993. Rivers inlet sockeye salmon: an experiment in adaptive management. *North American Journal of Fisheries Management* 13:254-262.
- Water Infrastructure Improvements for the Nation Act (WIIN). Pub. L. No. 114-322. (2016).
- Water Resources Development Act. Completion of Ecosystem Restoration Projects. (2016).
- Westgate, M. J., G. E. Likens, and D. B. Lindenmayer. 2012. Adaptive management of biological systems: A review. *Biological Conservation* 158(2013):128-139.
- Westgate, M. J., G. E. Likens, and D. B. Lindenmayer. 2013. Adaptive management of biological systems: A review. *Biological Conservation* 158:128-139.

- Williams, B.K. (2001) Uncertainty, learning, and the optimal management of wildlife. *Environmental and Ecological Statistics* 8:269-288.
- Williams, B. K., and E. D. Brown. 2018. Double-loop learning in adaptive management: The need, the challenge, and the opportunity. *Environmental Management* 62:995-1006.
- Williams, B. K., and E. D. Brown. 2012. *Adaptive management: The U.S. Department of the Interior applications guide*. U.S. Department of the Interior: Washington, DC.
- Williams, B. K., R. C. Szaro, and C. D. Shapiro. 2009. *Adaptive management: The U.S. Department of the Interior technical guide*. Washington, DC: U.S. Department of the Interior.
- Williams, Byron K., Robert C. Szaro, and Carl D. Shapiro. 2007. *Adaptive management: the U.S. Department of the Interior technical guide*. Adaptive Management Working Group. Washington, DC: U.S. Department of the Interior.
- Wolf, F. M. 1986. *Meta-analysis: Quantitative methods for research synthesis*. Beverly Hills, CA: Sage.
- Yoe, C. 2017. *Planning manual part II: risk-informed planning*. Report 2017-R-03. Alexandria, VA: U.S. Army Corps of Engineers Institute for Water Resources.

Appendix A: Implementation Guidance Related to Monitoring and Adaptive Management

Implementation Guidance for Section 1161 of the Water Resources

Development Act of 2016 (WRDA 2016), Completion of Ecosystem
Restoration Projects can be found at the following address.

<http://cdm16021.contentdm.oclc.org/utils/getfile/collection/p16021coll5/id/1212>

Appendix B: Example USACE ecosystem restoration programs and projects

The Adaptive Management Technical Guide references several USACE ecosystem restoration programs that have/are implementing adaptive management. This appendix provides a brief overview of those cited and concludes with a table of other projects or programs employing adaptive management. The reader is encouraged to obtain the listed references and visit the web sites for those of interest to further understand how adaptive management is being applied in support of ecosystem restoration efforts.

Table B1 lists the legislation, direction, policies, and guidance for several large-scale programs: CERP, the Louisiana Coastal Area (LCA) program, MRRP, the Columbia River Channel Improvement Project (CRCIP), the Great Lakes-International Adaptive Management Programs, and the Upper Mississippi River (UMR), and Illinois Waterway System.

These programs reflect varying sources of authority, funding levels, and requirements for adaptive management. A clear recognition of the need for adaptive management and a strong emphasis on using adaptive management to ensure program success is common to all of these efforts. Each program is described in detail following Table B1.

Table B1. Summary of major ecosystem restoration plans and relevance of adaptive management.

Program	Description
Comprehensive Everglades Restoration Plan (CERP)	WRDA 2000 included specific legislative direction and funding for an Adaptive Assessment and Monitoring Program, at a total cost of \$100 million over 10 years. The WRDA language also called for promulgating programmatic regulations, which further specified implementation requirements for adaptive management by formalizing processes for developing goals, a monitoring program, and an adaptive management program. A RECOVER Office has been established to oversee efforts and formalize a monitoring and adaptive management approach and activities. Additional information is available at: http://www.evergladesplan.org/pm/program_docs/adaptive_mgmt.aspx .

Program	Description
Louisiana Coastal Assessment	Legislation in WRDA 2007 was not specific on including adaptive management, but it did include related items: a Science and Technology Component was authorized at \$100 million, allowing for monitoring and collection of data, and demonstration projects were authorized at \$100 million to test key applications for potential broader use. Adaptive management was specifically called for in the Chief's Report. An adaptive management program is under development. Additional information is available at http://www.lacoast.gov and http://www.lca.gov .
Missouri River Recovery Plan	Adaptive management has not been included in the Corps' authorizing legislation for this program. The Biological Opinion Reasonable and Prudent Measures recommend adaptive management to meet Endangered Species Act requirements. The record of decision for the Missouri River Master Water Control Manual also requests adaptive management. Currently, annual funding of several million dollars is directed to threatened and endangered species monitoring and completion of special studies. An adaptive management program is under development. Additional information is available at http://www.moriverrecovery.org .
Navigation and Ecosystem Sustainability Program	WRDA 2007 program authorization calls for the development of goals, performance measures, and performance indicators. The authorization also provides up to \$10,420,000 per fiscal year in system long-term resource monitoring funding if not separately funded under a related program. Per implementation guidance, the 1-percent monitoring limit and prohibition on adaptive management does not apply, but monitoring and adaptive management must be accomplished within the framework and the costs must be authorized for those purposes as reflected in the feasibility report (total cost of about \$300 million). An adaptive management program is under development. Additional information is available at http://www2.mvr.usace.army.mil/UMRS/NESP/default.cfm .
Great Lakes–International Adaptive Management Programs	Adaptive management is being considered for larger use on the Great Lakes. The International Joint Commission (IJC), which was established under the 1909 Boundary Waters Treaty between the United States and Canada, plays a vital role in the management of the waters of the Great Lakes. As such, the IJC has and continues to investigate the possibility of utilizing adaptive management practices in its Great Lakes regulatory operations. As part of its basic mission, USACE provides scientific, engineering, and management support to the IJC and directly participates in IJC studies and investigations. Through participation in the IJC's 2005 International Lake Ontario St. Lawrence River Study, International Upper Great Lakes Study (initiated in 2007 by the IJC), and ongoing investigations under the recently formed Lake Ontario Working Group, USACE staff continue to evaluate options for the regulation of Great Lakes levels and flows toward the development of a comprehensive adaptive management plan for the Great Lakes.

Program	Description
Columbia River Channel Improvement Project	Adaptive management was not included in the USACE authorizing legislation for this project. Adaptive management was part of the terms and conditions of the Biological Opinion Reasonable and Prudent Measures. The States of Oregon and Washington Water Quality and Coastal Zone Consistency Regulations also require adaptive management. An interagency adaptive management team developed an adaptive management plan in 2003 and continues to implement that plan. Additional information is available at https://www.nwp.usace.army.mil/issues/crcip/home.asp .

B.1 Comprehensive Everglades Restoration Plan (CERP)

The CERP vision states that “The overarching objective of the Plan is the restoration, preservation, and protection of the South Florida ecosystem while providing for other water-related needs of the region, including water supply and flood protection” (WRDA 2000). Success for the natural system will be to recover and sustain those essential hydrological and biological characteristics that both defined the original pre-drainage greater Everglades and made it unique among the world’s wetlands. These defining characteristics include the great extent of naturally interconnected and interrelated wetlands, sheet flow, extremely low levels of nutrients in freshwater wetlands, high levels of estuarine productivity, and great resilience of the plant community mosaics and abundance of many of the native wetland animals. CERP is being planned, implemented, assessed, and refined using the principles of adaptive management.

An adaptive management program will assess responses of the South Florida ecosystem to implementation of CERP. Adaptive management will determine if these responses match expectations, including the achievement of the expected performance levels and the interim targets. It is anticipated that adaptive management will help determine if the project operations, or the sequence and schedule of projects, should be modified to achieve the goals and purposes of CERP. CERP is intended to increase net benefits, improve cost effectiveness, and seek continuous improvement of the South Florida ecosystem based on new information resulting from changed or unforeseen circumstances, new scientific and technical information, and new or updated modeling.

The CERP web site is <http://www.evergladesplan.org/>. The CERP adaptive management web site is http://www.evergladesplan.org/pm/program_docs/adaptive_mgmt.aspx.

B.2 Louisiana Coastal Area (LCA)

The coastal wetlands of Louisiana are among the Nation's most productive and important natural assets in terms of habitat, wildlife diversity, storm protection, port commerce, and oil and natural gas production.

Unfortunately, Louisiana coastal wetlands account for 90 percent of the total coastal marsh loss occurring in the United States. Hurricanes Katrina and Rita in 2005 accelerated the loss of Louisiana wetlands, with deleterious effects on the ecosystem. In 2007, Congress authorized the LCA program to address wetlands loss threats in this important region. The program includes authority for 15 ecosystem restoration projects, three programs (Beneficial Use of Dredged Materials, Science and Technology, and Demonstration Projects), investigations into modifications of existing structures, and additional large-scale and long-term studies.

The LCA program emphasizes the use of restoration strategies directed at achieving and sustaining a coastal ecosystem that can support and protect the environment, economy, and culture of southern Louisiana. This will be done by maximizing restoration strategies to reintroduce historic flows of water, nutrients, and sediment to wetlands. The LCA program recognizes the importance of integrating the best available science and technology into restoration strategies and the use of demonstration projects to reduce scientific uncertainties. WRDA 2007 language (Section 7007) specifically includes authorization for a Science and Technology (S&T) program and a Demonstration Project program. The purposes of the S&T program shall be to identify any uncertainty relating to the physical, chemical, geological, biological, and cultural baseline conditions in the coastal Louisiana ecosystem; to improve knowledge of the physical, chemical, geological, biological, and cultural baseline conditions in the coastal Louisiana ecosystem; to identify and develop technologies, models, and methods to carry out this subsection; and to advance and expedite the implementation of the comprehensive plan.

The WRDA authorization supports adaptive management by directing the Secretary of Defense to carry out the LCA program in accordance with the report to the Chief of Engineers dated 31 January 2005. Language from the Chief's report calls for feasibility studies to identify specific sites, scales, and adaptive management measures and to optimize features and outputs necessary to achieve the restoration objectives. The authorization identifies monitoring and adaptive management as critical elements of LCA projects. The 2004 LCA Ecosystem Restoration Study began to

formulate a framework for adaptive management by identifying basic elements of adaptive management and defining the role of the S&T program in the implementation of an adaptive management plan/program.

The LCA web site is <http://www.lca.gov/>.

B.3 Missouri River Recovery Program (MRRP)

The MRRP seeks to create a sustainable ecosystem that supports populations of native species while providing for current social and economic values. The primary problem on the Missouri River is the alteration and degradation of riverine processes and habitat that has jeopardized the existence of the three Federally listed species: the interior least tern (endangered), the piping plover (threatened), and the pallid sturgeon (endangered). The MRRP includes areas along the Missouri River and is designed to improve these ecosystems and help the Federally listed species recover.

