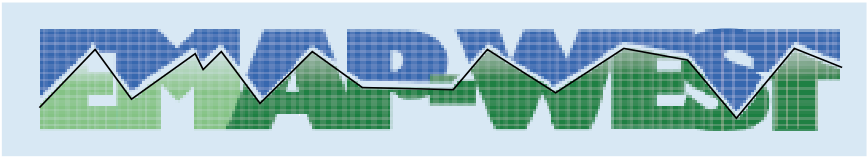
Environmental Monitoring and AssessmentProgram:West - Research Strategy



This strategy has been prepared utilizing input from several sources. The background material comes largely from preceding descriptions and plans of the Environmental Protection Agency s Environmental Monitoring and Assessment Program (EMAP). The individual sections describing the various program components were prepared by the program technical leadership. The strategy is intended to provide enough detail for the interested reader to understand EMAP-West as well as references (largely to sources readily available on the internet) that provide access to much more supporting detail.

Roger Blair, Technical Coordinator
February, 2001

Executive Summary

Safeguarding the natural environment is fundamental to the mission of the US Environmental Protection Agency (EPA). The legislative mandate to undertake this part of the Agency s mission is embodied, in part, in the Clean Water Act (CWA). A section of this Act requires the states to report the condition of their aquatic resources. The Office of Research and Development (ORD) has undertaken research to support EPA s regional offices and the states in their efforts to meet that reporting requirement.

The Environmental Monitoring and Assessment Program (EMAP) is one of the key components of that research. EMAP-West is the newest regional research effort in EMAP. From 1999 through 2005, EMAP-West will seek to develop and demonstrate the tools needed to measure ecological condition of the aquatic resources in the 14 western states in EPA s Regions 8,9, and 10.

The primary demonstration vehicle will be a series of reports on the ecological condition of water resources at the state and regional level. Other reporting units are possible, however, depending upon the sampling intensity of the program element. For example, reports could be made on an ecoregion scale or at the scale of a large watershed. Stakeholder input will be a main factor in the form and content of interim and final products. Transfer of monitoring technology to regional, state and tribal personnel is the intended legacy of EMAP-West.

EMAP-West consists of several components: Design and Analysis, Coastal, Surface Waters, Landscapes and Information Management.

- The Design and Analysis Team is responsible for the working with the resource groups to define the sample population and subsequent design by which field data will be collected. Data analysis is primarily the responsibility of the resource groups, but they will require statistical support from the Design and Analysis team.
- The Coastal component sampled small coastal estuaries in Washington, Oregon and California during 1999 and 2000. In 2001, Alaska and Hawaii will be the focus for field sampling while analysis of 1999 and 2000 data for the other states is underway. In Hawaii, sampling will focus on near-shore systems, with special studies added for outfall areas. Only one of Alaska s five coastal regions can be sampled with resources presently available. Off-shore sampling is being considered for year 2002 and the option for coastal wetland sampling is being considered for 2003. Final reporting will be completed in 2005,
- Surface Waters began sampling in the 12 state area covered by EPA Regions 8,9, and 10 (Alas aka and Hawaii not included) in 2000. The sampling design calls for sampling of streams (except the great rivers, Columbia, Colorado and Missouri) that is adequate for making a statistically sound estimate of condition at the state level. Also, in each Region, selected area are being sampled more intensively as special projects. Nearly 1500 sites will be sampled during the life of this program. As with Coastal, biological indicators of condition will be emphasized. Habitat and physical/chemical water parameters are also being measured. Final results will support assessments of surface water conditions on a state and regional basis. Major reports are expected in 2005, with smaller reports and more specific analyses to be completed in the following months.
- Landscape data are collected are collected via remote imagery across the entire west, unlike the sampling regime used by Coastal and Surface Waters. The main source of data is the

Multi-Resource Land Classification (MRLC) covering the entire western United States. From these data and other remote sensing sources, indicators of landscape status will be generated and their values associated with aquatic indicators of condition. Landscape analysis will be conducted in three phases: (1) generating remote sensing data bases and developing indicators of condition, (2) relating these indicators to aquatic condition and finally (3) assessing these relationships relative to their ability to predict aquatic condition. Final reports are scheduled for 2004 and 2005, with interim data sets being made available to regional and state agencies for their use in EMAP related analyses, as well as for other uses.

- No large program such as EMAP-West can be successful until the data are brought together in a user friendly form and made widely available. The Information Management component of the Program dedicated to assuring that all data collected in EMAP-West are fully documented and made available to the public in accessible formats, according to national data management standards. Individual program components are responsible for collecting data, assuring its quality, and providing appropriate documentation. The Information Management component then manages the incorporation of these individual data sets into the EMAP web site, EPA s Office of Water STORET database and ORD s Environmental Information Management System.

Management for EMAP-West consists of a series of working groups associated with each Program component. These groups deal with the detailed implementation of their respective component from field data collection through analysis and reporting. A technical committee, composed of the ORD component leaders, regional technical leads and the technical coordinator, has the responsibility of overall program coordination including budgeting, technical communication including peer review of products, and long-term and yearly planning documents. The committee s activities are overseen by a steering committee consisting of management representation from ORD, the participating Regions and the Office of Water. Led by the EMAP director, the steering committee provides management oversight of the program, approving budget and planning documents. This group also provides outreach to management levels in their respective parts of the Agency.

Introduction

This strategy document describes the direction of EMAP-West, a research and demonstration effort being implemented to monitor the ecological resources in the western United States (Figure 1).This effort is part of the U.S. Environmental Protection Agency's (EPA) Environmental Moni-

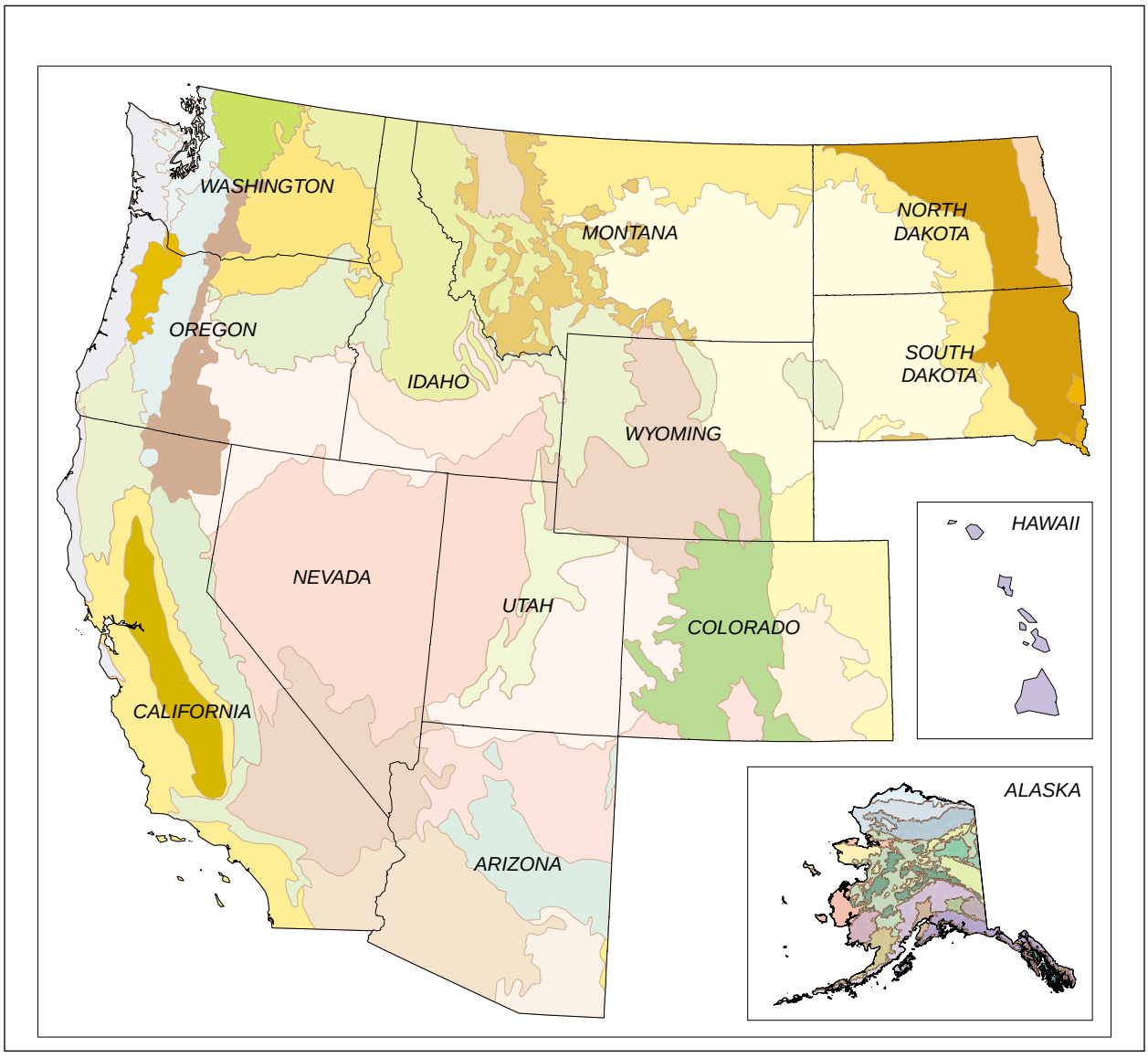


Figure 1.Geographic extent of EMAP-W with up-dated Level 3 Ecoregions. HI and AK are conducting coastal surveys only. The remaining states will conduct surveys of coastal and freshwater systems (rivers and streams) and collect landscape data.

toring and Assessment Program (EMAP) and represents the second major regional study. This strategy for EMAP-West has been prepared for those interested in the tools and approaches for deriving assessments of condition of the region's ecological resources. Special emphasis is being placed on freshwater and coastal aquatic systems and analysis of patterns in land cover.

Agency Mission

The U.S. EPA's mission is to protect human health and to safeguard the natural environment (*http://www.epa.gov/*). Policies and programs that promote the preservation of ecosystem integrity and sustainable use of natural resources are key elements in achieving that mission, which is defined via policies established by the Agency's media offices [e.g., Office of Water (OW)]. The policies are then implemented through EPA's ten regional offices and the appropriate state agencies. These policies must be formulated with a sound scientific knowledge of the environment. As the Agency's research arm, the Office of Research and Development (ORD), provides the scientific and technical support to develop that knowledge. A key part of the support ORD provides is EMAP. This program represents a major element of ORD's effort to support monitoring and increase our understanding of the nation's ecological resources. EMAP is designed to develop sound scientific approaches to monitoring important ecosystem characteristics and the human perturbations that alter them over space and time.

Calls for improvements in environmental monitoring date back to the late 1970's. Many reports. both internal and external, have stated the need for coordinated monitoring of the nation's ecological resources. Internal reports have been provided by the Agency's OW and Office of Policy (OP), formerly Office of Policy, Planning and Evaluation. External reports have come from the National Research Council[1] and the U.S. General Accounting Office[2] as well as from state, federal, and university aquatic biologists[3]. The 1988 U.S. EPA Science Advisory Board's (SAB) report, *Future Risk: Research Strategies for the 1990's,* [4] was the stimulus for many changes in EPA research. One of the SAB's recommendations was that the EPA take steps to enhance its ability to anticipate environmental problems before public fears are aroused and before costly, after-the-fact clean-up actions are required. Embodied in the SAB recommendation was the perspective that monitoring programs can be valuable for their ability to provide a picture of present conditions (status) and, if continued, to describe what happens to the condition of an ecosystem over time (trends). The SAB recommended that the EPA begin monitoring a broader range of environmental characteristics and contaminants than had been done in the past.

The Genesis of EMAP

EMAP was created in response to these recommendations. Taking the pulse of the nation's ecological resources and producing a national environmental report card became the driving focus for the Program[5]. Developing the tools necessary for measuring the condition of many types of ecological resources and the designs for describing status and detecting both spatial and temporal

1. National Research Council. 1977. Environmental monitoring. Volume IV. National Academy of Sciences. Washington, DC. 153 p.
2. U.S. General Accounting Office. 1981. Better monitoring techniques are needed to assess the quality of rivers and streams. Volume 1. CED-81-30. U.S. General Accounting Office. Washington, DC.
3. U.S. Environmental Protection Agency. 1987. Surface Water Monitoring: A Framework for Change. Water Office. Washington, DC.
4. Science Advisory Board. 1988. Appendix C: Strategies for ecological effects research. SAB-EC-88-040C. U.S. Environmental Protection Agency. Washington, DC. 35 p.
5. Messer, J.J., R.A. Linthurst, and W.S. Overton. 1991. An EPA program for monitoring ecological status and trends. Environmental Monitoring Assessment, 17:67-78.

trends was a significant challenge. EMAP responded to this challenge by developing indicators of ecological condition, along with new monitoring designs for major classes of natural resources such as forests, wetlands, deserts, agricultural systems, and surface waters. The resulting data would be used to evaluate the cumulative success of current policies and programs and to identify emerging problems before they become widespread or irreversible. This goal was established to ensure that we would eventually be able to answer several fundamental questions:

1. What have we accomplished with our collective efforts to restore and protect our ecological resources?
2. How do we know our programs, in aggregate, have been successful?
3. Can we provide data to confidently verify the answers?
4. Is the aggregate of our regulatory decisions protecting our ecological resources?

