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Methods for Aquatic Resource Assessment (MARA) FY 2008 - 2012

Freshwater Ecology Branch
Western Ecology Division

National Health and Environmental Effects Research Laboratory
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Recommending Officials:

Branch — John Stoddard for Tony Olsen — 9/27/07

Tony Olsen
Chief, Freshwater Ecology Branch

Quality Assurance — Robert J Ozretich — 10/5/07

Robert Ozretich
Manager, WED Quality Assurance

Approving Official:

Division — 12/11/07

Thomas D. Fontaine
Director, ORD/NHEERL. Western Ecology Division

EXECUTIVE SUMMARY

For the past 17 years, members of the Freshwater Ecology Branch (FEB) at EPA's Western Ecology Division (WED) have been engaged in research to develop the concepts and tools that would allow EPA and it's partners to monitor the status and trends in the condition of freshwater systems and the stresses impacting them. In addition to the research, FEB has also conducted large regional demonstration projects of how these tools can be used to result in the type of information needed by EPA. After the past 17 years of research, the EPA's Office of Water (OW) has stepped forward to implement these tools in partnership with the States and Tribal nations.

This document describes the breadth of activities in which members of FEB will be engaged as we transfer these tools to OW and support the national implementation of the tools. The work is captured under the banner "Methods for Aquatic Research Assessment (MARA). Four foci are proposed:

1. Provision of technical support for the Office of Water sponsored national aquatic surveys.

2. Evaluation of the monitoring designs and indicators needed by EPA Program Offices to meet their Government Performance Results Act (GPRA) commitments and to look for efficiencies that might arise if they collaborated with the OW national surveys.

3. Resolution of as many issues relevant to monitoring as possible by analyzing the data from past surveys in the mid-Atlantic, New England and the West.

4. Evaluation of existing indicators of condition and stress for relevance to the new direction of ORD's ecological research program – ecosystem goods and services.

INTRODUCTION

This research plan represents the fourth and final stage of research to be conducted by the Environmental Protection Agency's Western Ecology Division (WED) for the Environmental Monitoring and Assessment Program (EMAP) and signals the end of EMAP as a program within EPA's Office of Research and Development. The research proposed will be conducted by members of the EMAP project, primarily housed, but not limited to, the Freshwater Ecology Branch (FEB) at WED.

Before presenting the proposed research activities, a review of the history of EMAP and the four phases of its development will set the appropriate stage to evaluate this current research effort.

Initiation of EMAP

The need for significant advances in the way EPA and other federal agencies monitor the condition of our environment has been, and continues to be, recognized by the National Research Council, the U.S. General Accounting Office (GAO), and the U.S. EPA. In 1988, the U.S. EPA Science Advisory Board's (SAB's) report, *Future Risk: Research Strategies for the 1990s*, was the stimulus for many changes in EPA research. The report concluded that EPA needed more research on relating the effects of cumulative, regional, and long-term anthropogenic disturbances to ecosystem responses. Increased research was also needed to develop ecological indicators and protocols for monitoring, and to analyze and quantify uncertainty in assessments resulting from monitoring data. The goals of such research were improved detection of ecosystem status and trends, and greater predictive capability. The authors recognized that great benefit could be derived from the identification of trends in environmental quality before they begin to cause serious ecological or human health problems. They recommended that 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. They also recommended that EPA broaden its data-gathering and assessment efforts. Embodied in their recommendation was the perspective that monitoring programs can be valuable for their ability to paint a picture of present conditions, and if continued, they can help describe what has happened to the quality of an ecosystem over time. Their recommendations urged EPA to begin monitoring a far broader range of environmental characteristics and contaminants than it had in the past.

Toward these ends, the EPA Science Advisory Board recommended that EPA undertake research on techniques that can be used to help anticipate environmental problems and make a more concerted effort to be aware of, and interact with, the research efforts of other Federal agencies concerned with these problems. EPA was urged to evaluate environmental trends and assess other predictors of potential environmental problems before they become acute.

The SAB recommendations, the emerging vision of ecological risk assessment within EPA, and the importance of high quality monitoring information in this risk assessment paradigm were responsible for the creation of the Environmental Monitoring and Assessment Program (EMAP) within EPA's Office of Research and Development (ORD). EMAP's challenge was to develop and implement the tools necessary for measuring the condition of many types of ecological resources and the designs for detecting both spatial and temporal trends. EMAP used a tiered

monitoring approach and focused on developing indicators of ecological condition and new monitoring designs for major classes of natural resources such as surface waters, estuaries, forests, and wetlands.

Phase I (1989 – 1994)

EMAP's initial vision was articulated in its goal: "Monitor the condition of the Nation's ecological resources 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 very simple questions: What have we accomplished with our collective efforts to restore and protect our ecological resources? How do we know our programs, in aggregate, are or have been successful? Can we provide data to confidently verify the answers? Is the aggregate of our regulatory decisions protecting our ecological resources? This goal was further expressed in three operational objectives:

- To estimate current status, extent, changes, and trends in indicators of the Nation's ecological resources on a regional basis with known confidence;
- To monitor indicators of pollutant exposure and habitat condition, and to seek correlative relationships between human-induced stresses and ecological condition that identify possible causes of adverse effects; and
- To provide periodic statistical summaries and interpretive reports on ecological status and trends to the EPA Administrator and the public.

The program outlined a multi-tier approach to this monitoring. The foundation of this tiered approach was national landcover characterization based on remote sensing. The second level incorporated national and regional estimates of status and trends for important indicators of condition and exposure. A subregional focus for geographic areas which were of special concern formed the third tier. Finally, a tier of sites spread across the U.S. for intensive monitoring and research. This tiered approach incorporated concepts of both temporal and spatial scales and of the importance of different monitoring approaches: 1) wall-to-wall coverage (census), 2) statistically valid subsampling (probability based surveys) and 3) temporally intensive studies of a single or small collection of sites. Both indicators of stressors (e.g., metals in deposition, UV-b, tissue contamination, habitat alteration) and indicators of condition (e.g., external anomalies, fish index of biotic integrity, forest crown dieback) were incorporated into the overall approach.

In practice, however, the initial six years of EMAP focused on developing and demonstrating the remote sensing and survey tiers. Based on initial review of the existing monitoring efforts, these appeared to be the areas where the biggest gaps existed, especially with respect to aggregating the data for regional and national assessments. Operating under common approaches to indicators and design, individual components of the program (arid lands, agroecosystems, estuaries, forests, Laurentian Great Lakes, surface waters, wetlands) began to develop and evaluate the approaches in different portions of the country. These studies explored the range of useful indicators, the natural and anthropogenic variability and its influence on status and trends information, and the range and applicability of probability surveys for monitoring that resource. EMAP recognized early on that full implementation of this framework or even the landscape and resource survey tier could only be achieved if the budget was to grow to $100 Million/yr. and if

other federal agencies became active partners, bringing their own resources to the effort. At the height of Phase I, the EMAP budget reached $40 Million/yr.

While a great deal was accomplished during the first six years, national demonstration or implementation was not achieved for any of the resource areas, in spite of significant interagency partnering in many of the components. Simultaneously, an effort was launched to generate national landcover data from satellite imagery using the Thematic Mapper (TM) data. A spin-off from this effort evolved into the Landscape (ecology) "resource group" within the program with an objective to interpret the satellite information in the form of regional and national landscape assessments.