The major program components include habitat creation, flow modifications, science, and public involvement. The Integrated Science Program (ISP) of the recovery efforts is also implementing efforts targeted at long-term monitoring of the listed species, special studies to answer specific research questions, and ongoing development of a program-specific adaptive management program.

The MRRP has not been provided program-specific legislation or HQ USACE guidance specific to adaptive management, but the program has received direction on the incorporation and application of monitoring and adaptive management as part of the 2000 and 2003 Amended Biological Opinions under the Endangered Species Act. The use of adaptive management was also included in the Record of Decision (ROD) for the Missouri River Master Water Control Manual. The Master Manual ROD for the operation of the Missouri River Reservoirs discusses application of adaptive management. Decisions regarding actions proposed through the adaptive management process will meet the Corps' treaty and trust responsibilities to Native American Tribes represented in the Missouri River watershed and conform to all of the applicable requirements of Federal laws, including the National Environmental Policy Act, the Endangered Species Act, and the Flood Control Act of 1944.

The current situation on the Missouri River Basin highlights a two-fold need for adaptive management. For ongoing habitat creation activities and existing monitoring, adaptive management is being integrated with existing processes to ensure that management actions are driven by specific goals and objectives aimed at recovering species while meeting other authorized purposes. The second need is for adaptive management to inform and guide the development of the ongoing Missouri River Ecosystem Restoration Plan and EIS. Specifically, within the planning process, adaptive management will provide a structure for broader evaluation of actions to address the uncertainty. Within this process, adaptive management will influence the identification and implementation of the preferred alternative.

The MRRP web site is <http://www.moriverrecovery.org/mrrp/f?p=136:1:1265668070615376>.

The MRRP adaptive management web site is

<http://www.moriverrecovery.org/mrrp/f?p=136:17:1265668070615376::NO::>.

B.4 Navigation and Ecosystem Sustainability Program (NESP)

The Upper Mississippi River System (UMRS) is a nationally significant transportation system and river ecosystem that provides economic, environmental, cultural, and spiritual benefits to the Nation. UMRS stakeholders are a diverse group, spread over 1,200 miles of river and a 190,000-square-mile basin, with interests ranging from transportation and agriculture to tourism, recreation, and conservation of natural resources. The many agencies charged with river management have individual missions and geographic areas of jurisdiction. The need for integrated system management of the UMRS has long been recognized. That integrated approach to management and restoration has taken the form of NESP. Congress authorized NESP in the Water Resources Development Act of 2007.

NESP is an ambitious 50-year effort based on recommendations from the Upper Mississippi River-Illinois Waterway Navigation Study (USACE 2004). NESP will be implemented under an incremental adaptive management approach that will focus on delivering meaningful navigation and restoration benefits as early as possible, scheduling projects to provide early benefits, and generating knowledge that can be applied to future projects. A reach planning notebook has been developed to standardize and guide adaptive management at multiple scales for NESP. Program

language includes directives about sustainability and selecting projects that restore natural river processes.

These three large ecosystem management and restoration programs will be implemented using adaptive management as required by their authorizations. In practice, these large-scale comprehensive programs consist of many individual, yet interrelated and differently scaled projects. Adaptive management can be applied to each of these projects or combinations of projects.

The relevance of project-level application of adaptive management is reinforced by the fact that the only operational adaptive management program implemented thus far by the USACE is the application to the Columbia River Channel Improvement Project.

The NESP web site is <http://www2.mvr.usace.army.mil/UMRS/NESP//>. The NESP adaptive management web site is <http://www2.mvr.usace.army.mil/UMRS/NESP/Documents/Water%20Level%20Management%20Report%20Final%2028Oct2010.pdf>.

B.5 Columbia River Channel Improvement Project (CRCIP)

The CRCIP Adaptive Environmental Management Program was initiated as part of the terms and conditions defined by the 2002 NMFS Biological Opinion concerning the Corps proposal for channel improvements on the Lower Columbia River and estuary. Similar requirements for adaptive management were promulgated by the FWS and the states of Washington and Oregon. In addition, issues concerning 401 coastal zone certification required by the states were incorporated into the CRCIP Adaptive Environmental Management Program. Representatives from Federal and state agencies constitute the CRCIP Adaptive Management Team (AMT), which has been chartered to develop and implement the program.

The CRCIP adaptive management approach differs from programs aimed at ecosystem restoration. While there are ecosystem restoration actions associated with this program, the main emphasis lies in assessing potential negative impacts (risks) posed by channel improvements on listed native salmonids and otherwise valued ecological resources (e.g., Dungeness crab, smelt, sturgeon). As a result, a passive adaptive management approach has been undertaken. The program has been designed to monitor the possible impacts posed by channel dredging, where the main

driving force for dredging is to increase the opportunity for commercial navigation.

The general adaptive management approach is described in the CRCIP Adaptive Environmental Management Plan, which is publicly available. In addition, while the CRCIP AEM program is narrowly defined by the goals and objectives of the CRCIP, the AMT recognizes that this adaptive management program can contribute to the development of more comprehensive adaptive management programs for the Lower Columbia River and estuary. The continuing CRCIP AEM program has been in operation since 2003.

The CRCIP AEM program is in the process of transition from the project construction phase to a correspondingly appropriate adaptive management program for post-construction and operations and maintenance activities by 2013.

The CRCIP web site is <http://www.nwp.usace.army.mil/environment/aem.asp>.

B.6 Great Lakes–International adaptive management programs

Although less developed than the previous examples at this time, adaptive management is being considered for larger use on the Great Lakes. The International Joint Commission (IJC), which was established under the 1909 Boundary Waters Treaty between the United States and Canada, plays a vital role in the management of the waters of the Great Lakes. As such, the IJC has investigated, and continues to investigate, the possibility of using adaptive management practices in its Great Lakes regulatory operations.

As part of its basic mission, USACE provides scientific, engineering, and management support to the IJC and directly participates in IJC studies and investigations. Through participation in the IJC's 2005 International Lake Ontario St. Lawrence River Study, the International Upper Great Lakes Study (initiated in 2007 by the IJC), and ongoing investigations under the recently formed Lake Ontario Working Group, USACE staff continue to evaluate options for the regulation of Great Lakes levels and flows toward the development of a comprehensive adaptive management plan for the Great Lakes.

Table B2. Additional projects or programs employing adaptive management.

AM Program	Location	Context	Stage of AM	References
Trinity River Restoration Program	Trinity River, USA	Water management recovery of species of conservation concern (fish).	Implementation of AM plan ongoing, learning occurring.	US Fish and Wildlife Service and Hoopa Valley Tribe. 1999. Trinity River Flow Evaluation: Final report. USFWS and Hoopa Valley Tribe. http://www.trrp.net/ http://odp.trrp.net/FileDatabase/Documents/TRRP_2014_AnnReport1.pdf
Glen Canyon Dam Adaptive Management Program	Colorado River, USA	Large river water management for recovery of endangered species (fish).	Implementation of AM plan ongoing, learning occurring.	Melis T.S., Korman J. and C.J. Walters. Active adaptive management of the Colorado River ecosystem below Glen Canyon Dam, USA: using modeling and experimental design to resolve uncertainty in large-river management. In Proceedings of the International Conference on Reservoir Operation and River Management, Guangzhou, China 2005 Sep 18. http://www.usbr.gov/uc/rm/amp/

AM Program	Location	Context	Stage of AM	References
Platte River Recovery Implementation Program	Platte River, USA	Large river water management for recovery of endangered species (birds).	Implementation of AM plan ongoing, learning occurring.	Smith, C. B. 2011. Adaptive management on the central Platte River—Science, engineering, and decision analysis to assist in recovery of four species. <i>Journal of Environmental Management</i> 92: 1414–1419. https://www.platteriverprogram.org/Pages/Default.aspx
Middle Rio Grande Endangered Species Collaborative Program	Middle Rio Grande River, USA	Large river water management for recovery of endangered species (fish).	Plan developed but not yet implemented.	Murray, C., Smith, C., and D. Marmorek. 2011. Middle Rio Grande endangered species Collaborative Program Adaptive Management plan Version 1. Prepared by ESSA Technologies Ltd. and Headwaters Corporation for the Middle Rio Grande Endangered Species Collaborative Program, Albuquerque. 108 p.
NA	Murray-Darling River, AUS	Water management to enhance the environmental benefits of altered flow regimes.	Implementation of AM plan complete, learning occurred and management adjusted.	Allan C, Watts RJ, Commens S, Ryder DS. 2009. Using adaptive management to meet multiple goals for flows along the Mitta Mitta River in southeastern Australia. In <i>Adaptive Environmental Management 2009</i> (pp. 59-71). Springer Netherlands.

AM Program	Location	Context	Stage of AM	References
NA	North West Coast, AUS	Multi-species commercial trawl and trap fisheries management.	Implementation of AM plan complete, learning occurred and management adjusted.	Sainsbury, K. J. 1991. Application of an experimental management approach to management of a tropical multispecies fishery with highly uncertain dynamics. ICES Marine Science Symposia, 193: 301–320 Sainsbury, K. J., Campbell, R. A., Lindholm, R., and W. Whitelaw. 1997. Experimental management of an Australian multispecies fishery: examining the possibility of trawl-induced habitat modification. In Global Trends: Fisheries Management, pp. 107–112. Ed. by E. L. Pikitch, D. D. Huppert, and M. P. Sissenwine. American Fisheries Society Symposium 20. Bethesda, Maryland, USA.

AM Program	Location	Context	Stage of AM	References
Effects of Line Fishing (ELF) Program	Great Barrier Reef, AUS	Commercial and recreational fisheries management.	Implementation of AM plan complete, learning occurred and management adjusted.	Mapstone, B.D., R.A. Campbell and A.D.M. Smith. 1996. Design of experimental investigations of the effects of line and spear fishing on the Great Barrier Reef. CRC Reef Research Centre Technical Report No.7. Townsville: CRC Reef Research Centre. Davies C.R., Little L.R., Punt A.E., Smith A.D., Pantus F., Lou D.C., Williams A.J., Jones A., Ayling A.M., Russ G.R. The effects of line fishing on the Great Barrier Reef and evaluations of alternative potential management strategies. Townsville, Queensland, Australia: CRC Reef Research Centre; 2004. McCook LJ, Ayling T, Cappo M, Choat JH, Evans RD, De Freitas DM, Heupel M, Hughes TP, Jones GP, Mapstone B, Marsh H. 2010. Adaptive management of the Great Barrier Reef: A globally significant demonstration of the benefits of networks of marine reserves. Proceedings of the National Academy of Sciences 107:18278-85.

Appendix C: Regulations Relevant to Adaptive Management Applications

Regulations relevant to adaptive management applications listed in Chapter 5 are discussed in more detail below, with references to previous chapters where appropriate.