These questions were translated into four operational objectives:

1. Estimate current status, trends, and changes in selected indicators of the nation's ecological resources on a regional basis with known confidence.
2. Estimate the geographic coverage and extent of the nation's ecological resources with known confidence.
3. Seek associations between selected indicators of natural and anthropogenic stresses and indicators of the condition of ecological resources.
4. Provide annual statistical summaries and periodic assessments of the nation's ecological resources.

Although these objectives have remained essentially the same since the program's beginning in 1991, budget realities have focused the program on aquatic resources (inland surface waters and coastal systems) with design and analysis, indicator development and data management as additional key elements. The program also incorporates development of landscape-scale assessments based on remote imagery of land cover as a critical component to complement monitoring and assessment of single classes of ecological resources. The program seeks to reduce the uncertainty in estimates of condition of these resources.

EMAP advanced through a series of demonstration efforts in different geographic regions of the country. In 1997, the program began a "proof of concept" by bringing all of the demonstration activities to focus within the same region. These regional studies are part of the national monitoring framework proposed by the Committee on Environment and National Resources (CENR; see *http://www.noaa.gov/CENR/cenr.html*) under the auspices the President's National Science and Technology Council. This framework calls for the environmental agencies to merge their efforts to achieve a common goal of monitoring, understanding and managing our ecological systems for their sustained use and enjoyment. The first pilot under this framework was the Mid-Atlantic Integrated Assessment (MAIA) which covers a region from southern New York to northeastern North Carolina (see Figure 2).

EMAP's successful contribution to this effort was the impetus to move on to a second focused pilot, EMAP-West (EMAP-W), where the sampling design, indicators of condition and sampling procedures could be developed and tested under vastly different conditions. We draw on examples from the MAIA, where appropriate, to illustrate the approach to EMAP-W. This strategy sets the stage for EMAP-W which targets Standard Federal Regions 8, 9, and 10 which coincide with EPA

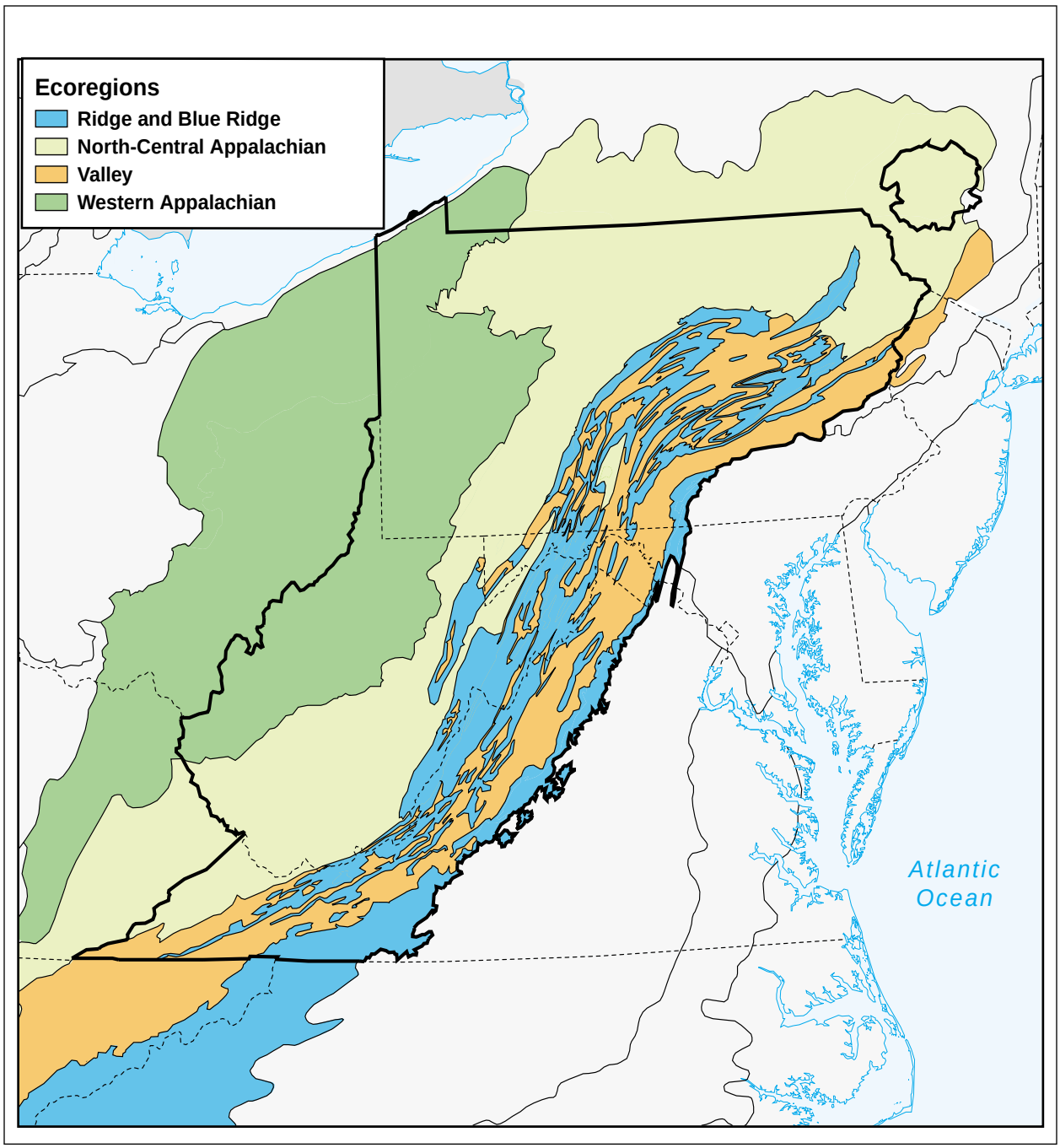


Figure 2.Level III ecoregions for the MAIA program. Bold outline encompasses the region referred to as the Mid-Atlantic Highlands (MAHA) discussed in the text.

Regions 8, 9, and 10 (See Figure 1).These Regions include the 14 western states of North Dakota, South Dakota, Wyoming, Colorado, Montana, and Utah (Region 8); Arizona, California, Nevada and Hawaii (Region 9); and Washington, Oregon, Idaho and Alaska (Region 10). Extensive sampling will occur in all 14 states and on many tribal lands with additional research issues being addressed in the Intensive Areas outlined in Figure 3. Hawaii and Alaska will be sampled for coastal condition only. Examples of the research issues that will be addressed in the Intensive Areas include the special challenges of measuring the condition of the mainstem and reservoirs in

the Missouri River drainage, establishing freshwater reference condition in the John Day basin of Oregon, and in large rivers in Idaho and the specific challenges of connecting freshwater and estuarine condition in northern California. Other areas with intensive work may be added as the opportunities arise and resources allow.

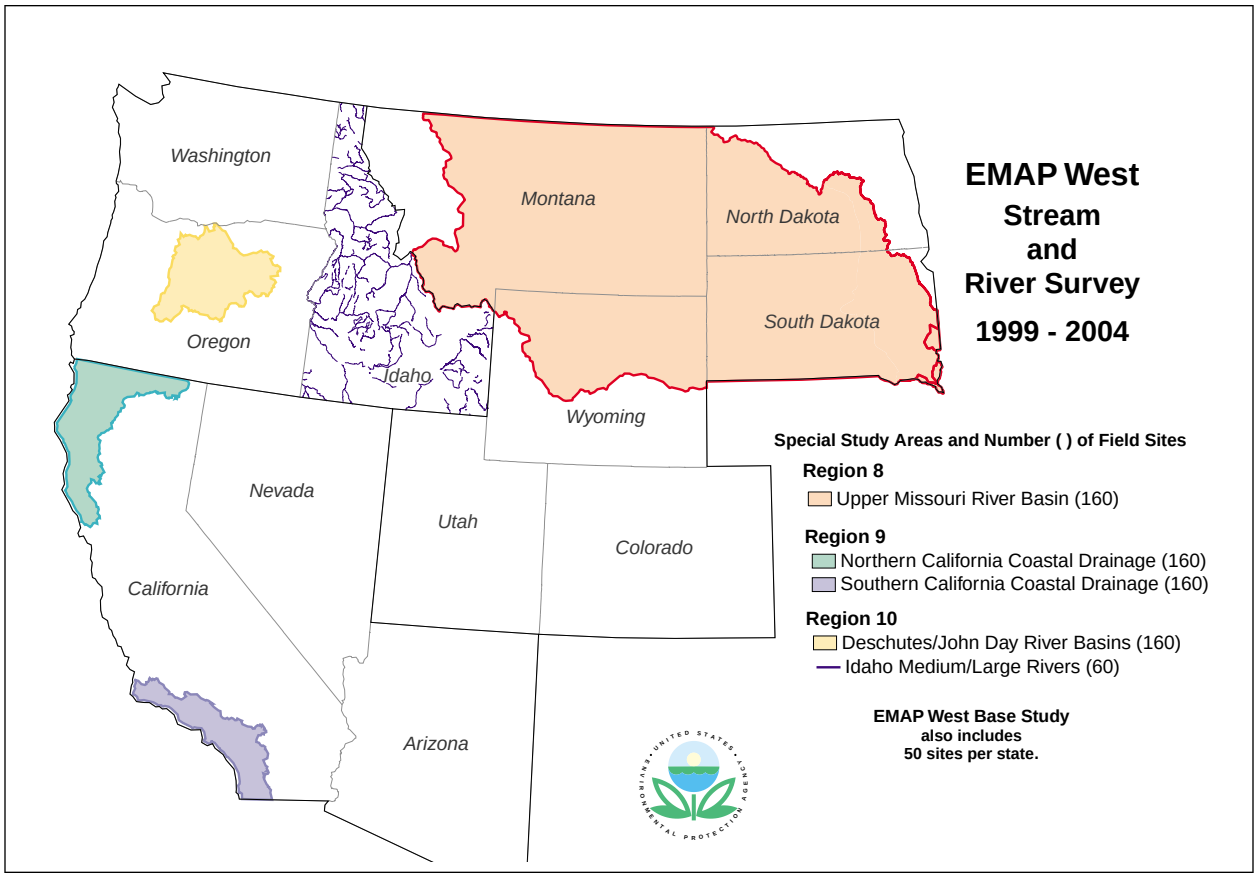


Figure 3. Map of the twelve western states included in Regions 8,9, and 10 cooperating in the stream and river survey. Shaded areas and rivers in Idaho are intensive study units.

Aquatic Focus

Legislative Basis

The key legislative motivation for establishing the aquatic components of EMAP is the Clean Water Act (CWA). As amended in 1987, the Clean Water Act recognizes three aspects of water resource quality that must be considered. The objective of the CWA is to "restore and maintain the chemical, physical and biological integrity of the Nation's waters [Section 101(a), Water Quality Act of 1987 (*http://www.epa.gov/region5/defs/html/cwa.htm*)]. The CWA also requires that the States report on the condition of all waters to the EPA every two years. These reports, known as the State 305(b) reports (after the section of the CWA that requires reporting), are consolidated by the EPA and then sent to Congress as the National Water Quality Inventory. Guidance from the EPA for this report asks the states and tribal nations to report on the amount of the aquatic

resource that is impaired, based on its designated use. Although the physical and chemical status of surface waters is important and will be measured as part of EMAP-W (see the lists of indicators in the sections that follow), the focus of the Coastal and Surface Waters component will be on "aquatic life use", which is one of the primary designated uses in all states and tribal nations.

A second legislative impetus for EMAP is the Government Performance and Results Act (GPRA *http://www.npr.gov/library/misc/s20.html*) passed into law in 1993. The intent of this legislation was to hold Federal Agencies accountable for the improvements they expected to achieve in carrying out their respective missions through the programs they had in place and the resources (both people and dollars) that they expended in conducting their work. Within the EPA OW, GPRA objectives are being formulated to document our progress in restoring and protecting aquatic resources. Measuring progress toward these objectives requires that effective assessment procedures based on established criteria be in place. ORD is providing scientific support for this element of the Clean Water Act with a GPRA objective "to provide the scientific understanding to measure, model, maintain, and/or restore, at multiple scales, the integrity and sustainability of highly valued ecosystems now and in the future - the primary focus will be on streams, rivers, and estuaries as assessment endpoints; specifically, fish and shellfish." Within this objective is EMAP's commitment to develop tools for monitoring and assessing the biological integrity of the nation's aquatic resources.

Monitoring Tools

Meeting the reporting requirements of the CWA and achieving the goals of GPRA requires two sets of monitoring tools. The first is the set of bioassessment tools; the second comprises design approaches for ecological monitoring on a regional scale. Bioassessment tools are the biological measures, or indicators, of the conditions of the aquatic systems at the time they were sampled. In general terms, we are concerned about the effects of human activities - positive or adverse - on the ability of ecological resources to continue providing a variety of goods and services in the future. Have our actions somehow limited the options available to future generations by impacting certain ecological processes or systems? As as nation, we have implemented many changes in our environmental policies and regulations and in the ways we manage our aquatic resources. If we are going to measure progress toward society's goals for improved aquatic condition, we must be able to assess the effects our actions. Implicit in this assessment is a standard against which the biological indicators are compared to determine impairment. The term *reference condition* is often used to connote this yardstick or baseline for comparison. When an accepted reference condition and its likely natural variability have been established for a given geographic area, they serve as a basis for the biological assessment of aquatic condition.