During this initial six years, EMAP and its components underwent 20 separate peer reviews of individual components of the program and an overall review by a panel contracted from the National Research Council (NRC) that published 4 individual reports. The EPA Science Advisory Board also reviewed several aspects of EMAP with particular attention to the development of indicators and the integration and assessment activities within the program. The results of these reviews along with the program's own analysis of the first six years of progress to shaping EMAP's future and the strategy followed during Phase II. Coincidental to these reviews, a new Assistant Administrator for ORD arrived with a mandate to shift $100million into the STAR grants program.

Phase 2 (1995-1999)

Concurrent with this first six years of research, the interest in monitoring and the scientific debate about how to most effectively accomplish it was rejuvenated. ORD spent 1995 evaluating the results of these initial studies and reviewing the aggregate of peer reviews which had taken place. 1996 was spent developing a revised strategy that was founded on the very same EMAP goals, many of which remain shared by other agencies. During this phase, EMAP brought in elements of the initial conceptual approach which had been put on hold (network of index sites), retained those elements which were effective (landcover production and resource surveys) and expanded upon them. Additionally, greater emphasis was placed on the scientific process for fully implementing the framework. The research efforts in the short-term were focused on the sciences of: integration, ecological indicators and monitoring designs that serve as common denominators among environmental agencies in their efforts to merge individual monitoring efforts into a national program.

In 1995, ORD also made a strategic decision to develop the grants program, Science To Achieve Results (STAR) with a funding target of $100million. The EMAP budget was reduced from $40million to $22million and $12million of that total was used exclusively for grants in the STAR program. While EMAP was able to define the categories of research conducted with the EMAP funds in the STAR grant program, this research had little impact or in some cases relevance to EMAP and the efforts to establish a national ecological monitoring network.

ORD also made the decision that EMAP could no longer afford to include all terrestrial and aquatic resources. Given EPA's mission and focus, EMAP narrowed its focus to aquatic resources – estuaries and other coastal waters, rivers and streams, lakes and reservoirs, and wetlands. Each of the resource groups worked within the same region, initially the Mid Atlantic region and later the West. Research on indicators, designs and the tools necessary to answer the

original objectives continued to be implemented within the framework of these integrated, regional studies.

At the instigation of the Assistant Administrator for ORD, EMAP also initiated a cooperative effort with the U.S. Park Service to monitor air contaminants impinging on a set of national parks across the country. This network was viewed by the AA as a critical part of a network to address the original objectives of EMAP.

During this period, the Regional – Environmental Monitoring and Assessment Program (REMAP) was emphasized. REMAP focused on introducing the EPA Regions and States to the concepts of sample survey designs and use of a suite of biological, chemical and physical indicators.

Substantial progress was made in the advancement of sample survey designs for aquatic resources, and the identification of effective indicators and their interpretation.

Phase III (2000-2006)

During this most recent Phase of EMAP, ORD made it very clear that EMAP would not be a long-term monitoring program. Once the research on how to implement the basic program for each of the aquatic resource types was completed, EMAP as an ORD program would end and other Offices within EPA would have to implement the monitoring and assessment if it was going to be implemented at all.

Thus, in 2002, EPA revised the goals of EMAP. The primary goals became:

- Develop the science needed for a state-based statistical monitoring framework to determine condition, and detect trends in condition for all the Nation's aquatic ecosystems.

- Transfer this technology in a useable form to EPA Program Offices, Regions, States, and Tribal Nations.

- Have this approach adopted and implemented by the EPA Program Offices, Regions, States, and Tribal Nations.

Phase III has been dominated by four activities: EMAP-West, National Coastal Assessment, the Great Rivers project on the Upper Mississippi and the Upper Missouri and the national Wadeable Streams Assessment (WSA).

The primary focus of the Corvallis Freshwater Ecology Branch (then the Aquatic Monitoring and Bioassessment Branch) during this phase was monitoring rivers and streams in the twelve states of EPA Regions 8, 9 and 10, which encompass the Western U.S. EMAP-West was a scientific evaluation of the applicability of our stream and river designs and indicators for a vast area of the country with high ecological variability. This work removed the remaining scientific barriers to a national framework for monitoring the condition of the nation's streams and rivers. The culmination of this effort was a joint project with the Office of Water that combined the streams

results from the west with new sampling of streams in the east and resulted in the National Wadeable Streams Assessment (WSA), the first reliable national picture of streams within the conterminous U.S.

EMAP's National Coastal Condition Assessment (NCCA) was a national demonstration of our approach in estuaries. The NCCA demonstrated the framework for a consistent, state-based, probabilistic monitoring framework in the 24 marine coastal states and Puerto Rico. This effort produced three national assessments of the condition of the U.S. marine estuaries, and serves as the baseline for future measures.

Phase IV (2008 - 2012) – Methods for Aquatic Resource Assessment (MARA)

During this final phase of EMAP, national monitoring and assessment of our Nation's aquatic systems will be conducted by the EPA Office of Water and Regions in partnership with the States and Tribal Nations. ORD will no longer fund large regional or national surveys.

EMAP work in the Freshwater Ecology Branch in Corvallis during this final phase will center around four areas that are the subject of this research strategy. These four areas are:

1. Provision of technical support for the Office of Water sponsored national aquatic surveys.

2. Evaluation of the monitoring designs and indicators needed to meet the combined monitoring and assessment needs arising from the Government Performance Results Act (GPRA) Goals of the program.

3. Resolution of as many issues relevant to monitoring as possible by analyzing the data from past surveys in the mid-Atlantic, New England and the West.

4. Evaluation of existing indicators of condition and stress for relevance to the new direction of ORD's ecological research program – ecosystem goods and services.

The remainder of this strategy will present our activities in each of these four areas.

I. Technical Support for Office of Water National Surveys and Assessments

As described above, for the impetus for EMAP, multiple reports over the past 35 years have identified the need for improved water quality monitoring and analysis at multiple scales. In 2000, the General Accounting Office (GAO) reported that EPA, states, and tribes collectively could not make statistically valid inferences about water quality (via 305[b] reporting) and lacked data to support key management decisions. In 2001, the National Research Council recommended EPA, states, and tribes promote a uniform, consistent approach to ambient monitoring and data collection to support core water quality programs. In 2002, the H. John Heinz III Center for Science, Economics, and the Environment found there is inadequate data for national reporting on freshwater, coastal and ocean water quality indicators. The National Association of Public Administrators stated that improved water quality monitoring is necessary to help states and tribes make more effective use of limited resources. EPA's Report on the Environment 2003 says that there is not sufficient information to provide a national answer, with confidence and scientific credibility, to the question, 'What is the condition of U.S. waters and watersheds?'

In response to this need, the U.S. EPA Office of Water (OW), in partnership with states and tribes, has begun a program to assess the condition of the nation's waters via a statistically valid approach and a coordinated suite of indicators (i.e., the concepts developed by EMAP). One of the goals of OW's work with the states and tribes is to build state capacity to conduct state-scale surveys, which will eventually supplant the national surveys in tracking the status and trends in the condition of the nation's waters. OW's strategy includes working with state and tribal partners to report changes in conditions of the nation's waters, improving the availability and usefulness of water quality monitoring information, and assessing progress in meeting the goals of the Agency's Strategic Plan. For the purposes of OW's strategy, monitoring will include lakes, rivers, streams, estuaries, and wetlands.

An OW budget initiative was funded by Congress' provision of resources in the form of grants to states to survey the condition of the Nation's waters. The FY06 and FY07 President's budget includes a separate line item for Section 106 Monitoring Initiative funds for states to participate in statistically valid surveys of the nations waters. OW is required to report to OMB on the status of the Monitoring Initiative.