C.1 National Environmental Policy Act

NEPA compliance and timely execution can be critical to a successful field adaptive management application. The key to successful integration of NEPA and adaptive management is a well-planned and thorough up-front consideration of the range of potential consequences and the subsequent management actions within the scope of NEPA. Expanding the NEPA process to include adaptive management principles requires the integration of learning-based strategies into the existing framework of NEPA (Williams et al. 2007).

C.2 Federal Advisory Committee Act

Stakeholder engagement is a necessary component of any successful adaptive management process. However, one legal constraint to consider for non-Federal stakeholder involvement is compliance with the FACA (5 U.S.C. § 552 [1994]). Under FACA, Federal agencies may not receive advice from a group that the agency has established or that it utilizes (i.e., manages or controls) unless the agency complies with the provisions of FACA. The FACA is a procedural statute that requires certain actions to set up and operate a committee or similar group to provide group-based (rather than individual) advice to Federal officials.

To meet FACA exemption, teams can follow FACA guidance from the FACA web page at <http://www.gsa.gov/portal/content/104514> and encourage stakeholder engagement throughout the adaptive management process in the following ways:

- Include all interested stakeholders in team meeting distribution lists.
- Post all meeting dates, agenda information, and working documents on a publicly available web site.
- Allow time for public comment after each important agenda topic.

- Hold face-to-face meetings with stakeholder groups to obtain their input and understand changing societal values.

C.3 The Clean Water Act

Adaptive management plans must adhere to all applicable regulatory permitting activities (e.g., state water quality and wetland mitigation permits). An adaptive management process that is clearly explained and supported by staff within the regulatory authorities may aid the permit process, implementation, compliance, and ability to adjust. Sec. 2036 of WRDA 2007 also indicates that any USACE water resource project report must contain specific recommendations with a specific plan to mitigate fish and wildlife losses if there are adverse impacts. Mitigation plan components include:

- Monitoring until successful,
- Criteria for determining ecological success,
- A description of available lands for mitigation and the basis for the determination of availability,
- The development of contingency plans (i.e., adaptive management),
- Identification of the entity responsible for monitoring, and
- Establishment of a consultation process with appropriate Federal and state agencies in determining the success of mitigation.

AMT decisions need to be consistent with any Section 401 or 402 CWA certifications that are issued for the project. Clearly identifying risk endpoints, uncertainty, monitoring and assessment, decision criteria, and contingency options to improve performance with respect to risk endpoints can help give assurances to regulatory authorities in order to issue permits.

C.4 The Endangered Species Act

The Endangered Species Act of 1973 (ESA) provides a broad, comprehensive approach to the conservation of threatened and endangered species. By Congressional direction, the ESA is administered by the U.S. Fish and Wildlife Service (FWS) and NOAA Fisheries (National Marine Fisheries Service). In general, the FWS deals with terrestrial and freshwater species, while NOAA Fisheries deals with anadromous fish and marine species.

In cases involving large-scale Federal programs, consultation is appropriate at both a broad programmatic level and at the level of individual projects or actions that may affect listed species. Careful consideration of effects and alternatives can set the stage (for example, through adoption of best management practices or design standards) for expedited consultation on later individual actions (Williams et al. 2009).

The Council on Environmental Quality's *Handbook for Integrating NEPA and Adaptive Management* (CEQ 2007) provides case studies to demonstrate various approaches to integrating adaptive management into NEPA and can be found at the following web site:

<http://www.whitehouse.gov/administration/eop/ceq/>. The CEQ case studies demonstrate that an adaptive management model with these features works well on a wide variety of resource management projects and project scales.

Appendix D: Support Organizations and Capabilities

D.1 Technical support within the USACE

Both institutionally, and as a field of practice as a whole, adaptive management as applied to ecosystem management and restoration is relatively new and requires time, training, and resources to evolve to a standard set of practices. The USACE will likely need additional research and guidance as the science advances, with the further likelihood of evolving policy to refine the approach and application.

The USACE has access to professional scientific, technical, and management capabilities within its organization to help bridge scientific and technical gaps as the fields associated with adaptive management become more established. Involving USACE individuals and collective resources with relevant skills and experience can increase the likelihood for successful application of adaptive management. The U.S. Army Engineer Research and Development Center (ERDC), Cooperative Ecosystem Studies Units (CESU) National Network, and professional facilitators should be considered for technical support and collaboration during the planning and implementation of adaptive management.

In August 2003, the Director of Civil Works designated five National Planning Centers of Expertise (PCXes) to enhance the Corps' planning capability. Currently, PCXes have been established for Coastal Storm Risk Management; Flood Risk Management; Inland Navigation; Deep Draft Navigation; Small Boat Harbors; Ecosystem Restoration; and Water Management and Reallocation. The role of the PCXes is to focus on plan formulation and the complex technical evaluation associated with formulation, including model certification, training and technical assistance, policy support and peer review. Each PCX is led by a team of experts in plan formulation, environmental sciences, economics, and related technical disciplines.

USACE PLANNING & CENTERS OF EXPERTISE LINKS

USACE PLANNING URL:

- <https://www.usace.army.mil/Missions/Civil-Works/Project-Planning/>

PLANNING COMMUNITY TOOLBOX-CENTERS OF EXPERTISE URL:

- <https://planning.erdcdren.mil/toolbox/people.cfm?Id=0&Option=Planning%20Centers%20of%20Expertise>

FLOOD RISK MANAGEMENT URL:

- <https://www.iwr.usace.army.mil/Missions/Flood-Risk-Management/Flood-Risk-Management-Program/>
- <https://cops.usace.army.mil/sites/PLAN/pcx/FRMPCX/>

ECOSYSTEM RESTORATION URL:

- <https://www.erdcd.usace.army.mil/Missions/Water-Resources/>
- <https://cops.usace.army.mil/sites/PLAN/pcx/ecorest/>

INLAND NAVIGATION URL:

- <https://www.lrd.usace.army.mil/Missions/Civil-Works/Navigation/Inland-Waterways-2/>

DEEP DRAFT NAVIGATION AND SMALL BOAT HARBOR URL:

- <https://www.sam.usace.army.mil/Missions/National-Centers-in-Mobile/Deep-Draft-Navigation/>

COASTAL STORM RISK URL:

- <https://www.nad.usace.army.mil/About/National-Centers-of-Expertise/Coastal-Storm-Risk-Management-Planning/>

WATER MANAGEMENT AND REALLOCATION URL:

- <https://www.swd.usace.army.mil/About/Water-Management-Center-of-Expertise/>

D.2 Engineer Research and Development Center

The U.S. Army Engineer Research and Development Center (ERDC) is one of the most diverse engineering and scientific research organizations in the world. The ERDC conducts research and development (R&D) in support of the Soldier, military installations, and the Corps of Engineers' civil works mission, as well as for other Federal agencies, state, and municipal authorities, and U.S. industry through innovative work agreements. Their mission is to provide science, technology, and expertise in engineering and environmental sciences in support of our Armed Forces and the Nation to make the world safer and better.

The ERDC synergistically addresses R&D in four major areas: Military Engineering; Geospatial Research and Engineering; Environmental Quality/Installations; and Civil Works/Water Resources through the capabilities of seven laboratories: the Construction Engineering Research Laboratory in Champaign, IL; the Cold Regions Research and Engineering

Laboratory in Hanover, NH; the Topographic Engineering Center in Alexandria, VA; and the Coastal and Hydraulics, Geotechnical and Structures, Environmental, and Information Technology laboratories in Vicksburg, MS. ERDC has a staff of approximately 2,300 Federal employees and supporting contractors.

ERDC scientists and engineers provide a wealth of experience and expertise, and they can assist the Districts as:

- Problem solvers: ERDC provides customers with interdisciplinary technical expertise and institutional knowledge. Because they are part of the USACE and Army teams, they have detailed understanding of District, Division, and installation responsibilities and mandates.
- Technology advisors: ERDC knows the state of the science and helps customers make the right technology choices. ERDC scientists and engineers have been on the leading edge of wide-ranging research and development activities addressing a multitude of water resources and environmental issues.
- Technology developers: ERDC develops innovative technology or modifies existing technology to meet customer needs. The ERDC develops cutting-edge tools, models, and supporting guidance to solve a wide range of water resource and environmental problems.
- Business development partners: ERDC gives customers a competitive advantage via technology and access to ERDC personnel and its unique partnering authorities. These capabilities provide rapid access to critical science and technology expertise wherever it resides, in other Federal labs, nongovernmental organizations, academia, and the private sector.
- ERDC has employees who are trained in adaptive management facilitation. More information can be found at the following web site: <http://www.erdc.usace.army.mil/>.

D.3 Cooperative Ecosystems Studies Unit

The Cooperative Ecosystem Studies Units (CESU) National Network is a network of cooperative units established to provide research, technical assistance, and education to resource and environmental managers. CESU emphasizes that multiple Federal agencies and universities are among the partners in this program. Ecosystem studies involve the biological, physical, social, and cultural sciences needed to address natural and

cultural resource issues and interdisciplinary problem solving at multiple scales and in an ecosystem context.

The basic relationship between the Federal government and the scientific community is shifting. The fiscal limits imposed by the Federal budget are long term, and support of science throughout the government will continue to be constrained. There is increased demand for usable knowledge and research applied to the national interest. Federal agencies must husband their science resources in creative ways that limit cost and magnify value to managers, scientists, Congress, and the public. Universities, private research institutions, and the broader scientific community face similar pressures and must respond and adapt to this new environment for science.

The CESU Network provides opportunities for Federal agencies, nongovernmental organizations and universities to collaborate on research, technical assistance, and education, which can help provide information to address key uncertainties related to ecosystem restoration projects. Any Corps office, with the appropriate authority, can participate in CESU activities and have work performed under a cooperative agreement by the four CESUs of which the Corps is a member. The Engineer Research and Development Center has joined several CESUs on behalf of the Corps of Engineers Civil Works Program under the authority of Title 10 U.S.C. 2358 (http://frwebgate.access.gpo.gov/cgi-bin/getdoc.cgi?dbname=browse_usc&docid=Cite:+10USC2358). The process for USACE offices to initiate work with CESUs is found under the “policy and procedures” button at the following URL: <http://corpslakes.usace.army.mil/partners/cesu/cesu.cfm>.

D.4 Facilitation for adaptive management

Facilitation is often used by the Corps to assist in implementing an adaptive management plan. A trained facilitator’s services can be used in many ways, but the most important aspect that they can provide is their neutrality during the adaptive management process. Several resources are available to assist with adaptive management programs. Some of the resources are free, and others are available as contract services. Below is brief list of available resources at the time publication of this guidance:

D.5 National Resource Management Gateway

The National Resource Management Gateway has a database that provides contact information for individuals within USACE who have experience in facilitation and are willing to provide that service for others.