The second set of tools is made up of the statistically based designs upon which a monitoring effort is based. These designs are critical because they establish the credibility with which one can make inferences to all waters from those waters that are actually sampled[6]. Although many individual monitoring data sets measure present condition, and a few have data appropriate to measure trends over time, no monitoring program has utilized the appropriate sampling framework to

6. Paulsen, S.G., Hughes,R.M., and Larsen, D.P. 1998. Critical elements in describing and understanding our Nation's aquatic resources. J. American Water Resources Association. 34(5): 995-1005.

allow both (1) inferences of condition and (2) their trends over time on a national basis. EMAP has developed such a design. It is being implemented in regional trials such as MAIA and EMAP-W, as well as by several individual states as part of their operational water quality monitoring. The sampling design strategy is based on the fundamental requirement for a probability sample of an explicitly defined population, where the sample reflects the spatial distribution of the population. The primary tool used to control the spatial properties of the sample is a triangular grid covering the entire conterminous United States. The use of a grid does not imply an underlying belief that all ecological resources are uniformly distributed. The grid is simply a tool to insure adequate spatial coverage.The topic of monitoring design is covered in more detail in the sections that follow.

EMAP-W Objectives

The objectives for EMAP-W are slight modifications of those original to EMAP.

1. Estimate current status in selected indicators of the West's inland aquatic and estuarine resources on a state and regional basis with known confidence.
2. Estimate the geographic extent and distribution of the West's inland aquatic and estuarine resources with known confidence.
3. Seek associations between selected indicators of natural and anthropogenic stresses and indicators of the ecological condition of target resources.
4. Provide a statistical summary and an assessment of the condition of the West's inland aquatic and estuarine resources.

These objectives are intended to maintain the breadth of EMAP, yet focus the study on the problems unique to large scale monitoring of aquatic resources in the West. No estimates of trends are possible, unless the sampling effort is adopted by the Regions and states and continued after the formal EMAP-W comes to an end.

Assessment Questions

Fulfilling these objectives will allow each state to respond to the following umbrella assessment questions:

1. What is the extent of the state's streams, rivers and estuaries?
2. What is the condition of these resources?
3. What associations exist between the status of these resources and the most important natural and anthropogenic stresses?

Many more specific questions can be addressed depending upon final decisions on how the program is implemented. These additional questions tend to be subsets or more detailed version of the above, rather than unrelated questions. For example, what is the condition of the streams in a given ecological region? The core set of indicators measured will allow each state and region to respond to the foregoing questions with statistically sound data.

In the process of achieving these objectives, we intend to develop strong partnerships among all the participants including states, tribal nations, EPA regions, OW, ORD and other Federal agencies. A successful pilot means those agencies responsible for monitoring the status and trends in condition of their ecological resources will be exposed to and embrace the technology in the

EMAP approach to monitoring. The primary mechanism for implementing this research effort will be cooperative agreements with the western states. Through these agreements and close working relationships with their EPA partners, Regions 8, 9 and 10, OW and ORD, we intend to transfer the technology for ongoing implementation of the EMAP approach to monitoring to the participating states.

The following sections address each of the components of EMAP-W: Design and Analysis, Coastal, Surface Waters, Landscapes and Information Management. These strategic overviews are intended to provide sufficient detail for the reader to understand how the program is designed and what the outcomes of its successful completion will be. The EMAP web site provides more detail (*http://www.epa.gov/emap/*) or the reader can contact those responsible for each component (see list in appendix A)

Design and Analysis

Sample Survey History

There is a large body of statistical literature dealing with sample survey designs that addresses the problem of making statements about many by sampling a few. Sample surveys have been used in a variety of fields (e.g., election polls, monthly labor estimates, forest inventory analysis) to determine the status of populations of interest, especially if the population is too numerous to census or if it is unnecessary to census the population to reach the desired level of precision for describing the population's status. A key point in favor of probability based designs is that they allow lower cost sampling programs because a smaller number of sites are able to support conclusions with known accuracy and precision about status and trends of a region. An example from political pollsters two generations ago serves as an excellent case in point. Before 1936, presidential election results were predicted from unrepresentative samples. That year, the Literary Digest poll of about 2.4 million club members and telephone owners picked Landon by a landslide over Roosevelt. Gallup predicted the Digest results, well in advance and within one percentage point, with a random sample of only 3,000 from the same lists. In addition, he predicted Roosevelt's victory with an error of six percentage points from a different random sample of 50,000 from the voting public. By sampling the correct population, the entire voting public, rather than a convenient sub-population, he correctly and relatively inexpensively predicted the eventual outcome.

In succeeding years, we have more and more frequently turned to probability surveys when we need solid, quantitative information about a particular topic. While probability surveys are used consistently in election polls and monthly labor estimates, they have also been consistently used in some natural resource fields[7]. The National Agricultural Statistics Survey (NASS) conducted by the Department of Agriculture and the Forest Inventory Analysis (FIA) conducted by the Forest Service have both used probability based sampling designs to monitor and estimate the condition and productivity of agricultural and forest resources from a commodity perspective. The National Resources Inventory (NRI) was instituted initially because of concerns about the impact of soil erosion on crop production. More recently, the National Wetland Inventory (NWI) developed by the U.S. Fish and Wildlife Service to estimate the extent of wetland acreage in the United States, has used a probability-based sampling design.

Definition

Governmental organizations have also monitored the condition of the aquatic environment for many years, focusing on estuaries, coastal waters, streams, rivers, lakes, reservoirs, and wetlands. However, most, if not all, of these monitoring efforts have been designed answer a specific localized question (e.g., is a municipal treatment plant in compliance?). More recently, monitoring programs have been asked to address more regional questions. Examples of the types of question that monitoring programs are asked to address are:

- What is the condition of the Nation's lakes?
- What is the condition of the streams and rivers in Colorado?

7. Olsen, A.R., J. Sedransk, et al. (1999) Statistical issues for monitoring ecological and natural resources in the United States. Environmental Monitoring and Assessment 54(1):1-45.

- What is the condition of the estuaries in USEPA Regions 9 and 10?

This type of question requires answers that apply to all of the aquatic resources of interest that occur in a geographic area. As in the election polls described above, the goal is to obtain a *fair* or *representative* picture of the resource. These example questions, phrased as the general public might initially pose the issue of concern, serve as a starting point for the design of a monitoring program.

However, during development of a monitoring program based on probability sampling, these questions would turn out to be too general. For example, what is meant by condition? Answering this question determines the selection of indicators to be measured. What is a lake; an estuary; a stream? Although everyone assumes that they know what a stream is, the design requires an explicit definition. Perhaps only streams that are perennial and wadeable are of interest in the study. In some cases, the geographic region requires further clarification. For example, what is meant by "the nation"? Does this term include American Samoa, the Virgin Islands, Puerto Rico, Hawaii, Alaska? The information that follows focuses on the survey design as it relates to the general questions. For a description with more detail, see the 1999 paper by Stevens and Olsen.[8]

Target Population and Examples

Before a monitoring program can begin, a clear, concise description of the aquatic resource is needed. In statistical terminology this description is called the *target population*. Both the target population for which information is wanted and the *elements* that make up the target population must be rigorously defined. The target population is the collection of elements about which information is wanted. Two examples that could be part of EMAP-W help to explain the concept of a target population and its elements.

In the first example, a study is proposed to answer the question: What proportion of streams and rivers in Wyoming have a fish index of biotic integrity (IBI) greater than 50? The target population consists of all streams and rivers within the state of Wyoming. Does this definition include the portion of Wyoming in Yellowstone National Park? Is the target population restricted to only perennial streams? Streams may be modeled as a linear network, such as is generally used to represent streams on maps and in geographic information systems (GIS). The elements of the target population are all the points of the linear stream network. In this case, the target population consists of an infinite number of elements. Field samples would be collected at a sample of locations (elements) from the stream network and a fish IBI determined at each location.

In a second example, a study of the estuaries in California is planned to determine the concentration of contaminants in sediments. Assume the state wants an answer to the question: What proportion of the estuarine area in California has unacceptable concentrations of mercury in sediments? The target population is all estuaries in California. For this study, an estuary is defined as any water body that is tidally influenced, saline, and has less than 50% of its perimeter adjacent to the ocean. As a result, an estuary is defined at its lower boundary by its articulation with the

8. Stevens, D. L., Jr. and A. R. Olsen (1999). Spatially restricted surveys over time for aquatic resources. Journal of Agricultural, Biological, and Environmental Statistics 4(4): 415-428.

ocean or another estuary and its upper boundary by the head of tide. This definition results in approximately 75 different estuarine areas along the California coast. Their surface area range from 1092 km2 for the main body of San Francisco Bay to 0.09 km2 for Sweetwater River. The elements of the target population are all locations of sediments within the bounds of the estuaries. An infinite number of locations exist within each estuary and the entire target population consists of the collections of all the locations across all the sometimes disconnected estuaries along the California coast.

Subpopulations

Identified sub-populations are sufficiently important that the study would be viewed as incomplete if estimates for them did not appear in a report of the study's findings. During the statistical analysis of the study, other sub-populations may be identified and reported on, but this information would be considered supplemental rather than essential to the study. With respect to sub-populations, the major implications for the design of the survey are (1) the increased sample size requirements and (2) the need for the survey design to make sure that the each sub-population receives the minimum required number of samples to meet precision requirements.

The foregoing discussion only briefly summarizes the issues associated with properly designing the sampling effort for EMAP-W. Much more information is available[9]. Considerable scientific effort has gone into the EMAP design and it has been reviewed several times over the life of the program. A central feature of EMAP, the design is one of the main reasons the EMAP approach to aquatic monitoring is unique. Monitoring programs are expensive and are often dropped because the questions posed change slightly or the population measured turns out no longer to be of interest. We believe the design proposed for this study, when combined with a core set of well-researched indicators, allows the flexibility to deal with changing priorities without abandoning the long-term requirements that region or state-wide statements of condition of aquatic resources.

9. Larsen, D. P. (1997). Sample survey design issues for bioassessment of inland aquatic ecosystems.î Human and Ecological Risk Assessment 3(6): 979-99
Paulsen, S. G., R. M. Hughes, et al. (1998). Critical elements in describing and understanding our nation's aquatic resources. Journal of The American Water Resources Association 34(5): 995-1005.

Coastal

The nation's estuaries have become one of the highest priorities for environmental protection. The growth of the population that lives near and/or recreates at our coasts and the intensification of agricultural and industrial activities have dramatically increased the stress on these productive systems. The result has been a series of initiatives to learn more about the condition of estuaries and the potential for restoration for particularly high-visibility estuarine systems such as Chesapeake Bay and Puget Sound. These initiatives have been successful in monitoring condition of individual systems and targeting individual stresses. However, there is no established, comprehensive monitoring program that provides a state-wide, regional or national picture of the status and trends of all estuarine systems.

The MAIA program mentioned previously provides a look at what this component of EMAP-W will produce. The Coastal component undertook a sampling program to cover the estuaries from Delaware Bay south to the northern half of North Carolina. This work was undertaken with close cooperation with the existing programs in the region involving the National Oceanic and Atmospheric Administration (NOAA), EPA Region 3, the states and existing bay programs. Figure 4 gives an example of how EMAP data are combined with other existing monitoring programs to provide an simple yet comprehensive picture of the condition of this resource.

Objectives

In addition to the overall objectives of EMAP-W, the coastal component of EMAP-W has the following specific objective and subobjectives:

- To create an integrated comprehensive coastal monitoring program across the West Coast states (including Alaska and Hawaii) to assess estuarine condition.

For EMAP-W, *estuary* is defined as any water body that is tidally influenced, is saline, and has less than 50% of its perimeter adjacent to the ocean. As a result, an estuary is defined at its lower boundary by its articulation with the ocean or another estuary and its upper boundary by the head of tide. The lateral boundaries of an estuary are defined as the mean high water mark.

Subobjectives

1. To achieve the overall objective with as little modification to existing state programs as feasible (or desired by the states).
2. To develop the monitoring program in a manner that will permit the use of its results to determine appropriate reference conditions for all measured or calculated variables.

The subobjective, avoiding modification of existing programs, will be implemented insofar as it does not interfere with the primary objective. The second subobjective, which relates to reference condition, is feasible, although its specific interpretation for some variables remains unclear. For some indicators, a simple interpretation of the upper (or lower as the case may be) 5% or 10% of the tailed distribution may be sufficient as a definition of reference conditions; however, for distributions where all sites are affected, it remains unclear what reference conditions might be (see the Surface Waters description below for an additional discussion of reference condition and its determination).