Table 1 shows the intended schedule and components of survey implementation. Surveys specific to each water body type will require a tailored timeline and workplan to guide their implementation.

Table 1: Conceptual schedule and components of survey implementation

	2006	2007	2008	2009	2010	2011	2012	2013
Lakes	Design	Field	Lab Data	Report	Research	Design	Field	Lab Data
Rivers	Research	Design	Field	Lab Data	Report	Research	Design	Field
Streams	Report	Research	Design	Field	Lab Data	Report	Research	Design
Coastal	Lab Data	Report	Research	Design	Field	Lab Data	Report	Research
Wetlands	Research	Research	Research	Research	Design	Field	Lab Data	Report

Design = define target population and conduct site selection for field sampling; select indicators and field/lab protocols
Field = collection of field data
Lab Data = processing of samples
Report = Analysis of data and production of assessment report
Research = Resolution of outstanding issues prior to next implementation of field survey

Key elements or steps to successfully implementing these national surveys and assessments are:

1. Implementation Strategy Development
2. Clarifying Monitoring Objectives
3. Survey Design
4. Development of Core and Supplemental Indicators
5. Quality Assurance
6. Field and Laboratory Implementation
7. Information Management
8. Data Analysis and Interpretation
9. Reporting

Each of these nine steps must be completed for each of the separate aquatic resource areas (i.e., lakes/reservoirs, rivers/streams, wetlands, and estuaries).

OW is responsible for the overall coordination and implementation of these efforts while ORD plays a key role in each of the elements. Each element/step is described below with the role of WED/FEB highlighted.

1. National Strategy Development

During the OW national strategy development, the project partners develop the scope of the survey, organize support structures, and conduct outreach to partners and participants. This phase is informed by research and the experience gained from implementing similar efforts. Some of the key activities are described below.

1. Communicate across OW and the Agency to share information about the survey and recruit needed support.

2. Form a planning committee that initially pulls together EPA expertise across offices, and is quickly expanded into a steering committee that includes additional federal agencies (e.g., USDOI, USDA), states, tribes, and other government partners. This committee provides input throughout the survey including design, implementation, and reporting. The steering committee may call on academics and other experts to lend their expertise throughout the survey process. OW provides logistical and administrative support to the committee.

3. Develop staffing plan including EPA lead and support staff for activities and component of the survey. Develop schedule and workplan (Refer to General Support and Infrastructure Planning Section). Identify critical activities requiring input from all states, tribes, and other partners (hereafter referred to simply as partners) via national and/or regional meetings. Define a process and schedule for maintaining routine contact with the EPA/State steering committee.

4. Identify and procure required resources such as contractor support, equipment funding, and travel funding.

5. Provide national forums to obtain input from a broad range of experts, including national and/or regional meetings with partners and other experts to discuss key design questions such as:
   - Scope of target population and reporting units
   - Objectives of the survey
   - Core indicators/parameters to measure and report on condition
   - Field and lab protocols
   - Data analysis/interpretation methods
   - Data management

6. Disseminate information via websites, meetings, etc.

ORD Role: ORD plays a key role in the surveys and is well integrated into the entire process. ORD provides technical analysis of past research related to the surveys, including design, indicator methods, thresholds, stressor/response relationships, and data analysis and interpretation and summarizes the implication for the OW national surveys and assessments. ORD provides an overall coordinator who interacts, at a minimum, weekly in assisting OW in refining their strategy for long-term national surveys.

2. Monitoring Objectives

The OW National Strategy for Water Monitoring lays out three main goals to strengthen the nation's water monitoring programs:

> Goal 1: EPA and its partners implement scientifically-valid assessments of water resource conditions at the state, regional, and national levels, and report on national water quality conditions and trends.
>
> Goal 2: EPA, states, tribes, territories, and interstate organizations more effectively manage water data, integrate water data systems across programs, and produce a national electronic warehouse of water data of documented quality that is accessible to others.
>
> Goal 3: EPA, states, tribes, territories, and interstate organizations better integrate water monitoring activities across programs, implement comprehensive monitoring strategies, and provide the information to more efficiently manage waters on a watershed basis.

The monitoring objectives of the assessment surveys support Goal 1. The objectives are:

> Objective 1. Estimate the current status, trends, and changes in selected ecological and recreational indicators of the condition of the nation's waters with known statistical confidence.

Objective 2. Seek associations between selected indicators of natural and anthropogenic stresses and indicators of ecological condition to provide a relative ranking of likely stressors impacting water resource quality

Each survey has a steering committee to fine tune the objectives for a particular survey assessment and to further define:

- Level of confidence needed in survey results
- Type and amount of data needed to obtain the desired level of confidence in results

ORD Role: ORD brings its technical expertise to bear on the survey design and the selection of indicators needed to meet the objectives. ORD provides insights into sample sizes necessary to meet uncertainty estimate requirements, insights into the indicators and field and laboratory protocols needed to address specific objectives.

3. Survey Design

The design of a water body assessment is driven by both the broad goals and objectives described above and more specific objectives identified by the steering committee, which includes states, tribes, and interstate agencies. The design phase includes generating the randomized site/water body selections and conducting site/water body reconnaissance. The following activities support this process.

1. Generate Randomized Site/Water Body Selection

- Define target population based on input from national/regional meetings and steering committee
- Define reporting units and other design constraints
- Develop sample frame and randomized design to represent target population for the water body type
- Generate random sites that support reporting resolution (national, regional scale, option for state or finer scales)

2. Define inclusion/exclusion criteria for verifying site/water body is within target population

- Develop forms for documenting evaluations
- Develop site evaluation protocols and get feedback from steering committee
- Disseminate final protocols and train all evaluators
- Track progress and consistency in site evaluation

3. Site/Water Body Reconnaissance

- Generate maps and evaluation packets for each site/water body and disseminate to states and tribes
- Conduct reconnaissance to determine appropriateness of including selected sites in the survey.
- Track results and maintain a master file on site status.

3. Evaluation and Feedback

- Identify research needs emerging from the design phase that may be pursued during field implementation or documented for future rounds of the survey.
- Identify lessons learned in navigating design process and proposals to improve future design activities.

ORD Role: ORD has extensive experience in implementing sample survey design concepts for aquatic resources on large geographic scales. ORD will be responsible for seeking clarifications on the survey objectives and proposing design options for meeting those objectives including identification of target populations, subpopulations of special concern and level of spatial resolution required. ORD performs the site selection and provides that information to OW.

4. Core and Supplemental Water Quality Indicators

The goals of the Clean Water Act (CWA) as stated in Section 305(b)(1)(B) are the drivers for selecting indicators. Indicators help us to determine whether water bodies provide for the "protection and propagation of balanced populations of shellfish, fish, and wildlife, and allow recreational activities in and on the water." Indicators provide information to support decision making regarding aquatic life, suitability for swimming and fishing, understanding key stressors, physical and chemical parameters, and how they help us meet the goals of the Act.

Supplemental indicators can be developed to support additional goals or to support regional or state scale surveys. Steps for indicator selection are outlined below.

1. Define reporting objectives (e.g., biological condition, fish tissue concentrations, recreational uses, etc.)

2. Use national/regional meetings and the steering committee to identify potential measures/parameters/indicators that are representative of reporting objectives

3. Identify evaluation criteria and constraints for sample collection, processing/analysis, and interpretation

4. Select core and supplemental indicators for describing the condition of the water body type

5. Identify which are collected in the field and which are compiled from other data sources (e.g., GIS data layers and remote sensing)

ORD Role: ORD will participate in the workgroups tasked with developing the list of core and supplemental indicators.