D.6 Environmental Conflict Resolution

The Collaboration and Public Participation Center of Expertise (CPCX) develops and maintains collaborative tools to assist the USACE in preserving the public interest and managing stakeholder interactions by anticipating, preventing and handling water-related conflicts and decision making. With approaches such as alternative conflict resolution (ACR), the CPCX seeks to prevent or minimize conflict by optimizing participation. Additional information can be found at the Center's website: <https://www.iwr.usace.army.mil/About/Technical-Centers/CPCX-Conflict-Resolution-Public-Participation/>.

The U.S. Institute for Environmental Conflict Resolution (ECR) was founded in 1998 as part of the Morris K. Udall and Stewart L. Udall Foundation. ECR is an independent and impartial Federal program that assists Federal agencies in resolving environmental conflicts. Additional information on ECR can be found on their web site: <http://www.ecr.gov>.

Appendix E: Adaptive management considerations for program and project implementation

This chapter addresses considerations for the implementation phase of adaptive management not previously covered. Potential challenges to adaptive management are introduced, suggestions for surmounting these challenges are offered, and descriptions of additional capabilities and resources to support adaptive management efforts are provided.

Implementing adaptive management is simply putting the plan into action. In so doing, it should be remembered that a fundamental tenet of adaptive management is that the entire process is adaptable. If the AMT determines that specific aspects of monitoring, assessment, and decision making are not meeting needs, those aspects can be adjusted. The adaptive management plan can be correspondingly revised and the process of implementation continued until the goals and objectives are achieved.

E.1 Executing the adaptive management cycle

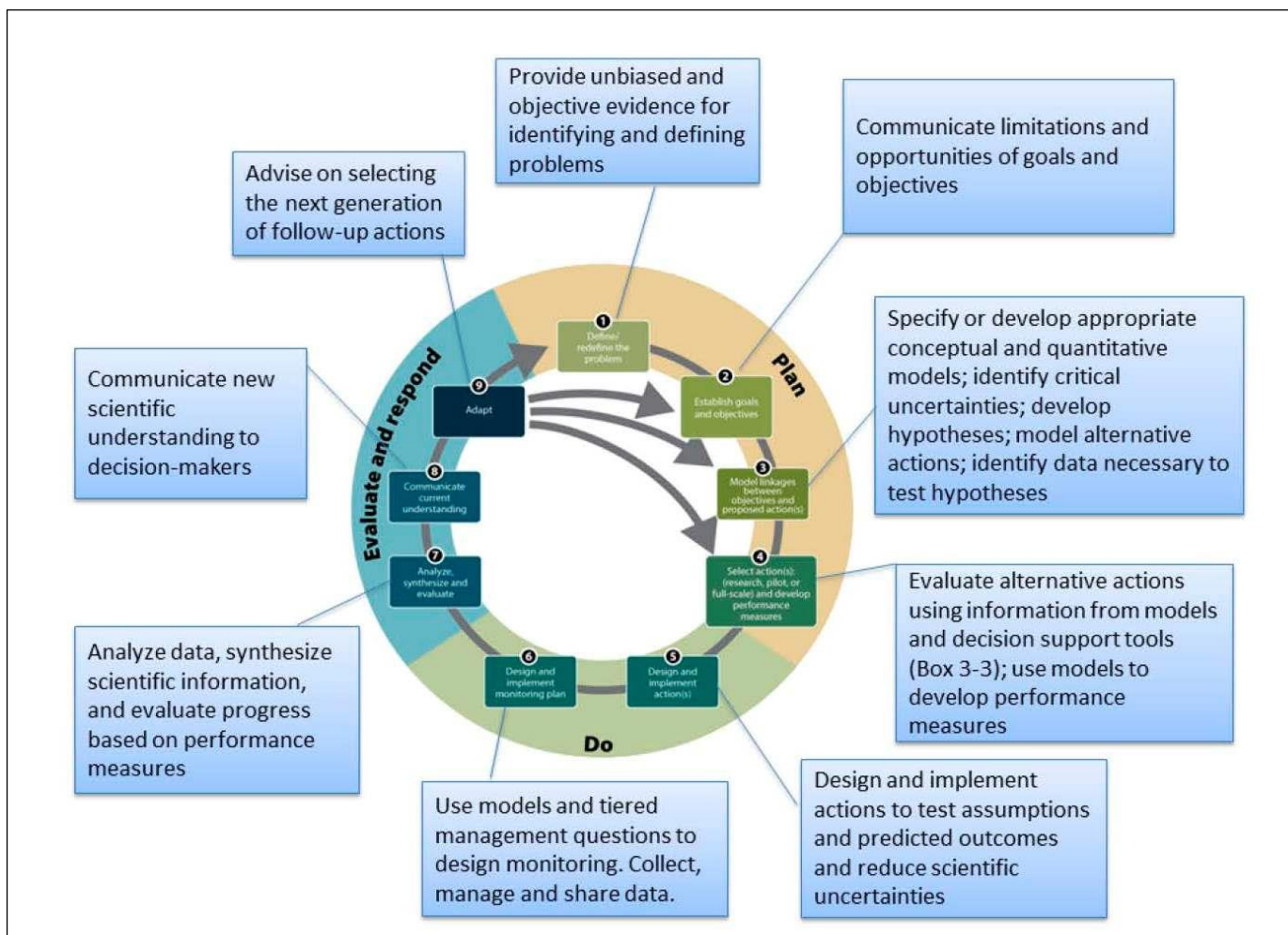
Implementation of adaptive management nominally involves monitoring, assessment, and at least one decision. The simplest circumstance involves a single project where monitoring and assessment confirm that success has been achieved (or a reliable trajectory toward success is established) and the decision consists of a declaration of success and cessation of federal funding for further monitoring or adaptive management. The project is turned over to the sponsor for operation and maintenance (if required).

More commonly, ecosystem restoration projects will demonstrate a trajectory toward success, but success will not be assured for some time. This may be due to lingering uncertainties, long response times for ecosystems, or myriad factors. If the 10-year time limit for federal funding of monitoring passes before success can be established, the sponsor should assume responsibility for further monitoring and adaptive management.

Planning is an ongoing (if intermittent) part of adaptive management implementation. There are many types of planning decisions, but one of the most common occurs when a problem or opportunity is identified, an

analysis is undertaken to evaluate alternative adjustments to management, and a preferred alternative selected. These steps often benefit from a structured decision making process, described below. Other considerations for implementing adaptive management are shown in Figure E1.

Figure E1. Considerations for implementing adaptive management.



E.1.1 Structured decision making under adaptive management

Adaptive management is primarily a response to planning situations that contain decision-relevant uncertainties, and the planning steps are often revisited as part of the adaptive management implementation. There are many types of planning decisions, but one of the most common occurs when a problem or opportunity is identified, an analysis is undertaken to evaluate alternative solutions, and a preferred alternative selected. These steps often lead to the development of a consequence table of the type shown in Table E1, which is reproduced from the USACE Planning Primer (Orth and Yoe 1997).

Table E1. Illustrative Consequence Table Source (USACE Planning Primer).

	PLAN A	PLAN B	PLAN C
ECONOMIC EFFECTS	+\$ 30	-\$ 5	+\$ 10
ENVIRONMENTAL EFFECTS	-100 acres	+ 70 acres	+ 200 acres
SOCIAL EFFECTS	moderate growth	low growth	moderate growth
OTHER EFFECTS	+	- -	+ + +

In the present context, there are several features of this table that are worth considering:

1. The rows in the table contain *predicted* outcomes of effects across a broad range of objectives and constraints for various alternatives (columns). The table is not just limited to the primary objective of the project (which in the context of habitat restoration may often be beneficial environmental effects, rather than the negative impacts implied in this example). Rather, it is the *trade-off* between benefits to objectives and the impacts on constraints that informs rational management decision making.

Looking at some of the trade-offs shown in this table, Plan A has the best economic benefit, but causes the loss of 100 acres of some environmental resource. Plan B creates 70 acres of something, but at a direct cost of \$5 and with other negative social and economic impacts. Plan C generates \$10, creates the most acres, has no

negative social effects, and has other benefits. Plan C can be said to dominate Plan B; that is, if we agree that the table represents the spectrum of things that matter, and if we agree that the estimates are accurate enough for the decision context, then there is no rational reason to select Plan B since Plan C beats it in every respect. One could rationally select Plan A over Plan C, however, but only by judging the importance of $(30 - 10 =)$ \$20 of economic effects to be more important than the net 300 acres of environmental difference and whatever significance is captured in the difference between their ‘other’ effects. Suppose, for the sake of discussion, that this is not the case, and the decision-maker expresses a preference for Plan C over Plan A based on an evaluation of this trade-off.

2. There will be *uncertainty in the estimates of the consequences* (i.e. in the values that are portrayed in the table for both objectives and constraints).
3. All predicted estimates are uncertain to some degree, but only some could make the difference between preferring one plan over another, i.e. because they are decision-relevant uncertainties.

For example, suppose Table 9 was modified to incorporate communication of two large uncertainties (Table E2).

Table E2. Modified Illustrative Consequence Table; differences from Table 9 shown in bold.

	PLAN A	PLAN B	PLAN C
ECONOMIC EFFECTS	+\$ 30	-\$ 5	+\$ 10
ENVIRONMENTAL EFFECTS	-100 to +200 acres	+ 70 to +150 acres	+ 200 acres
SOCIAL EFFECTS	moderate growth	low growth	moderate growth
OTHER EFFECTS	+	- -	+ + +

The uncertainty presented in Plan B’s environmental effects may be relatively large, but it is not decision-relevant, because Plan C still dominates Plan B regardless of this value as long as the true value remains within this range estimated range. However, the uncertainty in environmental performance for Plan A could create a very real

conundrum for the decision maker. If the actual value were at one end of this range, at -100 acres, we have previously stated that the decision maker would choose Plan C. But if the value were at the other end of the range of uncertainty, at +200 acres, then the decision maker has a very different trade-off to consider. This that case, she must decide if the difference in 'other effects' is worth the \$20 difference in economic effects. Suppose, again for sake of discussion, that if Plan A would actually result in +200 acres, then that would be the preferred choice in the decision-maker's opinion.

In some (but not all) decision contexts, it may be possible to avoid the irreversible commitment of resources to one alternative over another until greater clarity is brought to such decision-critical uncertainties. Examples include:

- Repeated decisions (e.g. dam flow releases, habitat construction programs)
- Decisions for which experiments to reduce uncertainty could be undertaken in advance of an irreversible commitment of resources (e.g. major infrastructure projects)

Adaptive management, then, may often (though not exclusively) be used to fill such gaps. In these cases, adaptive management *is in service of* planning decisions, rather than something that is different to or independent of planning decisions.