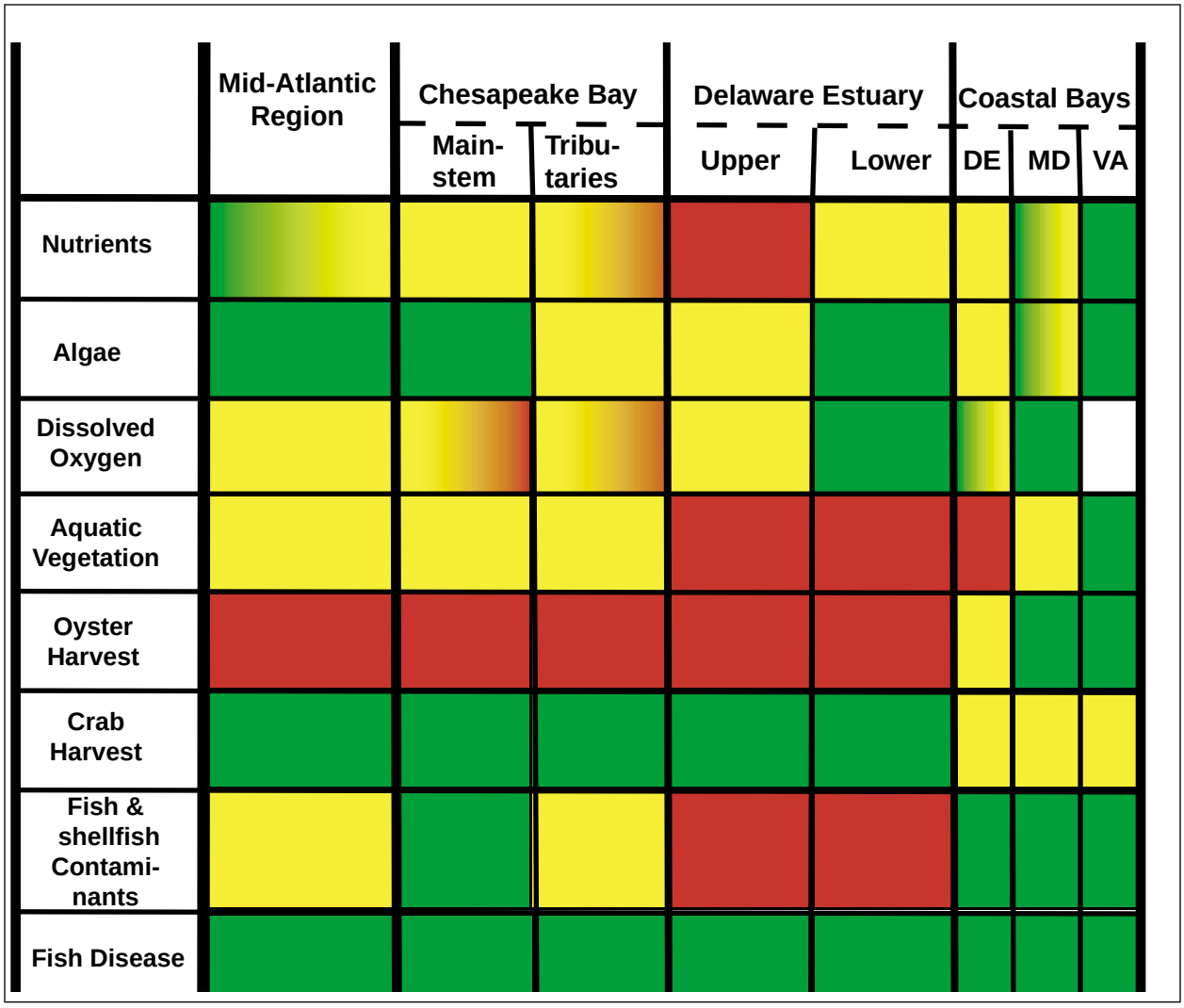


Figure 4. Summary of condition of estuarine indicators for the Mid-Atlantic Region. From the report Condition of Mid-Atlantic Estuaries, EPA 600-R-98-147.

Approach

The research approach in the coastal element of EMAP-W includes the same basic nine-step approach that was used in the coastal element in MAIA. These steps include:.

1. Identifying objectives and subobjectives
2. Identifying assessment questions
3. Developing a conceptual model
4. Selecting indicators
5. Designing the field survey
6. Designing QA/QC elements
7. Conducting information management
8. Implementing the survey
9. Reporting interim and final results.

The strategies used to develop assessment questions (step 2) in MAIA and in several states have been used in EMAP-W by the regions, OW, states, and ORD. The list of supplemental questions developed for the coastal component supplement the umbrella questions listed earlier. The process includes discussions within the regions to identify the questions.

A conceptual model was developed to characterize the interactions among biological resources, environmental stressors and natural environmental variability for west coast estuarine systems. This model was used to develop a list of indicators for the field survey. The present list of indicators is shown in Table 1.

A GIS coverage of the coastal resources of the Western United States was prepared to delineate the population of interest (based on the estuary definition above) of all estuarine resources. This coverage provides the underlying sampling area for the field survey design. Several “strawman” designs were constructed focusing on state estuarine resources as the common stratum to be used for design. However, plans to include a hier-

Table 1: Indicators to be measured in the estuaries in EMAP-W

Physicochemical
• Dissolved Oxygen • Salinity • pH • Temperature • River Discharge • Water Depth
Contaminants
• Sediments (metals, organics) • Tissues (metals, organics) • Fecal Coliform • Sediment Toxicity
Nutrients
• Nitrogen Species • Phosphorus Species • Dissolved Carbon
Turbidity
• Total Suspended Solids • Nephelometry • Secchi Depth
Living Resources
• Chlorophyll • Benthic Community Composition and Abundance • Fish Community Composition and Abundance • Fish Pathologies and Parasites • SAV Abundance • Mircobial Abundance • Algal Pigment Abundance
Sediments
• Total Organic Carbon • Grain Size • Silt/Clay Percent
Habitat
• Occurrence of SAV • Occurrence of Macroalgae • Habitat Type

archical design was discussed for inclusion in case some state resource agencies could not be convinced to participate in the effort. The hierarchical design would select 50 locations across the estuarine resources of all three states as a base with nested 50 site designs for Washington, Oregon, and California. In the hierarchical design, if a state agency were to participate in the collection the 50-site alternate design for that state will be used; if not, then the fewer number of base sample locations that meets the regional and national needs will be sampled by another entity. These estuarine areas did not include Puget Sound, Washington, Columbia River Estuary, Oregon, and San Francisco Bay, California.

In 1999, several potential areas of intensification were included in the designs for the field survey. Region 9 selected Northern California coastal streams (Bodega Bay north to the California-Oregon line) and Region 10 selected Tillamook Bay as their desired areas of intensification. Nested designs were created for these area that allocate approximately 30 sample sites in each of the respective subpopulations. Over the period of 1997-1999, NOAA sampled 300 locations within Puget Sound and its adjacent systems to characterize sediment contaminants, toxicity, and benthic communities. There is no reason to duplicate this effort within the coastal component of EMAP-W, as it is based on a probabilistic design and included indicators of interest to EMAP-W. However, some subsampling of the 300+ sites will occur to augment the indicators NOAA is collecting. NOAA has agreed to consider inclusion of the collection of these variables as part of its survey. NOAA's inclusion as a partner in EMAP-W will permit EMAP to focus on the small estuarine systems of Washington. NOAA will also sample 200 sites San Francisco Bay.

US Geological Survey (USGS)/Biological Resources Division (BRD) has described potential intensifications it might include in EMAP-W as part of its BEST program. Although plans are still preliminary, we will work to integrate any potential intensifications by the BEST program into the EMAP-W and to work with USGS/BRD in planning their efforts, as appropriate.

The coastal element of EMAP-W for FY2000 will organize the field effort to be executed by the resource agencies representing California, Oregon, and Washington which will focus on San Francisco Bay, Columbia River and Puget Sound, respectively. The participants will be Washington Department of Environment (DOE), Oregon Department of Environmental Quality (DEQ), the California Water Resources Board (CWRB), California Fish and Game, and the Southern California Coastal Water Resources Project (SCCWRP). The exact interaction of the California agencies remains to be determined. Cooperative agreements will be used to provide resources to execute the surveys with significant cost sharing by the participating states.

A multiple member Quality Assurance/Quality Control (QA/QC) team has been created to oversee the coastal element of EMAP-W. The team will be chaired by EPA/ORD with members from Regions 8,9 and 10, NOAA and USGS. This team will be responsible for the production of a QA Project Plan for the project.

Information management for the coastal element will be coordinated by an information management team created to oversee and execute all aspects of this activity for EMAP-W. The team is led by EPA/ORD and will include members from the participating partners. Reporting for the coastal element of EMAP-W will include EPA reports and peer-reviewed manuscripts.

Timeline

The coastal field sampling activities will continue in EMAP-W through 2003. The anticipated schedule shown in Figure 5.

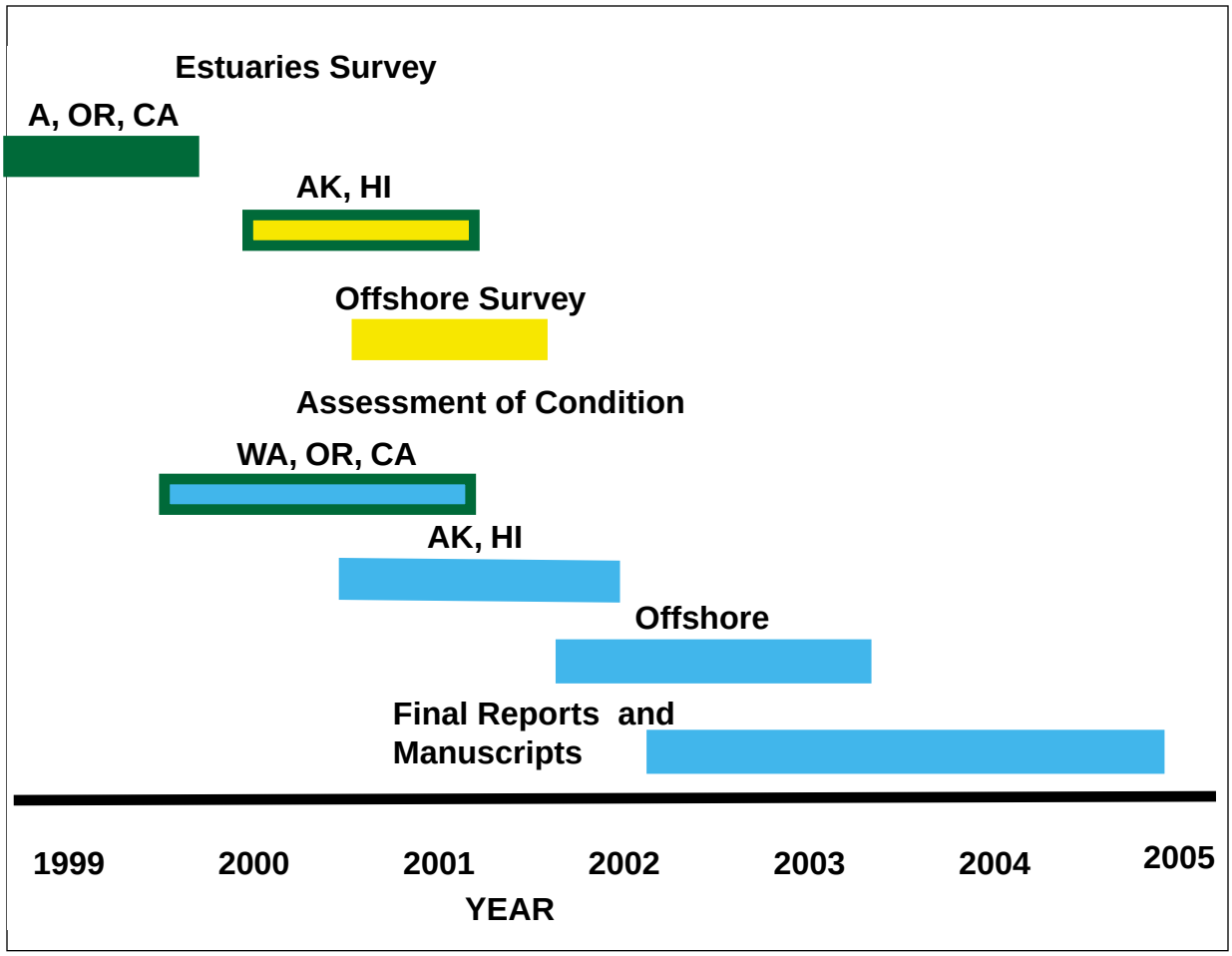


Figure 5. Timeline for Coastal EMAP-W.

Surface Waters

Although many states, as well as other federal agencies, have surface water monitoring programs, no single program provides the kind of comprehensive monitoring that would allow regional or national conditions to be reported in a statistically sound manner. This gap is especially evident for biological indicators; no agency, or combination of agencies, can currently report regionally or nationally on whether or not surface waters are meeting their designated use for aquatic life support. EMAP began the process of demonstrating the two critical tools needed for large scale reporting on the ecological condition of surface waters (survey design and biological indicators of condition) in MAIA. Before MAIA, three states within the region (Delaware, Maryland, and Virginia) had begun to use and evaluate biological indicators and probability surveys either statewide or for specific types of aquatic systems within the state. In MAIA, these efforts were coordinated with the other states in the region to demonstrate EMAP tools on wadeable streams across state, watershed and ecoregion boundaries (see Figure 2). The results from the upland regions of MAIA will soon be available as a region wide assessment, known as the Mid-Atlantic Highlands Assessment (MAHA).