5. Quality Assurance

National assessments must have a Quality Assurance Project Plan (QAPP). Those documents are peer reviewed in accordance with EPA Policy to ensure scientific validity. The QAPP describes the level of data quality necessary to meet the objectives of the survey with a known level of certainty.

A major quality assurance component of the assessments is the development of both a Field Operations Manual and a Laboratory Operations Manual. Each manual describes in detail the roles and responsibilities of all survey participants, and the manuals cover all steps in the process from field work to data verification. All standard operating procedures are defined in the manuals. The manuals serve as references for any questions or concerns that come up during sample collection and analysis, and data review and verification.

1. Develop Field Sample Collection and Laboratory Processing Protocols
    - Identify the range of methods to be used for sampling and analysis for core indicators.
    - Develop criteria to evaluate methods applicability for national survey.
    - Define the field protocols and lab protocols for sample collection and processing and obtain feedback from steering committee and/or national meeting.
    - Draft SOPs, appropriate forms (field forms, lab bench sheets) and data management standards and system structure.
    - Distribute to steering committee for review and comment.
    - Finalize methods for sampling and laboratory analysis.

2. Develop Quality Assurance Project Plan
    - Draft a QAPP consistent with EPA quality assurance program guidance.
        - Document all decisions made and protocols developed during the design phase beginning with the purpose of the survey and the data quality objectives.
        - Include all field and lab protocols, and the accompanying quality control activities and quality assurance oversight.
        - Outline the data summarization and interpretation methods to support reporting, and end with procedures for data archiving.
    - Distribute to states and other partners for review.
    - Obtain EPA review and sign-off of QAPP.
    - Finalize QAPP.

3. Conduct Audits
    - Schedule field visits/audits for each state crew to ensure adherence to assessment survey methods and protocols.
        - If resource constraints do not allow for field visits/audits to each state field crew, prioritize based on level of experience with EMAP/assessment survey methods and protocols.
        - Identify regional staff able to help conduct these visits/audits.
    - Conduct field audits following procedures in the QAPP.

ORD Role: ORD will provide review of the draft QAPP. ORD will participate in workgroups that are tasked with defining the field and laboratory protocols.

ORD will provide electronic copies as well as hard copies of QAPP documents used in previous EMAP surveys. ORD will provide recommendations for modifications to these documents for the OW surveys.

6. Field and Laboratory Implementation

The overall objective is to ensure the required number of sites are sampled or otherwise accounted for, and that the field crews conduct the sampling correctly. It also is important to ensure that the field and laboratory data for each site is correct and meets the survey analysis requirements. For the national assessments, there are no second chances.

1. Site Reconnaissance
   - Transfer to states the list of sites to be sampled.
   - Relay any design rules/requirements to states.
   - Evaluate whether sites are suitable for sampling (due to access, safety, or other concerns) prior to sending out a field crew.
   - Track site evaluation forms and site replacements.

2. Planning
   - Incorporate any additional sampling requirements (e.g., repeat sites).
   - Work with each state to determine an implementation strategy for site visits (when to sample based on designated index period, how it will get done, who will do it). Coordinate this through/with the Contract and/or Project Officers.
   - Obtain a central contact person/coordinator from each state that always will be available to provide information. Field crew leaders are sometimes not available by phone.
   - Obtain from each state an original field sampling schedule and subsequent revisions. Some sites will require thought regarding how to account for them (crew interpretation vs. design interpretation). Track progress.

3. Field Logistics and Tracking
   - Develop a strategy for delivering field crew samples to laboratories (when and how to ship, temporary holding depots, tracking of samples, dangerous goods issues, etc.), based on data turnaround requirements, lab locations and capacities, and state constraints or requirements. Be aware of constraints related to lab contracts (e.g., a contract is not awarded by the time field sampling is scheduled to begin)
   - Establish a system for tracking the sampling status of all sites provided to the states – sampled or not, and if not, why. For instance, the field crew could check in with the field logistics coordinator by phone after each sampling visit, or the coordinator could check in daily with a state contact for an update.
   - Plan to review field sheets and lab results in as near to real-time as possible. There is minimal time for data review by Corvallis Information Management (IM) once sampling is completed. The national assessments allow one year from collection to validated data in order to produce a report within two years of field sampling.
   - Work with states to develop a procedure for submitting completed data forms (who will send them, how frequently, contact for resolving questions about forms). Ensure Corvallis IM is aware of when field sheets are expected and the required turnaround time.

- Schedule field visits/audits for each state crew to ensure adherence to assessment survey methods and protocols.
    - If resource constraints do not allow for field visits/audits to each state field crew, prioritize based on level of experience with EMAP/assessment survey methods and protocols.
    - Identify regional staff able to help conduct these visits/audits.

4. Crew Preparation and Training
    - Ensure States have obtained proper field equipment; be prepared to issue emergency replacements.
    - Print the forms and labels. It is important to know well in advance the required number of form packets so the responsible party can procure water-resistant paper and print the forms.
    - Prepare and distribute field sampling packets. Include forms, labels, sample containers, cooler, and shipping materials.
    - Ensure each state has all required field manuals.
    - Identify trainers and coordinate with Corvallis to schedule train-the-trainer sessions.
    - Coordinate with each state to schedule field crew training sessions based on anticipated sampling start date; availability of trainers, field crews, training facilities/accommodations; etc.
        - Ensure all equipment and supplies are available for the training sessions, including presentations/handouts, forms, gear, etc.).
        - Be prepared to deal with methods compatibility issues (existing state procedures versus assessment survey procedures).
        - Discuss the critical balance between having sites sampled in a consistent manner across all States and allowing field crews some flexibility to address unique situations.
        - Emphasize the necessity for filling out forms correctly and legibly because of constraints imposed by the short data turnaround time.
    - Evaluate experiences, and identify lessons learned, research needs, and next steps.

5. Sample Collection
    - Deploy field crews.
    - Collect and ship samples according to procedures in the QAPP.
    - Complete and deliver field forms.

6. Laboratory Processing
    - Coordinate with the laboratories to ensure samples are being processed and analyzed according to the required schedule.
    - Ensure the labs have all of the sample-related information required.
    - Identify any potential issues with data reporting early so they can be addressed.
    - If multiple labs are required, verify there are mechanisms in place to ensure data comparability and a process to evaluate it (e.g., performance evaluation samples).

ORD Role: ORD will make available the data management systems for field and laboratory implementation that have been used in past EMAP surveys. OW will provide the financial resources to cover these expenses. ORD will identify primary and alternate

field sites. ORD will make available past field and laboratory forms as well as any electronic versions. ORD will review final forms developed for the surveys. If OW chooses to use FEB's information management contract capabilities, FEB will ensure that scanning of field and laboratory forms as well as site and sample tracking are included and FEB will provide oversight of this activity.

7. Information Management

The goal of information management (IM) is to manage, archive and make accessible the data from the national assessments. IM is integral to all aspects of the national assessment surveys from initial selection of sampling sites through dissemination and reporting of final, validated data. QA and QC measures implemented for the IM system are aimed at preventing corruption of data at the time of their initial incorporation into the system and maintaining the integrity of data and information after incorporation into the system. The QAPP addresses IM in detail.