A disciplined approach to structuring decisions to identify *decision-critical* uncertainties may take a little additional effort, but as the previous example showed, could help avoid unnecessary expenditures on investigating irrelevant uncertainties and, more importantly, help decision-makers make more responsive, and ultimately better, decisions.

The USACE six-step planning process is a rational decision model rooted in the decision sciences. It is very closely related to a planning approach known as PrOACT, which itself a subset of a collection of tools and approaches of decision analysis sometimes collectively referred to as structured decision making (SDM). Since adaptive management is increasingly referred to as being designed to function within the context of a structured decision making (SDM) process (e.g. Williams et al. 2009), a

short discussion on the similarities between the six-step process and these others may be valuable.

PrOACT is an acronym for a decision process with the following steps (e.g. Hammond et al. 1999):

- Problem Definition
- Objectives
- Alternatives
- Consequences
- Trade-Offs

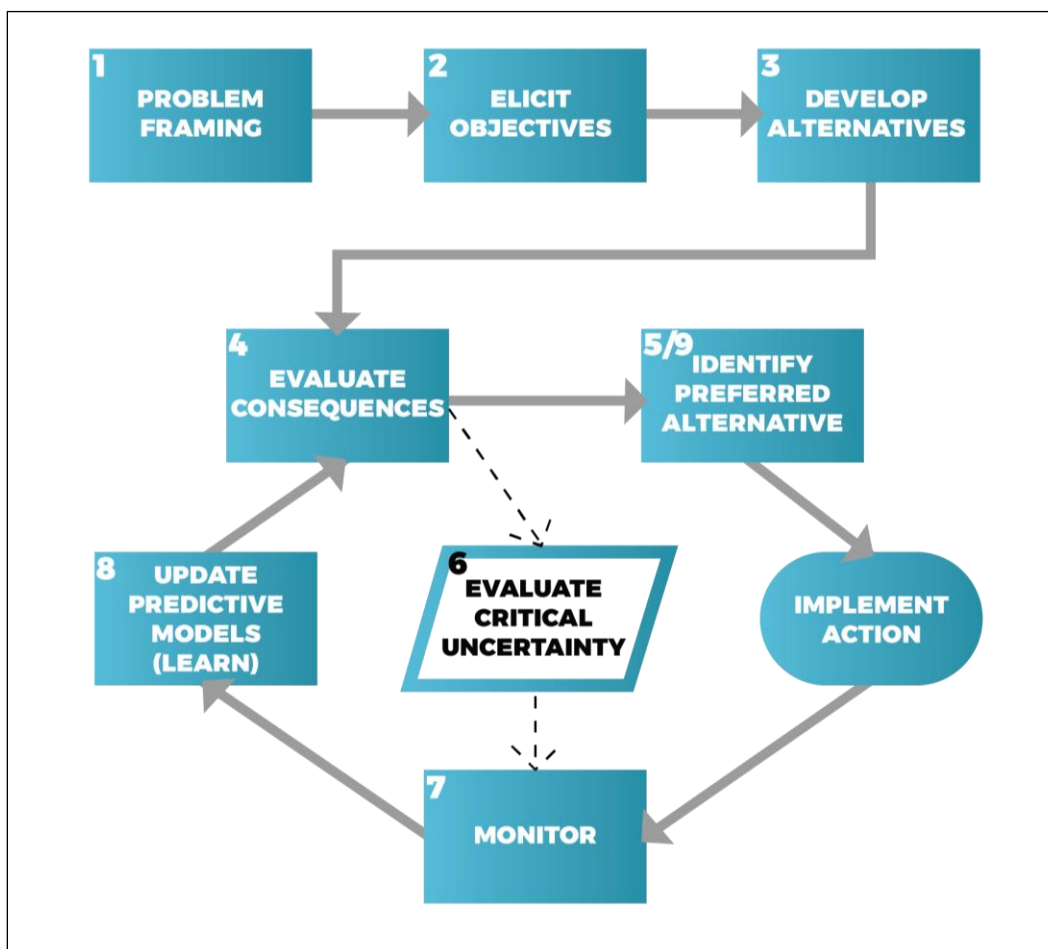
These steps can readily be mapped to the USACE planning steps, and the two processes can be considered functionally equivalent with a small number of important differences, some of which include:

- The USACE six-step process distinguishes between objectives and constraints ('do good, don't do bad'). In PrOACT, these are both simply considered objectives – some with positive directionality (more is good) and some with negative directionality (more is bad).
- In the USACE six-step process, objectives can sometimes be articulated as targets, e.g. "create 1,000 acres of habitat." In PrOACT, objectives never have associated targets; instead the 'things we care about' are stated as simple, directionally unambiguous verb-noun combinations, such as "maximize habitat," "minimize costs" etc. If minimum thresholds of performance are mandatory, these are stated as requirements of the decision context in the first step and used to constrain the definition of viable alternatives. The reason for this is that targets can unnecessarily constrain (why stop at 1,000 acres when 1,200 might be just as easy?) and they also embed trade-offs that might not be clear (perhaps 1,000 acres costs \$x, but 990 acres costs ten times less).
- In the USACE six-step process, the criteria used to evaluate the alternatives are developed at a relatively late stage in the process, as part of Step 4. In the PrOACT process, objectives are closely tied to 'performance measures' and both are addressed sequentially earlier, before developing alternatives (although iteration makes differences between the two processes largely ones of philosophy and emphasis rather than practical difference). The reason for this is that through 'value-focused thinking' (Keeney 1998), objectives can be used to create

- imaginative alternatives, by challenging planners to design new alternatives that push as hard as possible on each objective – ‘how could we create an alternative that maximizes habitat creation?’ ‘how could we create one that minimizes cost?’ etc.
- In the ProACT process, a much greater emphasis is placed on the use of consequence tables to articulate and communicate trade-offs for discussion purposes particularly with stakeholders, as illustrated in the earlier discussion and as discussed at length in Gregory et al (2012).

The link between a typical ProACT process and adaptive management is captured effectively in the schematic Figure E2 (Runge 2011).

Figure E2. ProACT and Adaptive Management (Source: Runge 2011).



The first five steps in this figure are the ProACT process. Having identified a preliminary preferred alternative, the action is implemented and an adaptive management cycle is initiated to investigate decision-critical uncertainties.

Learning occurs at different rates in different decision contexts, depending on ecological and institutional considerations. For some decisions, responses to treatments occur rapidly and key uncertainties may be reduced in just a few seasons or years. In such cases the learning is used to update models and new management actions may be selected and implemented without reconvening a full decision process. This fast-learning cycle has been termed “single loop learning” (Conroy and Peterson 2013). However, in many resource management contexts, the time required to reduce key ecological uncertainties is measured in decades rather than years. In such cases, by the time models can be updated, many things will have changed. In addition to new information about predictive modeling assumptions, there may be new legal or policy constraints, new stakeholders that need to be involved, new management objectives arising from new stressors or changes in social values, and new management alternatives that need to be considered. In such cases, a whole new cycle of decision making is triggered. This slower learning cycle is sometimes termed “double-loop learning.”

E.1.2 Productive stakeholder participation

Meaningful stakeholder participation increases the effectiveness and probable success of adaptive management. Ideally, stakeholders are engaged in every aspect of the program/project adaptive management implementation process, from initial problem formulation to identification of objectives and design of monitoring and assessment. EP 1105-2-57 provides guidance on stakeholder engagement (USACE 2019).

If key stakeholders are not initially or appropriately engaged, program/project managers may need to coordinate with agency outreach specialists to re-engage stakeholders and determine what issues might be limiting involvement with PDT and/or technical team efforts. This outreach effort may require additional information sharing to address any gaps and clearly identify each stakeholder’s role in contributing to adaptive management decision making. Effective stakeholder engagement also requires a commitment by program/project implementing agencies to consider stakeholder views and respond with reasons when agency decisions appear inconsistent with stakeholders’ perspectives.

Public involvement in adaptive management should begin as early in the planning process as possible. Engaging the public early in the process allows them to become vested in the project and project decisions.

Traditional USACE planning usually involves stakeholders early in the public review of either an Environmental Assessment or an Environmental Impact Statement or at public meetings where testimony is taken regarding the draft environmental documents. There are additional pathways for public stakeholder engagement in the adaptive management process, including open or facilitated workshops, task force or other public meetings, committee assignments, or written comments on draft environmental documents, typically as part of official public comment periods. Some Congressional authorizations may specify more direct roles for sponsors and stakeholders.

Identifying additional stakeholders for a project will depend largely on characteristics of the project and consideration of Federal Advisory Committee Act (FACA) requirements (see Appendix B for additional detail). For example, small noncontroversial projects can involve a small group of stakeholders from state and Federal agencies who meet periodically to review and concur on project goals and objectives. For large projects, such as the CRCIP and CERP (see Appendix B), FACA may become a consideration in constituting an adaptive management team. USACE Districts should check with their Office of Counsel to help determine how the team should be set up and how to comply with FACA requirements.

E.1.3 Demonstrating success in monitoring and achieving goals and objectives

Clearly stated program and project goals and objectives are crucial in decision making, performance evaluation, monitoring, assessment, and adaptive learning. Management objectives are particularly important in decision making, especially where project actions are based on predicted system responses that best correspond to overall program management objectives. In addition, clearly defined objectives guide comparisons of actual responses with modeled/predicted responses to facilitate learning and assess performance.

The following criteria can be used by USACE program and project managers to assess the success of adaptive management with specific reference to achievement of goals and objectives in specific applications:

- Monitoring and assessment have led to modifications in management practices,

- Success in achieving goals and objectives has been demonstrated.

Documenting that management practices as part of a project have been adjusted based on improved understanding – one of the important objects of project monitoring that leads to effective evaluation and provides evidence to support learning and decision making – will be evident based on answers to the following questions:

- Are monitoring and assessment efforts being focused to determine how and whether projects and the program are meeting project goals and objectives?
- Are uncertainties being addressed and conceptual models being used and refined?
- Are assessments able to indicate performance status and a need to adjust?
- Is project performance information being conveyed to managers and are options being developed and/or analyzed through a collaborative process to adjust project/program implementation if necessary?
- Are recommended modifications to project/program plans or operations being implemented?
- Has adaptive management increased the effectiveness of the project or program in achieving the stated goals and objectives?
- Have stakeholders demonstrated an increased understanding of technical issues and/or modified their positions on issues? Have the agencies?
- Have lessons learned been conveyed to other USACE districts, agencies, or practitioners so as to improve ecosystem restoration or fish and wildlife mitigation on other systems?

If the responses to these questions are largely positive, then the adaptive management process is working, new knowledge is being gained and applied, and USACE programs, projects, and operations are being adjusted (if or as needed) to more efficiently meet goals and objectives.