The surface waters component of EMAP-W will use a similar strategy (building on existing state capacities) to implement probability sampling of biological indicators across the West, with the eventual goal of providing the same kinds of assessments that have been possible for MAHA. Figure 6 shows how data on condition of streams can be analyzed in conjunction with the occurrence of important stressors to rank their importance based on the number of stream miles affected.

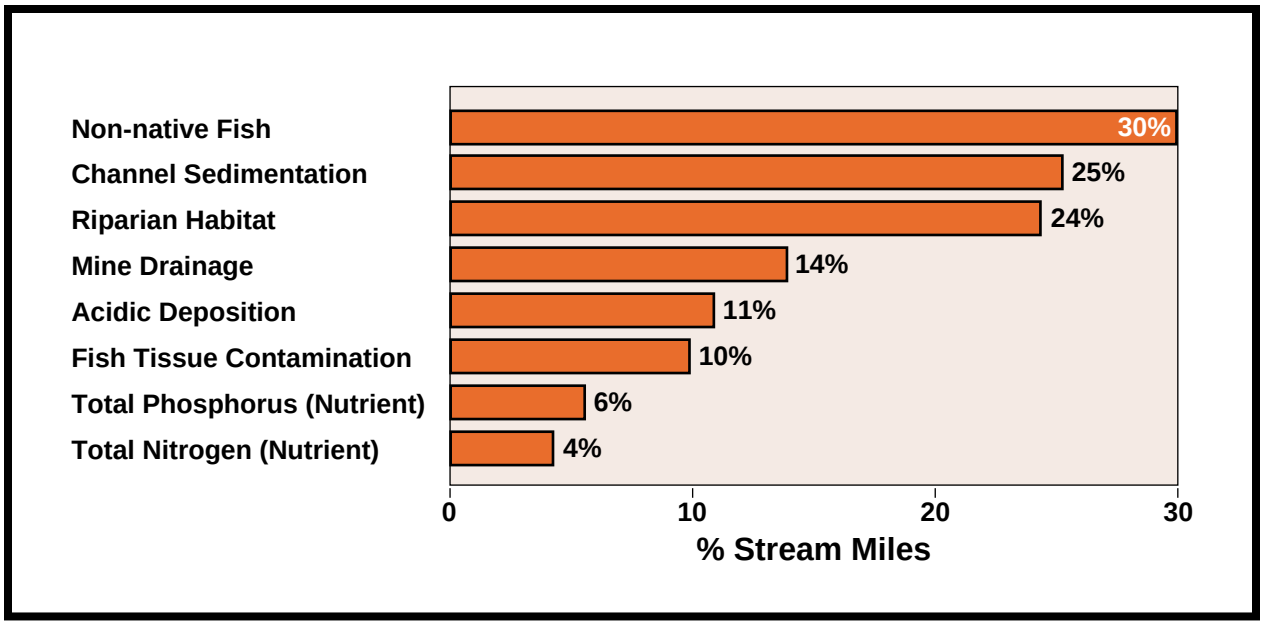


Figure 6. Relative percentage of stream miles exceeding an agreed upon threshold appropriate for the stressor of interest in the Mid-Atlantic Highlands region.

Objectives.

The primary objectives of the surface waters portion of EMAP-W are to:

1. Develop the monitoring tools (biological indicators, stream survey design, estimates of

reference condition) necessary to produce unbiased estimates of the ecological condition of surface waters across a large geographic area (or areas) of the West.

2. Demonstrate those tools in a large scale assessment.
3. Estimate the extent of perennial and non-perennial streams.
4. Meeting these objectives will allow us to reach the goal to provide the tools to answer to three general assessment questions:
5. What proportion of the stream and river length in the western United States is in acceptable ecological condition?
6. What is the relative importance of potential stressors (habitat modification, sedimentation, nutrients, temperature, agriculture, resource extraction, etc.) in streams and rivers across the West?
7. With which stressors are streams in poor ecological condition associated?

Approach

The process of conducting a probability survey starts with defining the target population – the population to be represented in the survey and to which results will apply. For the surface waters component of EMAP-W, this target population includes all perennial streams and rivers as represented in EPA's River Reach File (RF3), with the exception of the Great Rivers (the Columbia, Snake, Colorado and Missouri). Surveys will be conducted at a number of scales, including a coarse survey for all 12 western states (EPA Regions 8, 9 and 10, except Hawaii and Alaska), and more intensive surveys of focus areas in each EPA Region (Figure 3). Sample sizes (i.e., numbers of stream sites) have been chosen to allow estimates of ecological condition to be made for each state, each regional focus area, numerous aggregated ecological regions (e.g., mountainous areas of the Pacific states, the Southern Basin and Range), major river basins, and many other potential geographic classifications. For large rivers, sample sizes have been chosen to allow separate estimates of ecological condition for the rivers in each EPA Region. The expected sample sizes in each state are listed in Table 2 The list includes both the survey for all 12 states and regional focus area surveys

Table 2: Expected number of perennial stream sites for sampling in EMAP-W

Region/state	Number of Sample Sites
Region 8	
Colorado	73
Utah	84
Wyoming	87
North Dakota	94
South Dakota	103
Montana	103
Region 8 Total	578
Region 9	
Arizona	53
Nevada	50
California	370
Region 9 Total	473
Region 10	
Idaho	110
Washington	110
Oregon	210
Region 10 Total	430
Total Study	1481

One of the challenges of conducting surface water surveys in the West based on a survey design is that RF3 is an imperfect representation of the stream network that actually exists on the ground. RF3 is a digitized version of all the combined 1:100,000-scale USGS maps for the region. It includes codes for both perennial streams (our target population) and non-perennial streams (e.g., ephemeral or intermittent streams), but we know from pilot studies that these codes are often in error, and that, for the West, the error rates may be high. Therefore, the first step in conducting the surface waters portion of EMAP-W will be an evaluation of the accuracy of the RF3 stream database. This evaluation consists of drawing a very large (ca. 3500 sites) sample of perennial and

non-perennial streams from RF3, and cross checking the status of each stream using information from local experts, independent map sources, or site visits. The goal of this assessment is twofold:

1. Produce a valid selection of streams for sampling in years 2000-2003 (thereby avoiding the cost of sending crews to sites that are misrepresented on RF3 and are actually nontarget),
2. Evaluate the "true" number of perennial and non-perennial streams in the West so that we can correct RF3 estimates of the total number of stream miles in each category.

Beginning in 2000, sample crews will visit the selected sample sites in each state and collect data on a core set of indicators (Table 3) . All of the partners in EMAP-W have agreed that these core

Table 3: Core indicators for Surface Waters in EMAP-W. Toxicity indicators shaded to note that they will be analyzed only if additional funds become available.

Indicators		Method
Biological	• Aquatic vertebrate assemblages	• Electrofishing
	• Macroinvertebrate assemblages	• Kick samples in index habitats (primarily riffles) and reach-wide
	• Periphyton assemblages (streams only)	• Brushed from rocks or woody debris
	• Phytoplankton assemblages (rivers only)	• Vertical net tow
Water Quality	• Major Ions (cations, anions, pH)	• Grab sample
	• Nutrients (total nitrogen and phosphorus, nitrate, ammonium, silica)	• Grab sample
	• Turbidity (turbidity, suspended sediments)	• Grab sample
	• Carbon species (dissolved organic carbon, dissolved inorganic carbon, acid neutralizing capacity)	• Grab sample and syringe sample
Habitat	• Quantitative in-stream physical habitat (stream discharge, temperature, channel morphology, substrate size, fish cover, large woody debris, etc.)	• In-field quantification
	• Qualitative physical habitat	• Rapid Bioassessment Protocols
	• Quantitative riparian habitat (human disturbance, land use, canopy cover, etc.)	• In-field quantification
Toxicity	• Fish tissue contaminants (mercury, select list of metals, select list of persistent organic contaminants)	• Whole individuals collected from 2 trophic groups (large predators, small foragers) as part of fish assemblage sampling

indicators will be of value across the West. For toxicity indicators, (shaded in Table 3) tissue will

be sampled and frozen to be analyzed later if resources become available. An additional list of research indicators (riparian condition, continuous temperature, microbial organisms, sediment toxicity, additional tissue contaminants) is being considered for implementation on a smaller scale in more focused geographic regions (e.g., states, regional focus areas, or ecoregions).

Although EMAP-West is not sampling the Great Rivers as the part of the core west-wide program. a significant research effort is underway in the Upper Missouri River (UMR) basin. ORD scientists are piloting an assessment of the mainstem of the Great River itself, including its associated large reservoirs, riparian and floodplain areas. Assessment of very large rivers and reservoirs has been outside the scope of previous EMAP studies. Because of their size and complexity, these systems require novel approaches. The UMR research effort is developing methods (indicators, sampling and assessment design), which it will then apply to coupled reservoir–river reach segments of the UMR. The principal objective is to develop and test an assessment approach for a Great River and report results of the multi-resource assessment by segment couplets, as well as for the entire UMR. Sampling emphasizes water quality, trophic status, habitat, and biological components (plankton, invertebrates, riparian vegetation) within and among river and reservoir reaches. A developmental goal is to identify critical aquatic habitats supporting lower food web components and to relate variability in aquatic habitat/biology to adjacent riparian, tributary, or floodplain/landscape environments. Habitat types may themselves serve as ecological indicators of condition throughout the UMR and/or be targeted a separate spatial strata in the assessment design. The EMAP-UMR program will be conducted during 2000-2004. Additional details can be obtained by reviewing the study plan[10].

Timeline

Field data collection for Surface Waters will continue in EMAP-W through 2004. The anticipated schedule for measuring and reporting data is shown in Figure 7. Additional activities such as research on reference condition and indicators will be undertaken during the 2001 to 2004 time period as resources allow.

10. Environmental Monitoring and Assessment Program: Aquatic and Riparian Resources of the Upper Missouri River. Contact: Dr. Dave Bolgren, 6201 Congdon Blvd., Duluth, MN 55804. Phone: 218-529-5010

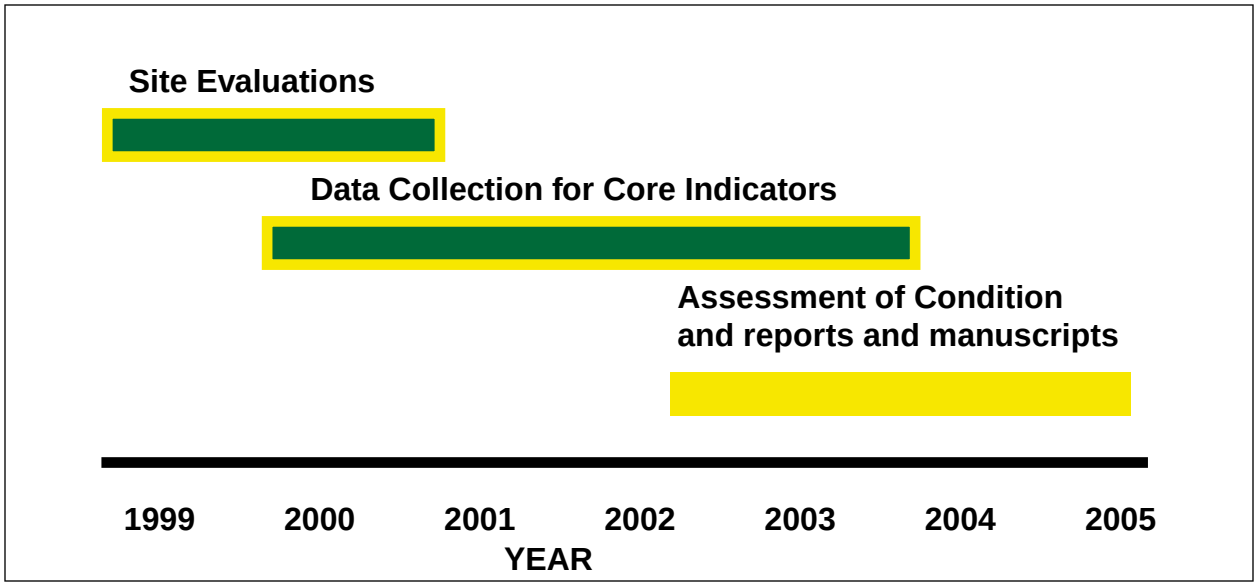


Figure 7. Timeline for Surface Waters in EMAP-W.