Records for the national assessments include planning documents (e.g., QAPP, Standard Operation Procedures (SOPs), and assistance agreements) and field and laboratory documents (e.g., data sheets, laboratory notebooks, field notebooks, and audit records). OW is responsible for maintaining all of these documents. Data is entered into the Assessment Database (ADB) and ultimately archived in the OW data warehouse (currently STORET/WQX).

ORD Role: If OW chooses to use FEB contractor information management capabilities, FEB will provide finalized data sets for the analysis team and for distribution to the survey partners. FEB will also work with OW for the successful transfer of the data to the destination of OW's choosing, presumably STORET/WQX.

8. Data Analysis/Assessment

To interpret the data collected and assess current ecological condition; chemical, physical, and biological measurements must be compared to a benchmark or estimate of what one would expect to find in a natural condition. Setting reasonable expectations for an indicator is one of the greatest challenges to making an assessment of ecological condition. Because of the difficulty of estimating the historical conditions for many water body indicators, the national assessments use the condition at a collection of "least-disturbed" sites as reference conditions.

The results from samples collected at the reference sites for various indicators represent the range of expected values for the least-disturbed reference condition. National assessments use this reference distribution as the benchmark for setting thresholds between good, fair, and poor condition. These thresholds are applied to the random sites to generate the percentage of the water body type in each condition class.

OW establishes procedures for scaling metrics, indicators and indices relative to reference condition and disturbance class. These procedures are described in a set of SOPs detailed in the QAPP. The procedures will involve a diagnostic component, including analysis to determine the primary cause(s) of degradation. EPA also will consider how multi-level data can be used to better inform condition assessment at a specific site. This may include using indicators from

multiple levels to assess more precisely the condition of the water body and causes of degradation. A stepwise approach is outlined below.

1. Conduct preliminary screening of data from laboratories for compliance with the data requirements defined in the QAPP and lab SOPs.

2. Describe data interpretation approaches for each core indicator and identify potential issues and research needs, including selection and monitoring of reference sites

3. Facilitate national meetings on data interpretation and reporting

6. Calculate indices, Cumulative Distribution Functions (CDFs), and population estimates.

7. Refine analysis for incorporation into the report

8. Identify lessons learned, research needs, and next steps

9. Evaluate data after loading into SWIMS and NCCA database in preparation for analysis.

10. Reexamine data summarization and interpretation methodology during laboratory processing and data clean-up; identify, discuss, and resolve issues working with the steering committee.

11. Upon completion of data clean-up, perform initial data summarization and interpretation

ORD Role: ORD will provide the technical leadership for the data analysis. The analysis will range from creating indicators to establishing the thresholds for interpreting the data. ORD will perform the population estimation analyses and provide data to the report writers in a format that is suitable for generating figures for the report.

9. Reporting

EPA, working with partners, produces the final assessment reports that document the ambient condition of the nation's water bodies. A number of factors ultimately will determine the type of information presented in the final reports. They include the availability of resources and the level of effort provided by cooperating states and tribes. At a minimum, we expect the reports will present the results of the national assessments. Also included may be examples of how states and tribes that expanded the survey to a state or tribal scale used the information to support their programmatic decision making. Reporting will take the following steps:

1. Outline report and begin developing introductory and background text.

2. Incorporate data analysis into draft report.

3. Put draft report through a review process with the following groups: a) steering committee, b) state and tribal partners, c) scientific/academic community, d) EPA offices/regions, and e) the general public.

4. Finalize report

ORD Role: ORD will play a significant role in writing the report. The overall direction and focus of the report will be under the guidance of OW with ORD providing significant portions of the initial drafts of the report.

FEB Quality Assurance Statement for Focus Area I: The Office of Water's activity is clearly a Level I activity and will be covered under an OW QAPP for each survey and assessment. FEB will not be collecting any primary data and will simply be providing technical recommendations on decisions that OW will need to make. No FEB QAPP will be developed for Focus I.

II. Monitoring for Program Office Accountability

The national surveys being implemented by the Office of Water provide a unique opportunity for the Offices within EPA to leverage their efforts and collaborate on monitoring. As an element of our activity at FEB, we will examine each of the EPA Program Office reporting requirements and look for overlap and opportunities in the monitoring requirements between the various Program Offices and the Office of Water national surveys. Below is a description of EPA's reporting process and FEB's view on what we can add to identifying potential efficiencies within EPA.

EPA is committed to using the taxpayer funds it receives from Congress to produce meaningful environmental results. The Agency has established five long-term strategic goals that describe the results it is striving to achieve: (1) Clean Air and Global Climate Change, (2) Clean and Safe Water, (3) Land Preservation and Restoration, (4) Healthy Communities and Ecosystems, and (5) Compliance and Environmental Stewardship. Each of these goals has a series of specific objectives and performance measures that will track progress.

These five goals are supported by a planning and budgeting framework, or strategic "architecture," which serves as the structure for EPA's annual planning, budgeting, and accountability work. By integrating these activities under one framework, the Agency has been better able to assess its performance, evaluate its programs, and use that information to make budget and program improvement decisions. EPA's strategic planning and budgeting architecture comprises strategic goals, objectives, annual performance goals, and annual performance measures.

The Office of Management and Budget (OMB) has also worked with the EPA to develop a Program Assessment Rating Tool (PART) used for producing an assessment conducted under each of the strategic goals to determine the Agency's progress.

EPA is working to integrate GPRA and PART measures to meet standards for performance measurement established by EPA and OMB. This integration is another step in EPA's ongoing efforts to establish a set of measures that clearly defines environmental outcomes and achieve EPA's Budget and Performance Integration goals. Additional information on PART assessments and EPA's progress in making program improvements is available at ExpectMore.gov.

The structure for this process within the Agency is as follows:

STRATEGIC GOAL: Identifies the overall environmental result that EPA is working to achieve in carrying out its mission to protect human health and the environment.
OBJECTIVE: Supports EPA's strategic goals by identifying more specific environmental outcomes or results the Agency intends to achieve within a given time frame, using available resources. EPA's 2003-2008 Strategic Plan includes 20 objectives.
ANNUAL PERFORMANCE GOAL (APG): Specific results EPA intends to achieve in a given fiscal year. APGs represent the year-by-year accomplishments that EPA believes are needed to achieve its objectives. APGs generally include a target to be achieved (relative to a

baseline) and performance measure. Some of EPA's APGs, however, are specific environmental outcomes or results that may take longer than a year to realize and quantify.

ANNUAL PERFORMANCE MEASURE (APM): The metric that EPA uses to evaluate its success in meeting an annual performance goal. In many cases, the APG is itself the performance measure.

It is FEB's belief that monitoring and assessment play key roles in determining progress toward each of the goals. There is, however, no mechanism within EPA to evaluate monitoring and assessment needs across the Program Offices within the Agency. As a component of this final phase in EMAP, the EMAP project within FEB will undertake a detailed evaluation of each Agency annual performance goals and measures, in consultation with each of the responsible Program Offices. The purpose of this evaluation is to determine what monitoring is necessary to meet that Offices goals and how collaborative monitoring effort might best be fashioned across the agency to more effectively meet the Agency's information needs.

This may be as simple as adding an indicator to ongoing surveys. For example, OW is currently implementing (as described above) national surveys to assess conditions of aquatic resources within the U.S. These surveys and assessments are designed to meet OW GPRA and PART needs. During the 2007 lake survey analysis of mercury in lake sediments was added to the core measurements to assist Office of Air and Radiation (OAR) in meeting a portion of its strategic goals and performance measures. The Office of Prevention, Pesticides and Toxic Substances (OPPTS) is exploring a stream indicator based on watershed modeling of crops and pesticide use. These models of pesticide use can be applied to watersheds sampled in OW's stream, river and lake surveys to evaluate potential impact of pesticides on aquatic biota.