It is important to recognize that management objectives may change as learning accumulates during implementation of the process. Refinement of objectives as understanding accumulates and stakeholder perspectives change is fundamental to the adaptive management process. Periodic reassessment of objectives is a necessary part of the iterative adaptive management and learning cycle.

E.1.4 Demonstration of adaptive management principles

Specific applications of adaptive management will be effective to the extent to which the principles outlined in Chapter 1 are followed.

Productive applications generally share the following characteristics:

- Key uncertainties have been identified and are being reduced through rigorous monitoring, assessment, decision making, and technical support as needed;
- Current and updated scientific understanding provides the basis for all aspects of the adaptive management process;
- Program and project plans and designs are sufficiently flexible to permit structural or operational modifications suggested by adaptive management to meet goals and objectives;
- Established roles and responsibilities are followed in gathering scientific information (e.g., monitoring, research), assessing performance of management measures and success progress, and communicating project achievements (e.g., evaluation reports) to decision makers;
- Decisions to continue or modify project implementation derive from a clearly defined decision-making process with well-defined decision criteria; and,
- Responsible agencies are willing and able to execute recommended adaptive management actions to improve progress towards stated goals and objectives.

E.2 Data management, reporting, and communications

E.2.1 Data management

Data management includes the collation, storage/retrieval, analysis, summarization, and communication of monitoring results and related information (e.g., published information, model results) used in support of adaptive management. This is typically a task of the AMT, and individuals with responsibility for data management activities (data managers) should be identified during the development phase of adaptive management.

The information base provided by the data management system includes existing data and information that were used in the development phase, the results of monitoring, modeling and analysis results, and additional scientific and technical information that accumulate during the course of

the adaptive management process. The information base will importantly serve as an archive of the process upon completion of adaptive management. A growing archive of adaptive management programs will serve as a valuable resource in future USACE planning and applications.

Data management for small or uncomplicated projects might be addressed with a simple collection of data spreadsheets that is periodically updated and analyzed by one or two personnel following scheduled monitoring activities. Larger-scale, complex adaptive management processes may require correspondingly more sophisticated relational databases and complex analysis. This may necessitate engagement of support beyond the AMT.

The data management plan should identify the computing hardware and any specialized or custom software used in data management for an adaptive management program. The AMT should collaborate with the data managers to identify the types of data and information to be included in the data management system, establish convenient formats for storing and retrieving data, and guarantee the preservation of the data (i.e., backup versions, electronic and/or hard copy). The data management plan should include preservation of the results of all analyses used in performing assessments for an adaptive management program. Programs used to perform the analyses should be verified, documented, and preserved (archived) within the data management system.

E.2.2 SMART Planning Risk Register and example

The Risk Register is an important risk management tool for USACE. The RR is a log (spreadsheet) in which one records the relevant details of the risks that could result from actions taken or not taken during each stage of a project's life cycle (Table E3). RR includes outlining the uncertainty of risk. Adaptive management may be an appropriate risk mitigation strategy associated with achieving actual project performance.

Table E3. Risk Register Example - Loxahatchee River Watershed Restoration Project.

Date	Risk Number	Risk Type	POC	Milestone	Discipline	Scoping Choice or Event	Risk and its cause	Consequence	Consequence rating
7/26/2018	ENV-3	Redesign		TSP.	Environment	Using Lake Okeechobee water from L-8 basin	Water quality of water in the forested areas of the L-8 basin is good. Water quality in the L-8 Canal is good when Lake Okeechobee is not releasing water to the canal. Water quality is poor (high nutrients) when Lake Okeechobee is releasing. There is a water quality compliance risk.	Flowing nutrients through Grassy Waters Preserve (GWP) and causing aquatic nuisance vegetation. Could affect state water quality certification resulting in an unimplementable project.	H
	Evidence for Consequence rating	Likelihood rating	Evidence for likelihood rating	Uncertainty rating	Risk Rating	Risk Management Options	Affected Study Component	Outcome	Notes
	Issue identified in prior planning effort and likely to occur with Lake Okeechobee water supply flows routing through GWP.	L	TSP does not directly use water from L-8 Canal. Lake Okeechobee water supply releases are still likely to occur during the dry season.	L	M	During planning, minimize the cascading effects of water quality issues by incorporating flexible features in the design and operations., Evaluate potential water quality effects to identify which alternatives may have less risk., Develop operational measures/alternatives to reduce risk., Consider storage with sufficient residence time to reduce nutrient concentrations before release..	None	TSP does not rely on Lake Okeechobee water; only minimal Lake Okeechobee water would be used. Water Quality tool shows that TSP does not reduce water quality in receiving waters.	At Alternatives Milestone, this risk was scored High (H, M). For TSP milestone, risk reduced to Medium (H, L).

Date	Risk Number	Risk Type	POC	Milestone	Discipline	Scoping Choice or Event	Risk and its cause	Consequence	Consequence rating
7/26/2018	EHH-4	Analytical Error		TSP.	Eng. - H&H	Use existing model (LECSR-NP) for plan evaluation	Calibration may be difficult to achieve. May not be able to quantify all hydrological changes due to project alternatives in different parts of the study area	A. High uncertainty of ecosystem benefits. B. Level of resolution/assumptions of existing (H&H) models/detailed modeling information related to hydraulic design may not be available for all management measures. C. Loss of project support with respect to flood damage risk reduction and water support analysis. D. Schedule and cost increase to do additional detailed modeling earlier in the planning process.	H
	Evidence for Consequence rating	Likelihood rating	Evidence for likelihood rating	Uncertainty rating	Risk Rating	Risk Management Options	Affected Study Component	Outcome	Notes
	Based on past planning experience on this project, stakeholders were very interested in flood control and water supply and wanted detail early on in the plan formulation process.	L	Based on prior planning experience with the Loxahatchee project this is likely to occur.	L	M	Incorporate new LIDAR (from Martin County) into the model., Early and clear coordination of project scope and level analysis at each stage of planning with all stakeholders., Clear decision-management plan on when and how much modeling/detailed design analysis will occur., Move from less detail to more detail during PED., During planning, create inset model that uses approved code and good calibration and verification for aquifer storage and recovery..	None	Intensive collaboration among modelers (significant time and budget) resulted in significant improvement in LECsR model performance. Added LIDAR data. Modeled existing conditions are very close to existing conditions data. Model outputs are suitable to evaluate alternatives and identify TSP.	As a result of the improved model performance, the Risk Rating of this action for the TSP Milestone was reduced from High (H/M) to Medium (M/M).

Date	Risk Number	Risk Type	POC	Milestone	Discipline	Scoping Choice or Event	Risk and its cause	Consequence	Consequence rating
43040	PFM-15	Analytical Error		TSP.	Plan Formulation	Climate Change	Accurately predicting climate change effects on rainfall and hydrology, and saltwater intrusion in the aquifer.	Under or over-estimating the amount of water available for the environment, and not achieving actual restoration benefits during implementation.	M
	Evidence for Consequence rating	Likelihood rating	Evidence for likelihood rating	Uncertainty rating	Risk Rating	Risk Management Options	Affected Study Component	Outcome	Notes
	Recent years (2000-2014) have seen a higher frequency of dry years, and extreme rainfall events.	M	Recent years (2000-2014) have seen a higher frequency of dry years, and extreme rainfall events.	L	M	Design structures that may alleviate or have the ability to integrate greater operational flexibility., Utilize the POR analysis for extreme events (dry and wet years) to describe impacts on TSP if those conditions become more frequent..	None		no cost or time impacts. multiple risk types. no risk management recommendation.

Date	Risk Number	Risk Type	POC	Milestone	Discipline	Scoping Choice or Event	Risk and its cause	Consequence	Consequence rating
43048	ENV-19	Project Performance Risk		TSP.	Environment	Limited Optimization of Reservoir Operations to determine benefits during comparison of alternatives	Current tools are limited in the capability of optimizing operations of storage features to improve achievement of performance measure targets.	Benefits of project are not optimized as high as could be	M
	Evidence for Consequence rating	Likelihood rating	Evidence for likelihood rating	Uncertainty rating	Risk Rating	Risk Management Options	Affected Study Component	Outcome	Notes
	Optimizing operations with additional flexibility added by project can improve restoration benefits. In addition, there is some uncertainty with restoration response that might point towards additional improvements through operations to be achieved during implementation.	M	We have good understanding of ecology and hydrology, but will likely need to test operations.	M	M	Characterize uncertainty in benefits calculations in qualitative way., Build in flexibility to operations plans and NEPA coverage to allow for adaptive management tests to improve operations during implementation, refine operations of TSP after the Agency Decision milestone.	None		

Date	Risk Number	Risk Type	POC	Milestone	Discipline	Scoping Choice or Event	Risk and its cause	Consequence	Consequence rating
43040	ENV-21	Study Delays		TSP.	Environment	Communication/Expedited BO/BA & other detailed analyses	Potential for limited review of natural resources when developing the BO, BA, or other detailed analyses.	Less detailed assessment of potential impacts to habitat and wildlife which could lead to identifying an incorrect plan or impacting T&E species.	M
	Evidence for Consequence rating	Likelihood rating	Evidence for likelihood rating	Uncertainty rating	Risk Rating	Risk Management Options	Affected Study Component	Outcome	Notes
	There has been initial coordination on this project in the past. We have several planning aid letters through 2006.	M	In past experience, we have found ways to reduce this problem. Make sure to do the mitigation to have medium likelihood.	L	M	Use information from prior planning aid letters., Coordinate early and often with FWS/FWC on trust resource issues, determine how to screen measures to address their concerns, and evaluate alternatives that address their concerns.	None		no cost or time impact in excel sheet. no risk management recommendation.