Landscapes

Unlike the sampling required for individual aquatic resources, landscape data can be gathered "wall to wall" (see *http://www.epa.gov/ceisweb1/ceishome/atlas/learngeog/remotesensing.html*- for more information on remote sensing). With the use of remote sensing techniques and the availability of the Multi-Resource Land Classification (MRLC) data, the entire western United States will be covered (see Figure 8 for an example of MRLC coverage of the Mid-Atlantic region). The

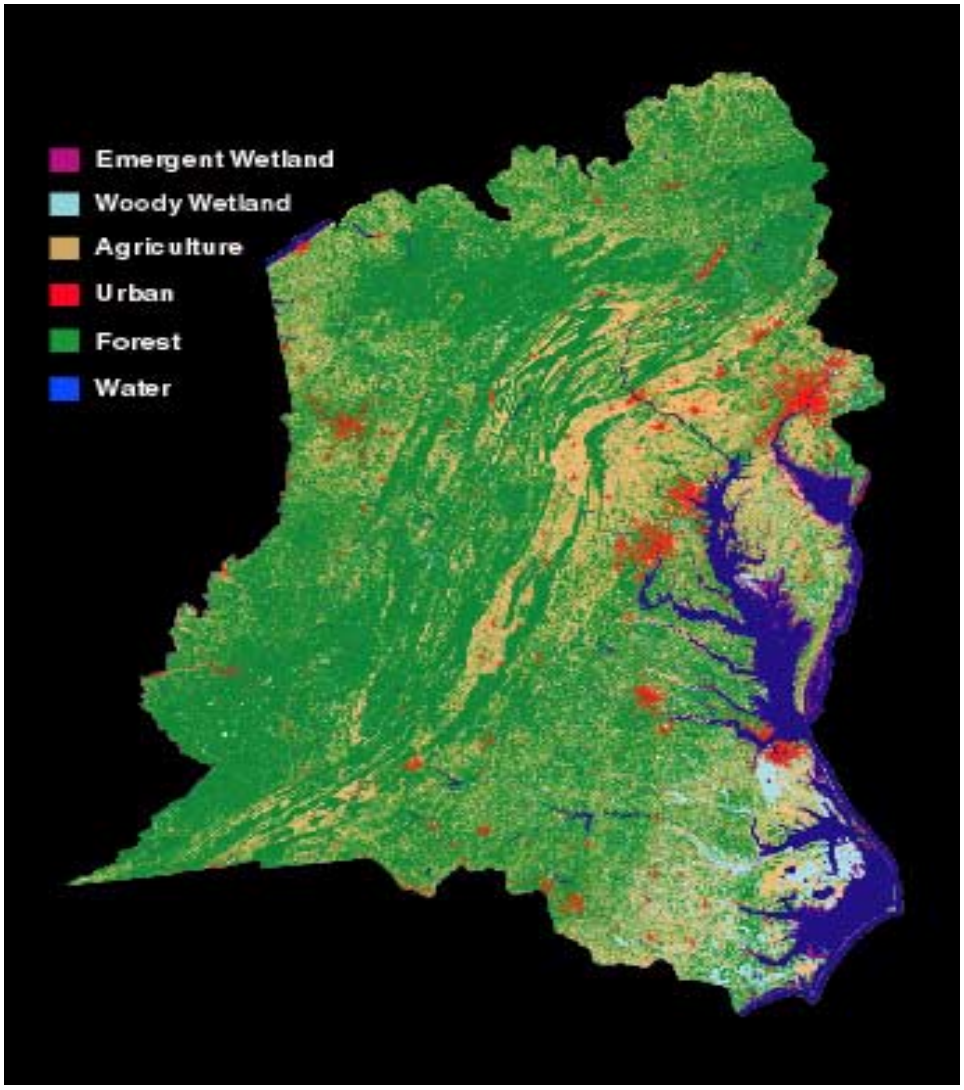


Figure 8.Multi-Resource Land Classification map of the mid-Atlantic region.

Landscape component of EMAP-W is tasked with assessing spatial variability in landscape pattern and the degree to which landscape pattern influences the conditions of estuaries and inland surface waters at watershed scales. If conditions in aquatic resources are closely linked to watershed scale, landscape patterns, then it might be possible to assess potential conditions of aquatic and terrestrial resources. This possibility exists because the new set of landscape data being gener-

ated will cover the entire surface of the western US at relatively fine scales.

The science of landscape assessment has been significantly advanced as a result of EMAP. In 1996, a regional scale land-cover database was developed for MAIA and this database, along with other regional landscape coverages (e.g., topography, soils, road networks, stream networks, and human population density), was used to assess landscape conditions across the entire region down to a scale of 30 meters. The assessment used a set of landscape indicators to evaluate the spatial patterns of human induced stresses and the spatial arrangement of forest, forest edge, and riparian habitats as they influence forest habitat suitability and aquatic resources. Advances in computer and geographic information systems (GIS) technologies have made it possible to calculate landscape metrics over large areas (e.g., regions) at relatively fine scales. As a result, this information can be used to develop multi-scale plans to prioritize activities to restore ecological function and condition. As part of the MAIA analysis, the Landscapes group developed an atlas displaying these metrics and describing their interpretation. This document is available at the EMAP web site (http*://www.epa.gov/emap/html/pubs/docs/groupdocs/landecol/atlas/ma_atlas.html*).

The western US presents a set of additional problems not encountered in the work in the mid-Atlantic Region. First, land cover and vegetation in the western US is considerably more diverse than in the mid-Atlantic, which presents a challenge in developing and interpreting landscape indicators. Second, the study area is many times larger than the mid- Atlantic which means there will be a significant data processing challenge. Finally, many of the stresses on western landscapes, including grazing and timber harvest, do not result in changes in land cover types, but rather in substantially altered states of land cover conditions. New remote sensing data and analytical approaches are needed to determine the extent and magnitude of these stresses.

The EMAP-W landscape assessment will focus on the influence of landscape pattern on aquatic resources because EPA has a primary responsibility in assuring the protection of water resources. However, the landscape approach evaluates many aspects of the terrestrial environment, because these attributes are intricately linked to ecological and hydrological processes that influence aquatic resource conditions. Due to gaps in our understanding of landscapes and their influence on aquatic resources, it will be necessary to implement a set of research and development projects to achieve the overall goal of a western landscape assessment relative to aquatic resources. These projects will be concentrated on the intensive areas (see Figure 3), but will also take advantage of data and resources in other places where their analysis will contribute to our understanding.

Objectives

In support of the overall objectives of EMAP-W, the Landscapes component has the following specific objectives:

1. Establish quantitative relationships between various indicators of landscape pattern and water quality, discharge, and biota in different biophysical settings (e.g, watershed size, gradient, geologic setting, climate regime).
2. Determine how the importance of different landscape patterns in explaining water quality, discharge, and biological condition varies within and among different regions of the West.
3. Determine which stressors contribute most to observed landscape condition.

Approach

The landscape monitoring and assessment approach will involve the analysis of spatially explicit patterns of biophysical features, including soils, topography, climate, vegetation, land use, and drainage pathways. We will quantify the associations between those patterns and measures of environmental endpoints. These endpoints include habitat and aquatic resource conditions, on areas ranging in size from small watersheds (a few hundred hectares) to entire basins (several million hectares). Landscape metrics that directly measure spatial patterns are used as indicators which are in turn evaluated relative to their relationship (and ultimately their ability to predict) ecological endpoints of interest such as forest habitat and various aspects of aquatic resource conditions.

Five general project components are envisioned to achieve the goal of a western landscape assessment. These include:

1. Spatial data acquisition, assembly, and accuracy assessment.
2. Development of new remote sensing methods to detect watershed level stresses.
3. Landscape indicator generation.
4. Quantification of the degree to which existing and new landscape indicators explain variation in aquatic resource conditions.
5. Development of multi-indicator assessment techniques.

Each of these components contains research and development, as well as implementation activities. However, key scientific gaps must be resolved in order to complete the overall assessment planned for EMAP-W. See Jones, et. al. for a more detailed treatment of this strategy.[11]

Timing

The EMAP-W landscape component will be implemented in three phases (Figure 9)..

Phase I will involve an initial test of some of the GIS approaches needed to do landscape assessments across the western United States. Many of the landscape data, such as digital elevation models (DEM's) come in pieces; therefore, it is necessary to mosaic them together into a single database to generate watershed areas for individual aquatic samples sites and to calculate the range of landscape indicators for those areas. During this initial phase we also will evaluate the quality of existing spatial data, and the effectiveness of existing GIS approaches to generate watershed areas. Finally, Phase I will involve the development and testing of new landscape indicators.

In Phase II, we will evaluate the quantitative relationships between aquatic resource variables and landscape indicators on a new set of areas where the relationships are hypothesized to be different than the Phase I study areas. By the end of this phase, we should know how aquatic resource conditions vary with landscape pattern across the range of biophysical conditions in the western states. Research on landscape indicators and remote sensing approaches will be completed at the

11.Jones, K. Bruce, et. al. 2000 Assessing landscape condition relative to water resources in the western United States: A strategic Plan. Env. Mon. and Assess. 64:227-245

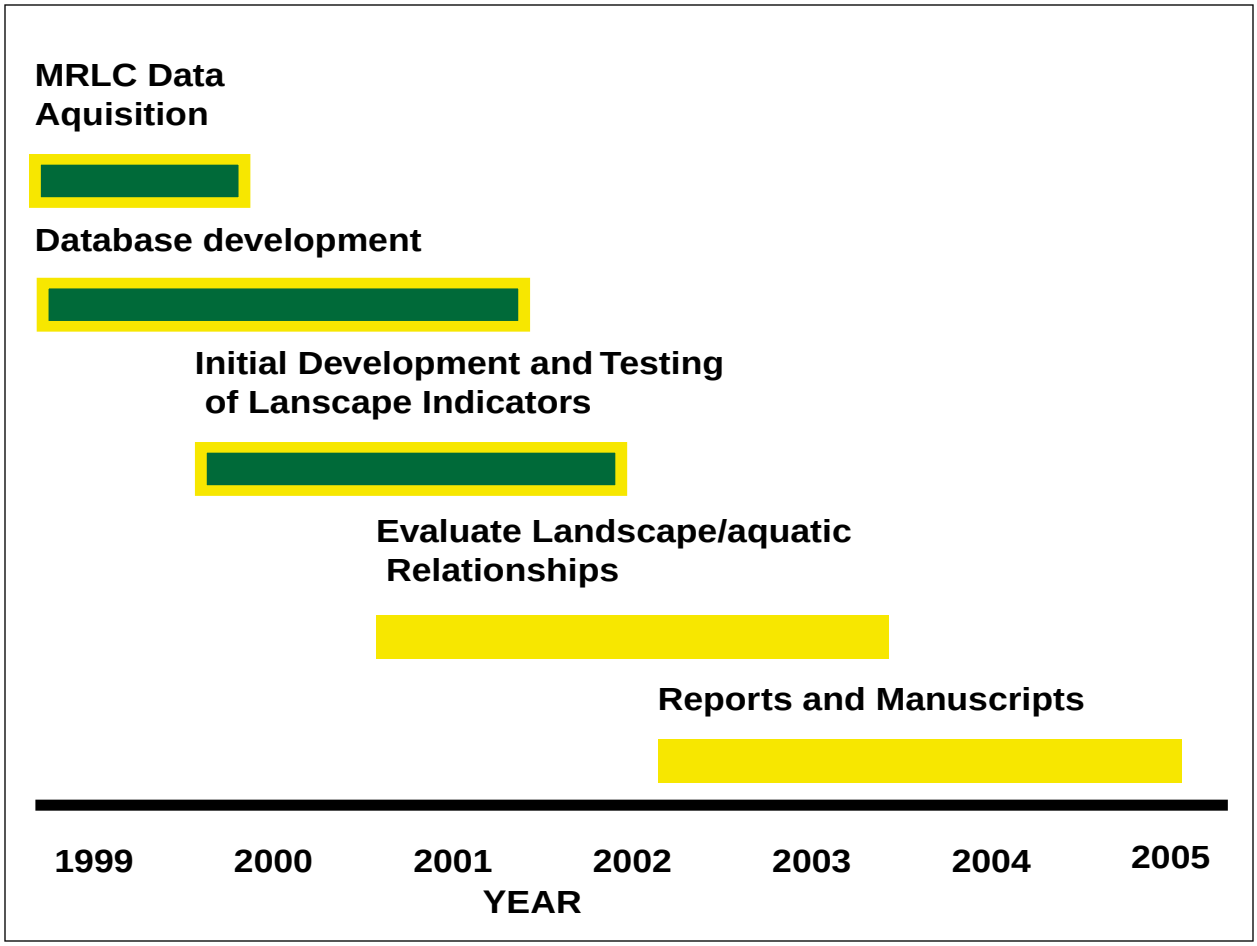


Figure 9. Timeline for Landscapes component of EMAP-W.

conclusion of this phase. We also will initiate the assembly of landscape data needed to calculate landscape indicators across the entire 12-State area of the western United States.

Phase III will focus on completing the calculation and interpretation of landscape indicators relative to aquatic resource conditions. By this phase, we will have determined which geographic units to which the landscape indicators best apply (e.g., watersheds, individual stream segments) Summary reports and manuscripts will be prepared during this phase, with expected completion by the end of 2005 for program reports.

The project will be implemented primary through collaboration between the primary EMAP groups and EPA Regions 8, 9, and 10. We also anticipate collaboration with the USGS EROS Data Center, the U.S. Forest Service, the U.S. Agricultural Research Service, the Natural Resources Conservation Service, the Bureau of Land Management, the USGS/BRD and several of the western States.