In other cases, there may be a need to survey specific subpopulations as well as conduct national-scale surveys. For example, Office of Air and Radiation (OAR) has a need under the Clean Air Act to monitor and assess changes in aquatic systems in acid sensitive regions of the country. This was a complement to the broader aquatic surveys being implemented by OW as part of their national strategy. This collaboration between OAR, ORD and OW has already led to more cost-effective monitoring and assessment within the EPA. Collaboration with other federal, state and tribal agencies may also lead to cost effective, collaborative efforts.

The EPA's current goal and objective structure is outlined below:

GOAL 1. CLEAN AIR AND GLOBAL CLIMATE CHANGE: **Protect and improve the air so it is healthy to breathe, and risks to human health and the environment are reduced. Reduce greenhouse gas intensity by enhancing partnerships with businesses and other sectors.**

Objective 1.1: Healthier Outdoor Air
Through 2010, working with partners, protect human health and the environment by attaining and maintaining health-based standards and reducing the risk from toxic air pollutants.

Objective 1.2 Healthier Indoor Air
By 2008, 22.6 million more Americans than in 1994 will be experiencing healthier indoor air in homes, schools, and office buildings.

Objective 1.3 Protect the Ozone Layer
By 2010, through worldwide action, ozone concentrations in the stratosphere will have stopped declining and slowly begun the process of recovery, and the risk to human health from overexposure to ultraviolet (UV) radiation, particularly among susceptible subpopulations, such as children, will be reduced.

Objective 1.4 Radiation
Through 2008, working with partners, minimize unnecessary releases of radiation and be prepared to minimize impacts to human health and the environment should unwanted releases occur.

Objective 1.5 Reduce Greenhouse Gas Intensity
Through EPA's voluntary climate protection programs, contribute 45 million metric tons of carbon equivalent (MMTCE) annually to the President's 18 percent greenhouse gas intensity improvement goal by 2012. (An additional 75 MMTCE to result from the sustained growth in the climate programs are reflected in the Administration's business-as usual projection for greenhouse gas intensity improvement.)

Objective 1.6 Enhance Science and Research
Through 2010, provide and apply sound science to support EPA's goal of clean air by conducting leading-edge research and developing a better understanding and characterization of environmental outcomes under Goal 1.

GOAL 2. CLEAN AND SAFE WATER: Ensure drinking water is safe. Restore and maintain oceans, watersheds, and their aquatic ecosystems to protect human health, support economic and recreational activities, and provide healthy habitat for fish, plants, and wildlife.

Objective 2.1: Protect Human Health
Protect Human Health: Protect human health by reducing exposure to contaminants in drinking water (including protecting source waters), in fish and shellfish, and in recreational waters.

Objective 2.2: Protect Water Quality
Protect Water Quality: Protect the quality of rivers, lakes, and streams on a watershed basis and protect coastal and ocean waters.

Objective 2.3: Enhance Science and Research
Enhance Science and Research: Provide and apply a sound scientific foundation to EPA's goal of clean and safe water by conducting leading-edge research and developing a better understanding and characterization of the environmental outcomes under Goal 2.

GOAL 3. LAND RESTORATION *AND* PRESERVATION: Preserve and restore the land by using innovative waste management practices and cleaning up contaminated properties to reduce risks posed by releases of harmful substances.

Objective 3.1: Preserve Land
By 2008, reduce adverse effects to land by reducing waste generation, increasing recycling, and ensuring proper management of waste and petroleum products at facilities in ways that prevent releases.

Objective 3.2: Restore Land
By 2008, control the risks to human health and the environment by mitigating the impact of accidental or intentional releases and by cleaning up and restoring contaminated sites or properties to appropriate levels.

Objective 3.3: Enhance Science and Research
Through 2008, provide and apply sound science for protecting and restoring land by conducting leading-edge research and developing a better understanding and characterization of environmental outcomes under Goal 3.

GOAL 4. HEALTHY COMMUNITIES AND ECOSYSTEMS: Protect, sustain, or restore the health of people, communities, and ecosystems using integrated and comprehensive approaches and partnerships.

Objective 4.1 Chemical, Organism, and Pesticide risks
Prevent and reduce pesticide, chemical, and genetically engineered biological organism risks to humans, communities, and ecosystems.

Objective 4.2 Communities
Sustain, clean up, and restore communities and the ecological systems that support them.

Objective 4.3 Ecosystems
Protect, sustain, and restore the health of natural habitats and ecosystems.

Objective 4.4 Enhance Science and Research
Through 2008, provide a sound scientific foundation for EPA's goal of protecting, sustaining, and restoring the health of people, communities, and ecosystems by conducting leading-edge research and developing a better understanding and characterization of environmental outcomes under Goal 4.

GOAL 5 COMPLIANCE AND ENVIRONMENTAL STEWARDSHIP: Compliance and Environmental Stewardship: Improve environmental performance through compliance with environmental requirements, preventing pollution, and promoting environmental stewardship. Protect human health and the environment by encouraging innovation and providing incentives for governments, businesses, and the public that promote environmental stewardship.

Objective 5.1: Improve Compliance
By 2008, maximize compliance to protect human health and the environment through compliance assistance, compliance incentives, and enforcement by achieving a 5 percent

increase in the pounds of pollution reduced, treated, or eliminated, and achieving a 5 percent increase in the number of regulated entities making improvements in environmental management practices.

Objective 5.2: Improve Environmental Performance Through Pollution Prevention and Innovation
By 2008, improve environmental protection and enhance natural resource conservation on the part of government, business, and the public through the adoption of pollution prevention and sustainable practices that include the design of products and manufacturing processes that generate less pollution, the reduction of regulatory barriers, and the adoption of results-based, innovative, and multimedia approaches.

Objective 5.3: Build Tribal Capacity
Through 2008, assist all federally recognized Tribes in assessing the condition of their environment, help in building their capacity to implement environmental programs where needed to improve Tribal health and environments, and implement programs in Indian Country where needed to address environmental issues.

Objective 5.4: Enhance Science and Research
Through 2008, strengthen the scientific evidence and research supporting environmental policies and decisions on compliance, pollution prevention, and environmental stewardship.

During the coming years, the EMAP project within FEB will delve more deeply into the specific performance goals and performance measurements within each of the broad Agency goals, evaluate the monitoring and assessment requirement to determine if the goals and measures are being achieved. We will then look across the monitoring and assessment needs to determine the survey design(s) and indicators necessary and present a modified monitoring and assessment approach for the Agencies consideration.

FEB Quality Assurance Statement for Focus Area II: No environmental data will be collected under this area. We consider this activity a Category 3 effort for demonstrating the proof of concept of potential efficiencies in collaborative monitoring across the Agency.

III. Analysis of Existing and Future Survey Data

A very important part of the activity over the next four years will be the continued analysis of data collected throughout the 17 years of EMAP as well as analysis of data yet to be collected in the OW national surveys. All of the evaluations and analyses described are suitable for submission for publication in the peer-reviewed literature and will contribute to improved future monitoring and provide insights into aquatic ecology on scales infrequently evaluated.