Date	Risk Number	Risk Type	POC	Milestone	Discipline	Scoping Choice or Event	Risk and its cause	Consequence	Consequence rating
43047	PFM-26	Study Cost Increase		TSP.	Plan Formulation	Sea Level Change. Using one sea-level scenario to evaluate all project alternatives, then apply all sea level change curves to the TSP.	May be required to assess all three sea level rise scenarios on all project alternatives. Increase .	Additional sea-level rise change curves may indicate projects benefits are significantly reduced. EC requires significant amount of time and effort modeling various sea level rise scenarios. Requires evaluation of all alternatives - impacts schedule	M
	Evidence for Consequence rating	Likelihood rating	Evidence for likelihood rating	Uncertainty rating	Risk Rating	Risk Management Options	Affected Study Component	Outcome	Notes
	Portion of project benefits affected by sea-level rise is low: however, nationally significant portion of project area is at risk. Objectives of project are consistent with mitigating for sea level rise.	L	Based on experience, reviews not likely to require substantial changes to plan formulation. Will have substantial public involvement and frequent vertical team reviews. Restoring flows to Loxahatchee Northwest Fork is consistent with mitigating the effects of sea-level rise.	M	L	Present a narrative and GIS based evaluation of sea level rise scenarios on the TSP. Include an explanation of how formulation and plan selection would not be impacted by sea level rise..	None		

Date	Risk Number	Risk Type	POC	Milestone	Discipline	Scoping Choice or Event	Risk and its cause	Consequence	Consequence rating
	43305	ENG-27	Study Delays	TSP.	Eng. - General	Incorporate new storage technologies (e.g. ASR) to improve timing and increase volume of water deliveries	Understanding effectiveness of Aquifer Storage and Recovery (ASR) storage not yet tested in this location.	ASR might be ineffective in this area. Without adequate storage, increased flow volume and improved flow duration to the Loxahatchee River may not be realized, resulting in limited ecosystem restoration benefits	H
	Evidence for Consequence rating	Likelihood rating	Evidence for likelihood rating	Uncertainty rating	Risk Rating	Risk Management Options	Affected Study Component	Outcome	Notes
	Past planning effort concluded that storage location (relative to the Loxahatchee River), volume, and timing of delivery affect benefits to river.	L	Existing subsurface data and existing groundwater flow models indicate potential for successful use of ASR.	M	M	Desktop analysis of ASR integrated with reservoir to demonstrate capability., Gather additional site specific data (exploratory bore hole during PED)..	None	Analysis completed to reduce number of ASRs (8 to no more than 4 in a cluster) and location away from utility cone of influence on aquifer. Desktop analysis completed. ASR is feasible in this area. Concurred Mr. Coleman during IRC (3 June 2016). Revised Risk Rating - Low	Based on desktop analysis, likelihood is reduced and Risk Rating revised to Medium (H/L). At start of study it was rated High (H/M).

Date	Risk Number	Risk Type	POC	Milestone	Discipline	Scoping Choice or Event	Risk and its cause	Consequence	Consequence rating
43041	RES-37	Analytical Error		Alternative s.	Real Estate	Land Ownership Constraints	Real Estate: Absence of full ownership information. Full impact on existing land use conditions.	Increase risk of flooding private lands. Delay in implementation. Increased costs to relocate affected parties.	H
	Evidence for Consequence rating	Likelihood rating	Evidence for likelihood rating	Uncertainty rating	Risk Rating	Risk Management Options	Affected Study Component	Outcome	Notes
	Based on prior CERP studies.	L	past studies have indicated that this doesn't always occur.	M	M	Upfront coordination with local sponsor; state and local governments responsible land ownership/real estate to identify real estate ownership, Go ahead with current information level and risk into TSP phase..	None	Real estate records are being compiled early on in coordination with local sponsor.	multiple risk types no cost or time impact.

Date	Risk Number	Risk Type	POC	Milestone	Discipline	Scoping Choice or Event	Risk and its cause	Consequence	Consequence rating
43311	EGT-38	Redesign		CWRB.	Eng. - Geotechnical	Perform preliminary seepage modelling on selected features of the TSP.	Selected features may not perform as designed. Insufficient conveyance of surface flows due to extensive seepage. Impacts to adjacent roadways. Inaccurate estimate of flowway performance due to seepage losses or gains.	Re-design structure, re-grade, relocate features during PED. Potential increase of cost and schedule of PED. Potential increase cost of construction.	M
	Evidence for Consequence rating	Likelihood rating	Evidence for likelihood rating	Uncertainty rating	Risk Rating	Risk Management Options	Affected Study Component	Outcome	Notes
	unknown cost increases of PED and/or construction.	M	Sufficient geotechnical data exists at relevant features to enable feasibility-level analysis.	L	M	2-D seepage analysis will be performed on those features most susceptible to seepage effects. Use existing geotech evaluation and seepage modeling to inform this new effort..	None		

Date	Risk Number	Risk Type	POC	Milestone	Discipline	Scoping Choice or Event	Risk and its cause	Consequence	Consequence rating
43311	EHH-40	Redesign		CWRB.	Eng. - H&H	Evaluation of alternatives for Savings Clause (flood) used period-of-record POR) modeling data.	Modeling using POR analysis may underestimate flooding during short-term, high precipitation events. Design storm analysis would provide better description of TSP performance.	If flooding is underestimated in the modeling, design of TSP may be insufficient to maintain existing level of flood protection (Savings Clause).	H
	Evidence for Consequence rating	Likelihood rating	Evidence for likelihood rating	Uncertainty rating	Risk Rating	Risk Management Options	Affected Study Component	Outcome	Notes
	Final report has legal requirement to demonstrate compliance with Savings Clause for flood protection. Private property might be flooded. Public may oppose a report that relies only on POR analysis for the Savings Clause for flood protection.	L	the project will not flood private lands. If design storm analysis is not done during feasibility level design, it would be performed during PED.	L	M	Recommend HEC-RAS modeling of design storms during feasibility level design between draft and final report., Do not recommended deferring design storm analysis to PED..	None		

Date	Risk Number	Risk Type	POC	Milestone	Discipline	Scoping Choice or Event	Risk and its cause	Consequence	Consequence rating
43311	EHH-41	Project Performance Risk		CWRB.	Eng. - H&H	Limited optimization of reservoir operations during evaluation and comparison of alternatives and selection of the TSP. Incorporation of ASR operations will add more flexibility.	There was not enough time to do additional sensitivity runs to optimize performance of storage features to improve achievement of performance measure targets.	Ecosystem benefits of the TSP are not as high as they could be.	M
	Evidence for Consequence rating	Likelihood rating	Evidence for likelihood rating	Uncertainty rating	Risk Rating	Risk Management Options	Affected Study Component	Outcome	Notes
	Optimizing operations with additional flexibility added by project can improve restoration benefits.	M	We have good understanding of ecology and hydrology, but will likely need to test operations.	L	M	Build in flexibility to operations plans and NEPA coverage to allow for adaptive management tests to improve operations during implementation, refine operations of TSP after the Agency Decision milestone..	None		

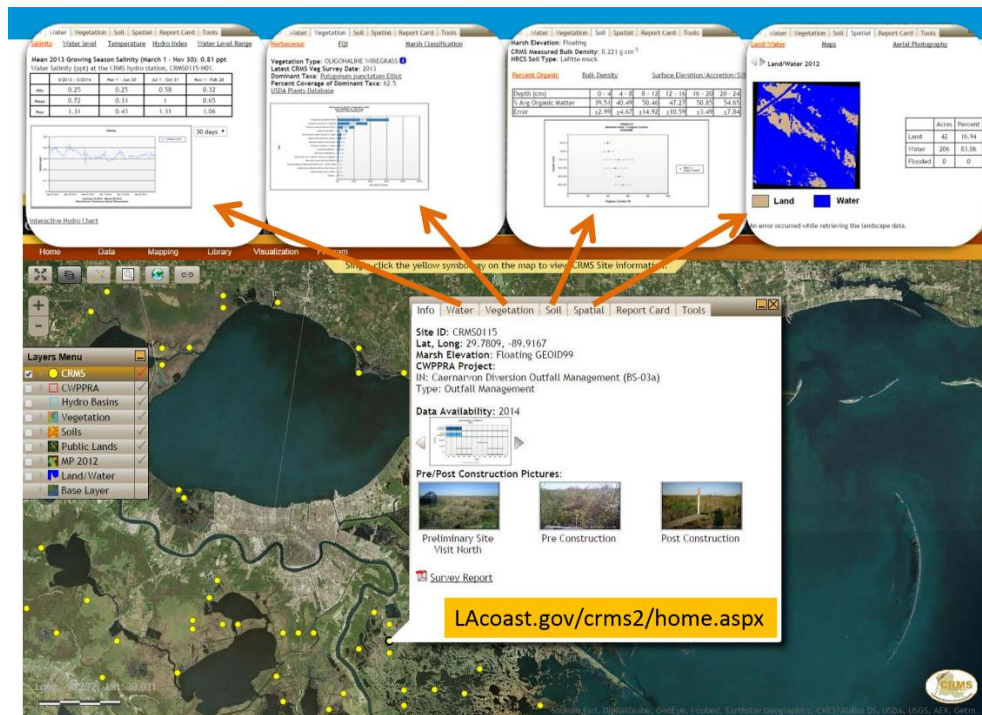
E.2.3 Communications and reporting

One of the most important aspects of an adaptive management process is reporting and communication, which provides information needed for decision making as well as fosters understanding of stakeholders and the general public. Each audience has somewhat different needs, and therefore requires different forms of information with varying levels of detail. A user-needs assessment can be used to identify requirements. Development of a communication plan that considers the different audiences and diverse reporting appropriate to each audience (e.g., decision-oriented syntheses, annual reports, reporting sessions, science workshops, peer-reviewed reports and journal articles, fact sheets, videos, presentation summaries) is essential.

Adaptive management benefits from open and transparent management wherein the results of monitoring, assessment, and decision making are routinely and consistently documented and communicated. These are essential to the program's success; they ensure PDTs, managers, and senior leaders are making decisions based on the best available information, they convey intent to the entities involved in the program, and they ensure transparency with the public. It is important that these communications conform to USACE standards and policies. A district's Public Affairs Office can assist with needed messaging.

Documentation minimally takes the form of annual (or more frequent) reports of monitoring and assessment results, but might also include scientific journal publications, reports of studies, fact sheets and "report cards," and decision documents. Electronic media (e.g., a web site) may be a convenient, efficient, and economical means for communicating and providing electronic access to information for an adaptive management program. As an example, see the Coast-wide Reference Monitoring System (CRMS) supporting the LCA (see Appendix B and Figure E3).

Figure E3. Example of online monitoring and assessment results in a “report card” format (from the CRMS website).



E.3 Challenges to adaptive management

Although adaptive management has been applied to natural resource management for decades, implementation has not been easy. Obstacles include concerns that implementing, rigorously evaluating, and potentially adjusting management actions may be too costly, too risky, and/or contrary to values of some stakeholders, as well as perceptions that a shift to adaptive management threatens existing management, research, and monitoring programs.

Challenges have emerged in previous applications to adaptive management, especially active adaptive management. Plans should be developed in anticipation of these potential pitfalls in effectively executing adaptive management. Walters (1997) identified challenges to putting an adaptive management process into practice, and these have proven prescient based on a number of recent reviews of adaptive management practice:

- Modeling in support of adaptive management is often replaced by never-ending model development and modeling exercises with the presumption that detailed modeling can replace field experiments in defining best management practices. There are also technical issues

- (e.g., accuracy, reliability) associated with the development and use of models in adaptive management. For ecosystem restoration, the most difficult technical issue may be the cross-scale linkages between hydrodynamic, water quality, and ecological models that are necessary in using the models to design and evaluate management alternatives.
- Using active adaptive management (i.e., system manipulations as large-scale experiments) has been often viewed as excessively expensive or ecologically risky compared to traditional management approaches. Costly modeling studies may be needed to design the management manipulation. Follow-on monitoring programs add to the costs of active adaptive management. Manipulations may result in economic losses (e.g., lost revenues from reduced navigation). The management manipulation might result in unanticipated effects on non-target populations or resources, with unacceptable consequences.
 - Those in management positions often oppose experimental management policies (e.g., adaptive management). Complex institutional settings involving multiple agencies with sometimes-overlapping responsibilities and legal mandates can lead to interference in operations and generate resistance to proposed changes in management policy.