Information Management

As is true with any large data collection effort, an effective information management program is central to the success of EMAP-W. Data that are not readily available to those who need to use them are nearly useless. This is too often the result of a programs that invest extensive resources in gathering information. Information Management (IM) has been a key feature EMAP for many years. Information Management supports the program and policy objectives and is an integral part of the Coastal, Surface Waters and Landscapes groups. Because these ecological data are collected under a consistent design and consistent methods over broad regions, are of high-quality, and are well-described, they have many potential uses well beyond the original study, such as global change studies, regional research, and citizen awareness. These circumstances lead to both (1) analytical databases that support the statistical analyses and (2) general-use databases that are widely available to secondary users[12].

The general approach taken by EMAP toward information management is guided by considerations for sharing national environmental monitoring data to conduct national environmental assessments. EMAP has adopted many of its information management policies and procedures from recommendations put forth by the National Research Council[13], the Ecological Society of America, and the National Science Foundation.

An element of IM that has taken on additional priority for EMAP-W is data archival in a generally available system. STORET (short for STOrage and RETrieval) is a repository for water quality, biological, and physical data and is used by state environmental agencies, EPA and other federal agencies, universities, private citizens, and many others. See the STORET web site for a more complete description.(*http:www.epa.gov/OWOW/STORET)* This system is being modified to accommodate EMAP data, with the goal of making data available in a system that is familiar to and used by many of the client states and non-governmental organizations.

Objectives

Information management objectives for EMAP-W include:

1. Supporting regional environmental assessments reports for Coastal, Surface Waters and Landscapes.
2. Supporting program components in answering assessment questions posed as the study progresses.
3. Developing and using common policies and standards for data collection and input to the central storage systems.
4. Making data available to users outside the study.
5. Developing ways of managing data that can be sustained by organizations in the region (e.g., utilizing STORET as the method for data archival).

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12. Hale, S.S., Hughes, M.M., Paul, J.F., McAskill, R.S., Rego, S.A., Bender, D.R., Dodge, N.J., Richter, T.L, and Copeland, J.L. 1998. Managing scientific data: The EMAP approach. Environmental Monitoring and Assessment 51: 429–440.
13. NRC. 1995. Finding the forest in the trees. The challenge of combining diverse environmental data. National Academy Press. Washington, DC. 129p.

The five-year vision for EMAP-W information management is that we will achieve:

- Full and open sharing of EMAP data.
- Sustainable, continuously updated data systems that support continuing environmental assessments.
- Consistent databases ready to accept data from a national coastal survey, national streams survey, and national landscape ecology.

Approach

The EMAP Information Management Plan: 1998–2001[14] describes the overall EMAP approach to managing program data and results and how Information Management supports the EMAP Research Strategy. Further details pertaining to EMAP-W are given by:

1. Data Policy Statements for EMAP-W[15]
2. Core Information Management Standards for EMAP-W [16]
3. Data Flow in EMAP-W[17] (see Figure 10)

An Information Management subcommittee provides guidance for all the overall direction of EMAP-W information management. This group consists of representatives from each EMAP-W resource groups (Coastal, Surface Waters, and Landscapes) and from the regions. Additionally, each of the EMAP-W resource groups has a formal or informal data group that is responsible for the data management standards and procedures particular to that group. These groups are responsible for providing data to the central IM system in the proper form.

Data Policy Statements

The Data Policy Statements for the EMAP-W[18] outline the expectations for data sharing and the time line. The fundamental objectives of the EMAP-W are dependent upon the cooperation of scientists from several disciplines. The program objectives require quantitative analysis of interdisciplinary data sets, therefore, participants must exchange data on a timely basis.We seek to enhance the value of data collected within the program by providing a set of guidelines for the collection,

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14. Hale, S., Rosen, J., Scott, D., Paul, J., and Hughes, M. 1999. EMAP information management plan. 1998–2001. EPA/620/R-99/001, U.S. Environmental Protection Agency, Office of Research and Development, National Health and Environmental Effects Research Laboratory, Research Triangle Park, NC.
15. USEPA. 1999. Data policy statements for the EMAP Western Pilot Study. U.S. Environmental Protection Agency, Office of Research and Development, National Health and Environmental Effects Research Laboratory, Research Triangle Park, NC.
16. USEPA. 1999. Core information management standards for the EMAP Western Pilot Study. U.S. Environmental Protection Agency, Office of Research and Development, National Health and Environmental Effects Research Laboratory, Research Triangle Park, NC.
17. USEPA. 1999. Data flow in EMAP Western Pilot Study. U.S. Environmental Protection Agency, Office of Research and Development, NHEERL, Research Triangle Park, NC.
18. Modified, with permission, from:
    Data Management for Global Change Research. Policy Statements for the National Assessment Program. July 1998. U.S. Global Change Research Program. National Science Foundation, Washington, DC. and U. S. GLOBEC. 1994. U. S. GLOBEC Data Policy. U. S. Global Ocean Ecosystems Dynamics. Report No. 10. Woods Hole, MA. *(http://globec.whoi.edu*).

storage, exchange, and archival of these data sets.

The overall purpose of these policy statements is to promote full and open access and use with confidence, both now and in the future, of the data and information used in and resulting from EMAP-W activities. These policies reflect the goals and policies of EMAP and incorporate federal laws, directives, and regulations regarding the maintenance and dissemination of data and information in the federal government. They apply to all participants in EMAP-W, including federal, state, local, tribal, foreign, and educational institutions as well as non-government organizations and their private partners, and will be incorporated into the provisions of any acquisition or assistance agreements funded by the EMAP-W.

Core Information Management Standards

The Core Information Management Standards document sets forth the core data management and GIS standards that all EMAP-W participants agree to follow. The Coastal, Surface Waters and Landscapes groups are developing more detailed standards that are specific to their groups. The goal of these core standards is to maximize the ability to exchange data among EMAP-W participants and with other studies conducted under the monitoring framework of the Committee on Natural Resources and Environment[19]. The main standards are:

- Federal Geographic Data Committee (*http://www.fgdc.gov*).
- National Spatial Data Infrastructure (*http://www.fgdc.gov/nsdi/nsdi.html*).
- National Biological Information Infrastructure (*http://www.nbii.gov*).

Data Flow

The Data Flow document provides more detail on the path data follow from the initial measurements through archival and reinforces the notion that as soon as data become available to any EMAP-W participant (ORD, Region, state, tribe), those data should be shared with all participants. The timeline provides target goals for data exchange. Figure 10 shows the basic flow of data. The Coastal, Surface Waters, and Landscape groups consist of ORD/region partners and will include states and tribes in the field data collection. The resource data centers bring together all the field data and the results data from samples sent to analytical laboratories (such as benthic invertebrate samples). The data centers are:

- Surface Waters: EPA Western Ecology Division (WED) in Corvallis, Oregon.
- Coastal: Southern California Coastal Water Research Project (SCCWRP) in Westminster, Califonia.
- Landscape: EPA Environmental Sciences Division (ESD) in Las Vegas, Nevada.

These centers are a source of preliminary data to all study participants and partners. EMAP Information Management and the EMAP web site are coordinated by the ORD Atlantic Ecology Division (AED). The EMAP internal web site is used for storing preliminary data. The EMAP public web site (*http://www.epa.gov/emap*) on the EPA public web server is used to distribute data and

19. CENR. 1997. Integrating the nation's environmental monitoring and research networks and programs: A proposed framework. Committee on Environment and Natural Resources, National Science and Technology Council, Washington, DC.

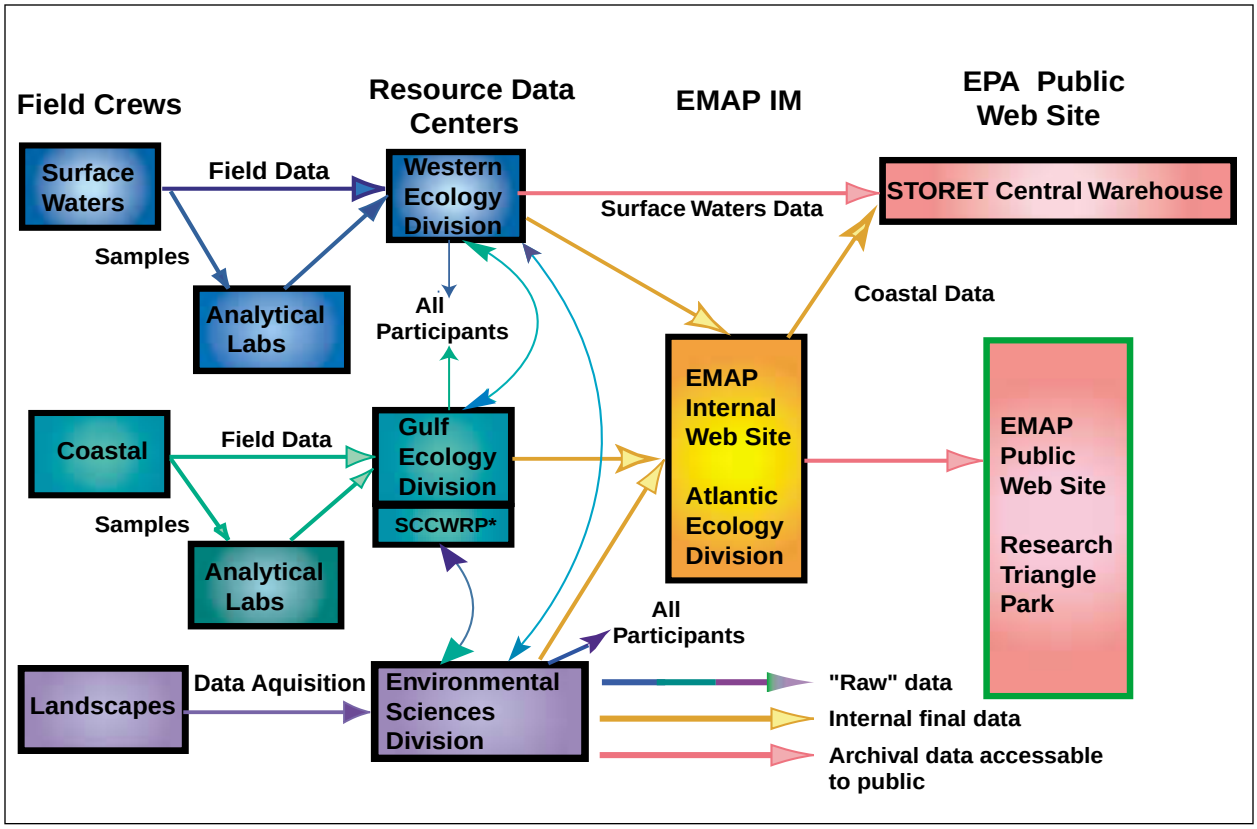

Figure 10. Data pathways for major components of EMAP-W showing major relationships among program elements.

information to researchers and managers in other organizations and to other data systems. STORET will be used as a long-term archival system for the Surface Waters and Coastal data. Data sets on the EMAP public site and in STORET must be 100% quality-assured and be accompanied by metadata (descriptive information necessary to access and interpret the main data set). Table 4 describes what occurs during each step of the data flow.

EMAP-W Web Site

The EMAP-W web site (*www.epa.gov/emap/wpilot*) will be used to convey information about the program and to distribute the data, metadata, and electronic versions of publications. Information about the data sets will be entered into the EMAP Data Directory. Publications resulting from the study will be entered into the EMAP Bibliography.

Other data systems

STORET. EPA Regions and many state agencies have local copies of the STORET Oracle database that they use for regional and local data. ORD will load EMAP-W Surface Waters data (Western Ecology Division) and Coastal data (Atlantic Ecology Division) to the central STORET warehouse. Both EMAP and STORET will benefit from this association. EMAP will use an archival system (STORET) that has existed since the 1960's and that has a long-term commitment from EPA. STORET will aid in fulfilling an objective of the EMAP geographic studies to build the

Table 4: Summary of data collection through archival showing responsibilities.

	Field Crews	Resource Data Centers	EMAP-IM	EPA Public Web Site
Function	Field data collection, Data entry Initial QA	Data entry, verification, validation, compilation Documentation QA (database integrity) EMAP data analyses and reports Data distribution to partners	QA (Consistency checks, completeness) System development Data distribution to partners	Data distribution to all others
Content	Data logger files Field paper forms Sample tracking	Resource group database Metadata Statistical programs GIS coverages	Data Directory Preliminary data & metadata GIS coverages Bibliography Reports	Data Directory QA'd Data & metadata GIS coverages Bibliography Reports
Data Format	Field computer system Data logger files Paper forms	Database system files (SAS, Oracle, Access) Arc/Info GIS files	ASCII data sets Oracle, SAS Arc/Info export files	ASCII data sets Oracle Arc/Info export files
Users	Field crews QA officers	EMAP participants & partners (Region, state, ORD)	EMAP participants & partners	Other researchers & managers, academia, the public Other data systems: STORET, EIMS, GCMD

capacity of groups within the area for long-term environmental monitoring and analysis. The value of STORET will be increased by the addition of EMAP data. The capabilities of STORET will also be enhanced (e.g., handling probability-based survey data, addition of FGDC federal metadata standards). This collaboration will also create opportunities for coordination on data standards (e.g., Integrated Taxonomic Information System, or ITIS, species codes). Users will benefit from having a consistent database (STORET) for water quality data from many sources.