The analyses planned fall into five major categories:

1. Individual Indicators
2. Associations Among Indicators
3. Spatially Explicit Modeling
4. Change and Trend Detection, and
5. Aquatic Ecology Insights

Individual Indicators

The individual Indicators used in our monitoring and assessment efforts are the foundation of any assessment. For our purposes here, an Indicator is any measure, metric, index or model output that is a primary reporting tool in the OW national assessments. It is critical that we use the data in hand to evaluate a number of dimensions of these indicators both to extract and disseminate the information and also to improve indicators used in the national surveys.

General categories of questions that will be addressed include:

- Is the sampling sufficient to capture the information of interest?
- What is the extent of within index period variability and how broad an index period can be tolerated?
- What are the natural drivers for each of the chemical, physical and biological indicators that need to be captured and taken into account in creating an index?
- Which of the indices and measurements still have a disturbance/impairment/stressor signal embedded within them at the reference sites? How do we account for or eliminate it?
- Have we or can we outline a specific process for developing and testing an indicator that can be repeated by States and Tribes and used across the country?
- What additional indicators of anthropogenic stressors are needed to provide an adequate suite of “stressor” indicators for national surveys?
- Habitat indicators are of increasing importance. Do we have an overall index for habitat quality and indices for each dimension of habitat condition?
- Invasive species are increasingly implicated in deterioration of aquatic systems. Have measurements of these proven useful? Is an overall invasive species index feasible and useful? What are the regional patterns in invasive species distributions that are emerging from past studies?
- What are the spatial and temporal variations in each indicator and are they of sufficient magnitude to limit indicator utility for status and trends?
- What are the most effective approaches for defining reference conditions? Are there alternatives to reference sites that are practical?

- How can we blend the concepts embedded within the Tiered Aquatic Life Framework (TALU) and Bio-Condition Gradient (BCG) developed for the OW Health and Ecological Criteria Division with the national assessments?
- What are the regional patterns for each of the indicators used over the past 15 years?

Specific issues that will be explored and submitted for publication:

1. Evaluate the sampling effort needed to collect all fish species expected throughout rivers and streams within a region? What is the added cost in time and distance to capture rare species?

2. Evaluate Jaccard Coefficient scores for increasing sampling effort (distance) in large rivers and in wadeable streams to determine sampling adequacy based on the presence or absence of species in separate collections.

3. Refine O/E modeling (Observed versus Expected modeling - aka predictive modeling in some corners of the indicator literature) and multimetric indices for fish, benthos and periphyton in different regions of the country.

4. Can a combination of fish, benthos, and periphyton metrics produce a multimetric index that does a better job at describing biotic integrity or ecological condition, or improve the capability to diagnose possible causes of impairment?

5. Evaluate O/E modeling. What are the returns in model performance with increasing regionalization of the models?

6. Use national WSA (and future lake) nutrient survey data to refine existing nutrient criteria. Can the national surveys improve the regional and waterbody specific coverage for nutrient critieria?

7. Demonstrate the use of the Relative Bed Stability Index for developing Bedded Sediment Criteria in the States.

8. Finalize a quantitative physical habitat quality index and compare to the performance of existing indices.

Indicator Associations

One of the critical functions of the national surveys is to describe the relative ranking of the stressors that were included in the survey. This aspect of the surveys is an important one for policy and management decisions as well as evaluation of progress. We have accomplished this via ranking stressors based on their relative extent (i.e., how widespread is poor condition for that stressor indicator) and relative risk (what is the likelihood of finding poor biotic quality when scores for the stressor are poor compared with finding poor biotic quality when scores for the stressor are good). To date however, little time has been spent exploring the details of the associations and patterns in associations among the indicators. These fall into two categories of analysis:

- Associations Among Instream Indicators (e.g., benthos and excess fine sediments)
- Associations Between Instream Indicators and Landscape as Well as Indicators of Watershed Quality (e.g., association between landcover and nutrients)

Instream associations will be examined both to improve the metric selection for the biotic indices as well as to evaluate which instream stresses appear to have the greatest impact on biota and how those impacts vary regionally.

A very significant interest is emerging for the second type of association – associations between instream indicators and landscape/watershed indicators. Part of this interest is related to the next topic (i.e., spatially explicit estimation) and part of the interest is in getting closer to the human activities that result in instream changes. For example, it is import to know that in particular types of streams increases in nutrients result in aggressive algal blooms and or changes in proportion of benthos that are Ephemeroptera + Plecoptera + Trichoptera (EPT). But it may be of more interest from a management perspective to know that the increase nutrients result from when a watershed exceeds a certain proportion of the watershed in row crops or logged areas. We are particularly interested in when the landscape/watershed indicators show a direct linkage to changes in the instream biota and when the impact is mediated by some intermediate steps such as a change in nutrients which in turn impact the biota. The issue of proximal versus distal "causes" of changes in instream biota is of importance from a management and policy perspective.

An important area of exploration within "Indicator Associations" analysis is the improvement on our approach to relative ranking of stressors. As mentioned above, we currently recommend presenting both the relative extent estimates for each stressor and the relative risk estimates. Both, taken in concert provide an assessment of relative ranking of each stressor. The human health field also faces this challenge and employs a measure, "population attributable risk" that is less widely know as the popular relative risk. It employs both estimates in an attempt to derive a single number for evaluating stressors. We will explore the application of this tool for aquatic assessments. We are also exploring improved methods for ranking the relative severities of correlated stressors.

Spatially explicit estimation and modeling (aka small area estimation)
The strength of the EMAP approach has been that it provides a rigorous and reliable method of inferring conditions across a population from the sample of that population. In addition, an estimate of the uncertainty is also available. The challenge, from a few people's perspectives, is that this output is useful from a broad policy perspective and may be limited in its application of exactly where the poor conditions are to be found. So we know what proportion of the stream length in a particular region is in poor condition but do not know where those poor segments are located. The category of spatially explicit estimation is intended to deal with this problem.

In its most basic form, this modeling uses data for which we have complete coverage (e.g., landuse data), a transfer function based on modeling relationships for existing sites (e.g., nutrient concentrations for EMAP sampling locations) and applies the model to sites for which no sampling has occurred. This is essentially the approach used by the USGS in the SPARROW model and other landscape models in use for different regions of the country. The EMAP studies provide rich data sets across the country for developing models of these types. The models,

when developed, have the potential to provide the ability to estimate the probability of ranges of quality for indicators of interest. At FEB, we developed a very simple model of this type predicting probability of high phosphorus concentrations in western streams.

Our primary focus during this final phase of EMAP will be on developing spatially explicit models for stream biota, nutrients and certain dimensions of habitat. We have one post doctoral fellow whose primary focus is the spatially explicit modeling for stream biota.

Change and Trend Detection

The design and indicator tools developed in EMAP were intended to provide the Agency, States and Tribes to monitor both status (current condition) and trends. By necessity, all of the EMAP and R-EMAP studies to date have produced estimates of status for the indicators of interest. After 17 years of studies in different parts of the country, sufficient temporal data, variation in study designs and indictors for a rigorous examination of the challenges facing Office of Water in detecting trends over time should exist.

Trends can be thought of in several ways. OW plans to conduct surveys for each resource type with multiple years in between. Thus trend detection could be thought of as lining up status estimates over long periods of time and looking for directional changes in the proportion of the resource in each condition class (e.g., good/fair/poor). Rather than trends in categories of condition, one can also envision lining up cumulative distribution curves for each of the status estimates and examining changes or patterns in shapes of the distributions. A third way of envisioning trend analysis is to have sufficient number of sites that are revisited over time, examine the trends at each site and then examine patterns in the proportion of the resource with increasing trends, decreasing trends and no change. Each approach has appealing traits as well as its set of challenges.