With adaptive management as a tool, identification of a “best” plan based primarily on economic or cost-effective criteria may also consider other factors, wherein the adaptability of the plan, its ability to address risk and uncertainty, and the capability to respond to changing conditions may represent critical selection criteria because they ultimately affect likelihood of achieving success and, consequently, the projected benefits.

However, adaptive management has associated costs (for monitoring and subsequent adaptive actions) that need to be considered relative to the benefits in order to make an informed decision about the best plan. There is nothing prescriptive regarding the length of time required to recognize substantive improvements in understanding and management. Expectations about the pace of learning can be problematic, particularly if there are budget constraints or a perceived urgency to achieve specific goals. Several conditions can influence the rate of learning, including the size and complexity of the managed system, the number and complexity of management alternatives, and the sources and implications of uncertainty (Table E4).

Table E4. Factors affecting adaptive management success adapted from a summary compiled by Marmorek et al. 2006.

Factors related to attitude/philosophy	
Historical context	Context can cause AM to develop in very different ways. Its proper consideration will help ensure that AM is applied in the appropriate historic and local context. Context can strongly influence in positive and negative ways the institutional drivers motivating the need for AM and the relationships among individuals/organizations involved.
Trust and commitment	Trust and commitment relate to the strength of the relationships among individuals and organizations and affect their ability to participate, interact, and engage in the AM process.
Mindset (around uncertainty, risk, and AM)	There can be aversions to acknowledging or dealing with uncertainties in decision making that relate to the risk tolerance of stakeholders and willingness of decision makers to invest in management actions that may be seen as surprises. Embracing uncertainty and learning from mistakes can enable success.
Factors related to process	
Problem definition	Ensures there is agreement among parties and focus on the correct problem, which includes how the problem is expressed. Problem definition needs to be durable and capture the larger context; otherwise, the focus can be lost or lead to crisis management.
Executive direction/ support	A clear and strong commitment from executives is required, backed up by regulatory authority to do AM, to ensure success.
Leadership and vision	Leadership is essential, but not sufficient for success. This attribute involves effective communication to gain broad support regardless of the level at which leadership is rooted, though local-level leadership may be important in some cases where top-down leadership will not work.
Planning	AM actions are inevitably implemented within existing planning processes. The dominant planning paradigm can inhibit success if too restrictive or enable it if sufficiently flexible.
Communication and organizational structure	Effective, broad-based, and two-way communication is necessary within and outside the organizational structure governing AM. This attribute includes a consideration of the choice of language, world view being represented, and venues for communication. There is also a need to maintain flexibility in organizational structure to respond to unexpected events.
Community involvement	The need for community involvement depends on context, which affects the decision about whether to involve the community, who to involve, and how to do it. For public/shared resources, a participatory approach that involves varied stakeholders in knowledge generation, deliberation, and decision making can enable success. The most effective AM programs have a small number of stakeholders who trust each other and can make decisions in an agile manner.
Facilitation, bridging, and team building	To enable trust and learning, it is important that those individuals involved are supported through neutral facilitation, team building, and a bridging organization that seeks to bring disparate interests together to explore preferences, interpret information, and make decisions.
Knowledge generation and flow	Decision making and participation should be based on a strong foundation of rigorous science in the formulation and evaluation of management actions, which can also include local and/or traditional knowledge. Knowledge should flow through the governance network in a transparent way that can be important for building mutual trust.

Knowledge interpretation and sense- making	It is important to have a transparent and inclusive process for interpreting the information generated through AM, translating the science into a form that facilitates decision making.
Integration of AM	It important that the administrative/logistical aspects of AM are embedded into existing management structures and processes rather than in their own isolated institutional structure. People working within institutions should be rewarded for activities that advance AM.
Factors Related to Resources	
Funding/ management resources	AM requires sufficient funding and management resources to be successful. Level of funding can be an indicator of the presence, or lack, of executive support.
Staff training	In some cases there may be a need for staff/those involved to receive AM training to learn new skills that facilitate successful implementation. Key areas include training around basic concepts of AM, details of the AM program, and the knowledge gained to inform future actions/decisions.
Capacity	Implementation of AM requires sufficient capacity across all entities involved. Governance structures should be realistic in reflecting the available and projected capacity of participating entities.
Legislation	A strong legislative driver is an important enabling condition to initiate and sustain AM.

E.3.1 Institutional reluctance to change

For adaptive management to be accepted on an institutional level, refinements in existing approaches to management and restoration may be needed. The targets of resource management are rapidly becoming more inclusive. For example, ecosystem management has traditionally been approached by targeting only one or a few system attributes, failing to account for the broader resource context and its implications for resource management. Adaptive management allows the resource problem to be framed in a more comprehensive context that includes issues such as system viability and sustainability. Lack of institutional recognition of this and other benefits to the adaptive management approach may persist, despite updates in policy or missions, as new guidance and practices take time to become incorporated and routine while former practices become obsolete. Notable differences in institutional characteristics that encourage or discourage changes in practices comprise important sets of obstacles to progress or openings for dialogue (Table E5).

Table E5. Summary of factors that have been identified to enable or inhibit effective governance of adaptive management programs (adapted from the science and adaptive management plan for the MRRP¹).

Factors Enabling Good Governance	Factors Inhibiting Good Governance
Collaborative, interdisciplinary working environment with free-flowing communication and easy access to well-synthesized information.	Communication among components/departments hindered by different mandates or between disciplinary specialists (i.e, stovepiping). Difficult to access required information.
Frequent re-examination of management and restructuring as needed.	Management done the same way for a very long period of time.
Leaders deliberately challenge themselves and staff to recognize change, innovatively adapt to challenges, and take calculated risks.	Leaders resist change, discourage risk and innovation, and create organizational culture of status quo.
Collaborative inputs to decision making over sustained period, generating buy-in and trust, allowing stakeholders to move from positions to interests, clarifying areas of agreement and disagreement.	Institutions isolated from public/stakeholders; very limited and inconsistent consultation. “Inform” rather than listen.
Recognize critical uncertainties and plan experiments to test alternative hypotheses/actions.	Plan based on past experience, practices, procedures established by senior staff.
Stress high-quality science at appropriate scales, with independent review panels. Data made available; different interpretations of data welcomed, used to postulate alternative hypotheses and design management experiments. Wide publishing of scientific findings.	Science discouraged or use of “advocacy science” to support agency’s position. Data kept internal; selective evidence used; insist on single, dogmatic agency position regarding data analysis.

Time itself is a challenge in implementing adaptive management. In many cases, the overall costs associated with adaptive management are tied as much to the timeframe of the project as they are to its complexity. Some adaptive management plans require extensive monitoring over long time periods (e.g., floodplain forest restoration) to measure the results of an initial action. Of course, models that forecast some future endpoint as a consequence of a decision or series of decisions should also be able to predict the resource status at various intervals prior to that endpoint, allowing management assessments to be performed on the predicted status over an abbreviated interval. The problem of time lags is further complicated by the fact that individual decision makers and/or managers may not remain in the same position over the needed timeframes,

¹ Fischenich, J. C., K. E. Buenau, J. L. Bonneau, C. A. Fleming, D. R. Marmorek, M. A. Nelitz, C. L. Murphy, G. Long, and C. J. Schwarz. 2018. *Missouri River recovery program science and adaptive management plan*. ERDC-EL TR (in preparation). Vicksburg, MS: U.S. Army Engineer Research and Development Center.

emphasizing the need for an adaptive management plan and governance process that outlasts career moves, and a data management, reporting, and communications strategy that ensures new managers can access important historical information.

E.3.2 Surmounting challenges to adaptive management

Implementation of adaptive management can often require a shift in focus toward resource sustainability as a strategic target, with resource planning and design, decision-based monitoring, and assumption-driven research as central activities. Institutional support, described above, is instrumental in moving the state of the science forward.

Managers must carefully assess the costs of the monitoring and assessment that inform decision making in an adaptive management process. The costs of timely monitoring and assessment over extended time scales can be substantial and often appear to be high at the outset of a project. The USACE and partnering agencies must be willing to cover the costs of monitoring and evaluation over the life of an adaptive management project.

During design phases, the cost and details of adaptive management plan contingency options need to be identified in detail and included in the cost ledger of the project implementation report as an O6 feature code. Congressional authorization of these costs ensure that the 902 limit has enough room for the options to be budgeted, implemented, and cost-shared without breaking that limit.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing this collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden to Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports (0704-0188), 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number. **PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS.**

1. REPORT DATE (DD-MM-YYYY) November 2019		2. REPORT TYPE Final		3. DATES COVERED (From - To)	
4. TITLE AND SUBTITLE A Systems Approach to Ecosystem Adaptive Management: A USACE Technical Guide				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S) J. Craig Fischenich, Sarah J. Miller, and Andrew J. LoSchiavo				5d. PROJECT NUMBER 476549	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Environmental Laboratory U.S. Army Engineer Research and Development Center 3909 Halls Ferry Road Vicksburg, MS 39180-6199				8. PERFORMING ORGANIZATION REPORT NUMBER ERDC/EL SR-19-9	
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) U.S. Army Corps of Engineers Washington, DC 20314-1000				10. SPONSOR/MONITOR'S ACRONYM(S) USACE	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release; distribution is unlimited.					
13. SUPPLEMENTARY NOTES					
14. ABSTRACT Implementation guidance for Sections 2036 and 2039 of WRDA 2007 and Section 1161 of WRDA 2016 requires that ecosystem restoration projects either include appropriately scoped monitoring and adaptive management plans or provide sound justifications for why adaptive management is not warranted. Under adaptive management, decisions are based on the best available (yet often incomplete and imperfect) scientific data, information, and understanding, recognizing uncertainties that introduce risks to the achievement of goals and objectives. Revision to management actions based upon information derived from ongoing monitoring and evaluation is possible. This guide provides an overview of adaptive management practice, emphasizing underpinning principles. An approach to determine the need for and development of adaptive management plans is presented, and the implementation of ecosystem restoration projects under adaptive management is presented.					
15. SUBJECT TERMS Adaptive management Ecosystem restoration		Monitoring Mitigation Ecosystem management		Risk-management Decision-making SMART planning	
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES 171	19a. NAME OF RESPONSIBLE PERSON
a. REPORT Unclassified	b. ABSTRACT Unclassified	c. THIS PAGE Unclassified			19b. TELEPHONE NUMBER (include area code)