EIMS. The Environmental Information Management System (*http://www.epa.gov/eims*) stores information about ORD (and other) data and where they can be found. The EMAP Data Directory, used for keeping track of the EMAP-W data sets, is periodically uploaded to the EIMS. EIMS is also available to use as a directory for the extensive non-EMAP data used in EMAP-W assessments. Any EPA region, state, or ORD laboratory can make EIMS directory entries for these external (non-EMAP) data sets, as Region 10 has been doing in the last few years. EMAP will benefit in that EIMS makes the existence of EMAP data sets more widely known. EIMS will benefit by increasing its store of knowledge of high-quality environmental monitoring data.

Timing

The timing of many of IM's activities depends solely on the pace of field data collection and subsequent processing by the resource groups. Figure 11 indicates a rough schedule based on the

anticipated flow from the individual program components. The bars show the timing from receipt

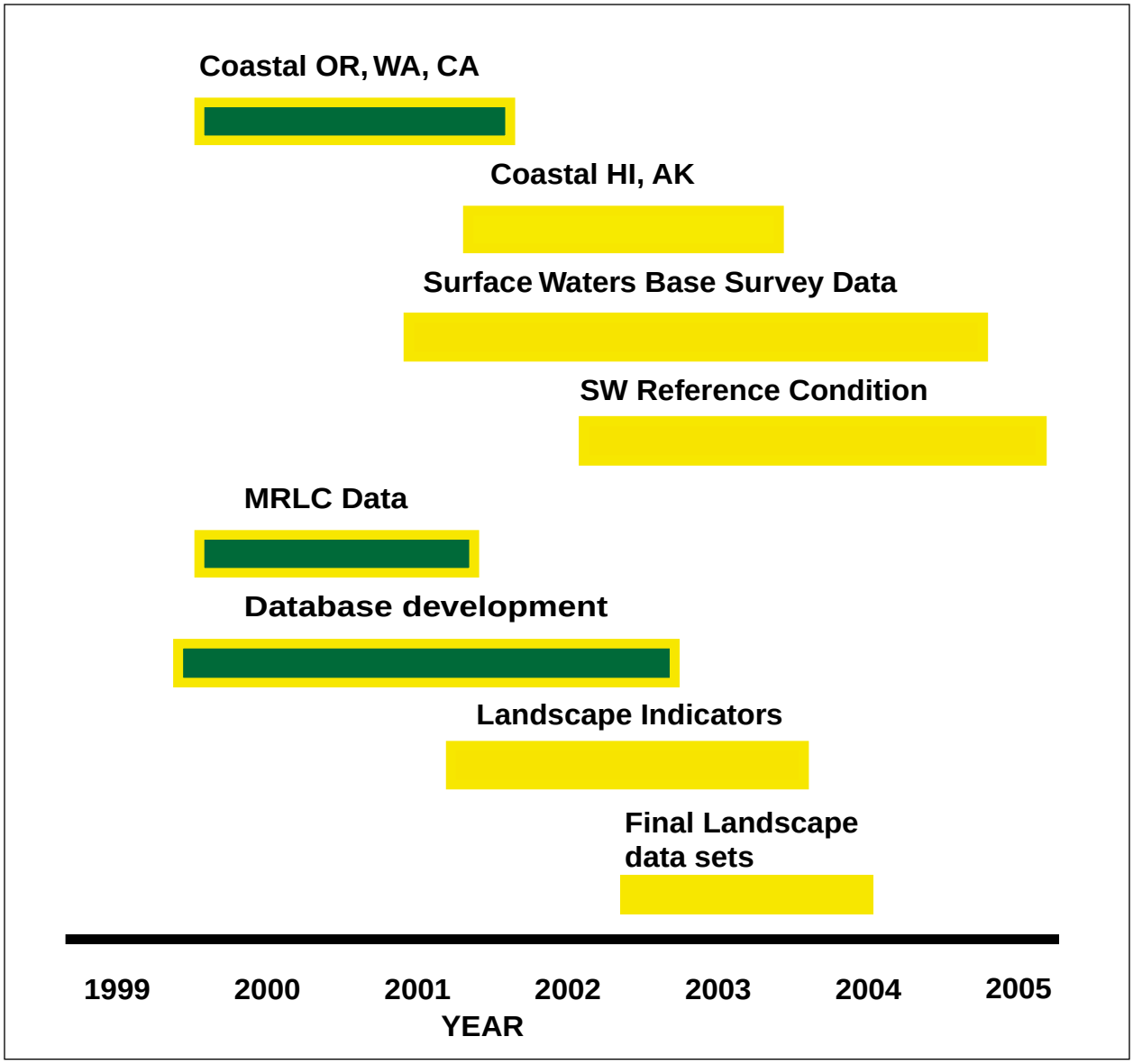

Figure 11. Timeline for developing data sets and incorporating them in internal and finally publicly accessible web sites.

of data to archiving in STORET and availability on the EPA web site,

Management

As is apparent by the descriptions in this document, EMAP-W is a large and complex effort involving many stakeholders. It will be successful only if a strong partnership among its participants is developed and maintained. Assuring that all understand the goals of the program and are aware of and have a role in its planning and progress is an essential part of maintaining that partnership. Effective communication among the core components of the program, as well as to those interested in its progress, is a major function of the management structure. The structure described below is intended to fulfill the oversight and communication needs of EMAP-W without overburdening those responsible for its conduct with unnecessary bureaucratic time requirements. The key components are the:

- Steering committee
- Technical committee
- Technical groups (Estuaries, Surface Waters, Landscapes, Information Management)
- Ad hoc subgroups dealing with specific issues (e.g., indicators, lab processes)

Steering Committee

This group, made up of EPA managers representing ORD, the regions, and OW, provide the general oversight required to keep the program on track. Responsible for the resources dedicated to implementing the program, this group is key to maintaining support at the highest levels with EPA. Through ad hoc membership of this group, other groups will likely be represented as the program progresses and partnerships are cemented. The primary responsibilities of the committee include:

1. Developing and overseeing program objectives and priorities.
2. Reviewing budget and allocations.
3. Tracking progress of major outputs.
4. Facilitating interactions with managers in other organizations.
5. Reviewing major communications and keeping top level managers within their respective organizations informed about EMAP-W progress and issues

This committee meets at least once annually and several times via phone conference in between face-to-face meetings. It is cochaired by the EMAP Director and the Lead ORD Region. Meetings are scheduled on an as-needed basis.

Technical Committee

This committee is made up of the technical leads for each program component. At present, this consists of the technical representatives from each of the Regions 8,9, and 10 and the leaders of Information Management, Landscapes, Design and Analysis, Surface Waters, and Coastal components. The committee is responsible for the coordinating the technical aspects of planning and implementing EMAP-W. This group must be certain that cross-component coordination proceeds smoothly and that all aspects of the monitoring effort is understood by the cooperating partners. Budget proposals and monitoring priorities originate with this group. Their core responsibilities are:

1. Prepare implementation and research strategies.

2. Prepare budgets and implement allocations according to established priorities.
3. Develop communications of plans, progress and accomplishments.
4. Oversee the implementation of program activities.
5. Coordinate inter-agency cooperation.
6. Oversee cross-component coordination.

Semi-annual meetings are expected with additional meetings when needed. Bi-weekly conference calls serve to keep momentum going and to assure that issues are handled in a timely fashion. This Committee is chaired by the EMAP-W Technical Coordinator.

Individual Technical Groups

The primary function of these groups is to be certain that the planning and implementation of the individual components is coordinated across state and regional boundaries. Fulfilling the umbrella objectives of EMAP while addressing local issues and concerns is a complex task that involves constant vigilance. Committed members of these groups are the key to the success of the program. These groups must grapple with the technical questions of their portion of the program while managing expectations. Their responsibilities include:

1. Preparing detailed implementation and research plans.
2. Coordinating partners' roles and responsibilities.
3. Responding to regional, state and local issues that arise during implementation.
4. Developing and conducting workshops to bring partners together to address technical and operational issues.
5. Transferring technology as needed to field crews, data managers, etc.
6. Providing budget and implementation alternatives to the technical committee.

These groups, chaired by the technical leaders, meet much more frequently than the other committees - both via conference calls and through workshops and similar forums.

Final Comments

The success of any large, complex program like EMAP-W is most often measured by how the data gathered are reported. Throughout this document, the schedule for each program component includes mileposts for reporting results. Frequent reporting of interim progress is important and will be a key element of the program. The ultimate measures, however, are the major Program outputs as listed in the Table 5. These reports will be developed in conjunction with the stakeholders in the program so as to assure that results are communicated in a format most useful to the states, EPA Regions and the public they serve. The form of these reports, the leadership in their preparation and the supporting elements have yet to be fully determined. This topic will be a major issue for the steering and technical committees to resolve as the program progresses. Proposed leadership and support roles are shown. Reports of condition for individual states will be

Table 5: Major Program outputs showing timing and responsibilities.

Report	Leadership	Support	Timing
Status of West Coast Estuaries	Regions, ORD	WA, OR, CA	Late 2001
Status of HI and AK Near Coastal Systems (individual reports)	HI, AK Region 9	ORD	Late 2003
Relationship of Landscape Indicators to Aquatic Condition	ORD, Regions	States	2004
Status of Surface Waters in the Western US	Regions	ORD, States	2005
EMAP-W Data - Form and Accessibility	ORD	Office of Water	2005

encouraged but will depend on the interest and support of the cooperating state and in regional interest. These assessments will be based on a series of data reports, prepared by ORD, that describe the statistical design, data collection and quality assurance methods and analysis procedures. These reports will include all the necessary information upon which to peer review the program outputs. They will not include assessments of condition where there are no clear references upon which to base the assessment process.

Finally, research papers will be published in the peer reviewed literature to provide the scientific underpinnings for the program. Many of these will occur late in the life of the program as they are often the result of complex analyses of final data sets. As the program develops, more detailed schedules for selected key papers will be provided.

Appendix

Steering Committee

Michael McDonald, **Chair**
EMAP Director
National Health and Environmental Effects Laboratory (NHEERL)
Research Triangle Park, NC 27711
919-541-7973
mcdonald.michael@epa.gov

William Benson
NHEERL/Gulf Ecology Division
Sabine Island Drive
Gulf Breeze, FL 32561-5299
850-934-9208
benson.william@epa.gov

Steven Bradbury
NHEERL, Mid-Continent Ecology Division
6201 Congdon Blvd.
Duluth, MN 55804
218-529-5010
bradbury.steven@epa.gov

Carol Campbell
Region 8
999 18th St., Suite 500
Denver, CO 80202-2466
303-312-6340
campbell.carol@epa.gov

Jonathan Garber
NHEERL, Atlantic Ecology Division
27 Tarzwell Drive
Narragansett, RI02881
401-782-3154
garber.jonathan@epa.gov

Janis Hastings
Region 10
1200 Sixth Avenue
Seattle, WA 98101
206-553-1582
hastings.janis@epa.gov

Margarete Heber
Monitoring Branch Chief, Office of Water
401 M St. SW
Washington, DC 20460
202-260-7144
heber.margarete@epa.gov

Carl Kohnert
Region 9
75 Hawthorne St.
San Francisco, CA 94105
415-744-1643
kohnert.carl@epa.gov

John G. Lyon
National Exposure Research Laboratory
Environmental Sciences Division
944 East Harmon Ave.
Las Vegas, NV 89119
702-798-2525
lyon.johng@epamail.epa.gov

Michael Slimak
National Center Environmental Research401
M St. SW
Washington, DC 20460
202-564-3324
slimak.michael@epa.gov

Gilman Veith
NHEERL
Research Triangle Park, NC 27711
919-541-4130
vieth.gilman@epa.gov

Technical Committee

Roger Blair, **Chair**
NHEERL, Western Ecology Division
200 SW 35th Street
Corvallis, OR 97330

Janet Hashimoto
Chief, Monitoring and Assessment Office
USEPA, Region 9, WTR-2
75 Hawthorne St.
San Francisco, CA 94105
415-744-1933

Gretchen Hayslip
Regional Monitoring Coordinator
USEPA, Region 10, OEA-095
1200 Sixth Avenue
Seattle, WA 98101
206-553-1685

Eric Hyatt
EMAP Coordinator
Region 8
Denver, CO
303-312-6504

Dan Heggem
Landscapes Lead
NERL/ESD
P.O. Box 93478
944 East Harmon Ave
Las Vegas, NV 89119
702-798-2278

Stephen Hale
Information Management Lead
NHEERL/AED
27 Tarzwell Dr.
Narragansett, RI 02882
401-782-3048

Walt Nelson
Coastal Lead
NHEERL/WED/Newport
2111 SE Marine Science Dr.
Newport, OR 97365
541-876-4041

Tony Olsen
Design and Analysis Lead
ORD/WED
200 SW 35th Street
Corvallis, OR 97333
541-754-4790

John Stoddard
Surface Waters Lead
ORD/WED
200 SW 35th Street
Corvallis, OR 97333
541-754-4441