Our analyses will take several forms.

1. Variance components and power estimation – Sufficient data exist for some of our indicators to tease out the components of variance that impact status estimation and trend detection. We will examine the variance components and then determine the power of each indicator to detect trends of various magnitudes.
2. Slight variations in survey designs (e.g., frame, spatial coverage, stratification) have the possibility of significantly impairing our ability to detect trends. We have multiple data sets across the country that will allow us to examine the impact of these design variations on trend detection.
3. Similarly, variations in our "response" designs for indicators (e.g., indicator, field protocols, reference-condition specifications, assessment models) have the possibility of hampering trend detection. Again, sufficient variation exists across studies conducted over the past 17 years to evaluate the significance of these issues for trend detection.

Aquatic Ecology Insights

We have spent very little time during the 17 years of EMAP examining the rich data sets for insights into aquatic ecology. Surveys of lakes, streams, rivers and wetlands over the broad geographic expanse of the United States surely hold information about how aquatic systems in the US differ, are similar and how they function. These insights will be critical as ecologists help shape our future policies to maintain and restore these systems.

While our highest priorities will likely focus on the previous four categories of research, we believe it is important to expend some efforts in this area and to invite others from academic institutions to make use of the data themselves.

We can examine several simple things that blend with work above:

1. Describe and understand the national patterns in the distribution and abundance of aquatic biota and the natural drivers and human disturbances that impact them. Management and restoration of biodiversity depends upon an understanding of its regional patterns, expectations, and controlling factors along the causal chain from landscape to instream controls. This information has not been developed at the national scale.

2. Compare *alpha*- (reach) and *gamma*- (ecoregion) scale fish taxa richness among ecoregions in the U.S., and their relationship. This is an unprecedented opportunity to advance ecological knowledge and theory linking local and continental scales.

3. Comparison of reach, basin, and ecoregional scale diversity in physical habitat structure, and its relationship to geology, climate, potential natural vegetation and the intensity of human disturbances. There is virtually nothing like this published, primarily because consistent field methods have not been broadly applied.

Quality Assurance Statement for Focus Area III: No environmental data will be collected while conducting research in this Focus area. We believe this work is a Category 3. All data used have been collected under previous EMAP QAPPs for the individual demonstration projects (e.g., MAIA, EMAP-West, Northeast Lakes, etc) or OW QAPPs (e.g., WSA or National Lakes Survey). FEB will evaluate with the WED QA Officer the application of QA requirements for modeling and how they might apply to research that is exclusively data analysis.

IV. Monitoring of Ecological Services

The EPA Ecological Research Program (ERP) has been the planning home for EMAP since EMAP's inception. The ERP is starting a new direction within which some of the final EMAP research will be housed. The general framework for this new research direction is described below.

New ERP Direction

The U.S. Environmental Protection Agency is responsible for protecting human health and safeguarding the natural environment. The EPA is one of only a few federal organizations that operate as both a regulatory and a science agency. Its regulatory activities are driven by the nation's environmental laws, which also authorize its research efforts. This research is housed primarily in the Office of Research and Development (ORD) which has established eight integrated research programs to address human health and ecology, including the Ecological Research Program (ERP). ORD's research, organized around the principles of risk assessment and risk management, provides the critical science that forms the basis of environmental decision-making.

The Ecological Research Program Strategy outlines new strategic directions for ORD's Ecological Research Program that focuses on the science needed to advance understanding of ecosystem services, those functions of an ecosystem from which people benefit such as clean air and water, flood control, pollination, and soil enrichment. Because of the importance of ecosystem services to human health and well being and the record rate of loss of ecosystem services over the last decade, the strategy places greater emphasis on ecosystem services than previous research strategies.

For more than a decade, the ERP within ORD has focused on ecosystem monitoring, diagnostics/modeling, and restoration, providing a strong research foundation for identifying environmental problems. The program has successfully advanced the development and implementation of statistically defensible, scientifically rigorous, and policy relevant monitoring designs. The research has contributed significantly to improving the ways in which communities, states, and other partners monitor, diagnose, model, and restore ecosystems.

With the new strategy, ERP is applying its unique research capabilities and knowledge, based on its past monitoring research, to improving understanding of ecosystem services. The previous multi-year research plans (MYP) included ecosystems services as a long-term goal. The new MYP under development will make ecosystem services a main strategic focus. This new strategic emphasis on ecosystem services builds on past scientific successes and will provide the methods, models, and tools, for others to assess the cost and benefits of using ecosystem services.

Rationale for Focus on Ecosystem Services

The scientific community as a whole has recognized the importance of improved understanding of ecosystem services and the need to better identify, quantify and assess these services so that environmental decision makers can evaluate the trade-offs to human health with their use. The Board of Scientific Counselors has identified this gap in scientific information as well in its June 2005 report

For ERP, this change is being driven by scientific success, a changing budgetary environment, the considered advice of peer reviewers, and the Millennium Ecosystem Assessment (MEA) for the United Nations (http://www.maweb.org/en/index.aspx).More than 1300 scientists were involved in the production of the MEA document, resulting in one of the most comprehensive reports to date on ecosystem services. Many of the document's suggestions and concepts have been adopted for ERP's new strategy, including its depiction of the complex relationship that exists between ecosystem services and human well-being, illustrated in Figure 1, below. One particular finding that resonated with the ORD research team states:

> *"Even today's technology and knowledge can reduce considerably the human impact on ecosystems. They are unlikely to be deployed fully, however, until ecosystem services cease to be perceived as free and limitless, and their full value is taken into account."*

Consistent with this idea of economics and ecosystem impacts, the EPA Administrator is accelerating the pace of environmental protection while maintaining our nation's economic competitiveness. The entire Agency therefore must strive to meet the challenge of illustrating to the public the full value of ecosystems and the services they provide toward human well-being. The nation's health, security, economic potential, and much of its culture are directly and intimately tied to ecosystem characteristics and quality. Even so, policy and management decisions have failed to take these relationships into account. As a result, it is incumbent upon ERP to safeguard the natural environment by helping to establish a greater understanding of the value of ecosystem services and their interdependent relationship to human activities and well-being. That focus is the primary concept driving the program's new strategy.

Within the definition, there are multiple categories used to characterize and classify ecosystem services. One helpful framework was a categorization scheme adopted by the Millennium Ecosystem Assessment; which has four classes of services: supporting, provisioning, regulating and cultural (Figure 1). These categories help characterize the array of values that ecosystems provide us. In general, *ecosystem services* are things or characteristics, and include resources such as surface water, oceans, vegetation types and species. The *ecosystem processes* and *functions* creating these services are the chemical, physical and biological interactions among ecosystem components. Ecosystem services are sometimes distinguished from functions or processes as a matter of *context*. Thus what may be a service in one case is a function or process in another, where the process is an intermediate input to the final ecosystem service. For proper accounting, services are identified in relationship to particular goals, problems, regions or decisions that are of concern.

The vision for the ERP is to transform the way we understand and respond to environmental issues by making clear the ways in which our choices affect the type, quality, and magnitude of the services we receive from ecosystems -- such as clean air, clean water, productive soils, and generation of food and fiber.

The starting point for this vision is to conduct fundamental research on the structure and function of ecosystems and the services they provide. While noble, this effort alone is insufficient in meeting the Agency challenge: To advance a more comprehensive theory and practice for quantifying ecosystem services, their value and their relationship to human well being, for consistent incorporation into environmental decision making.

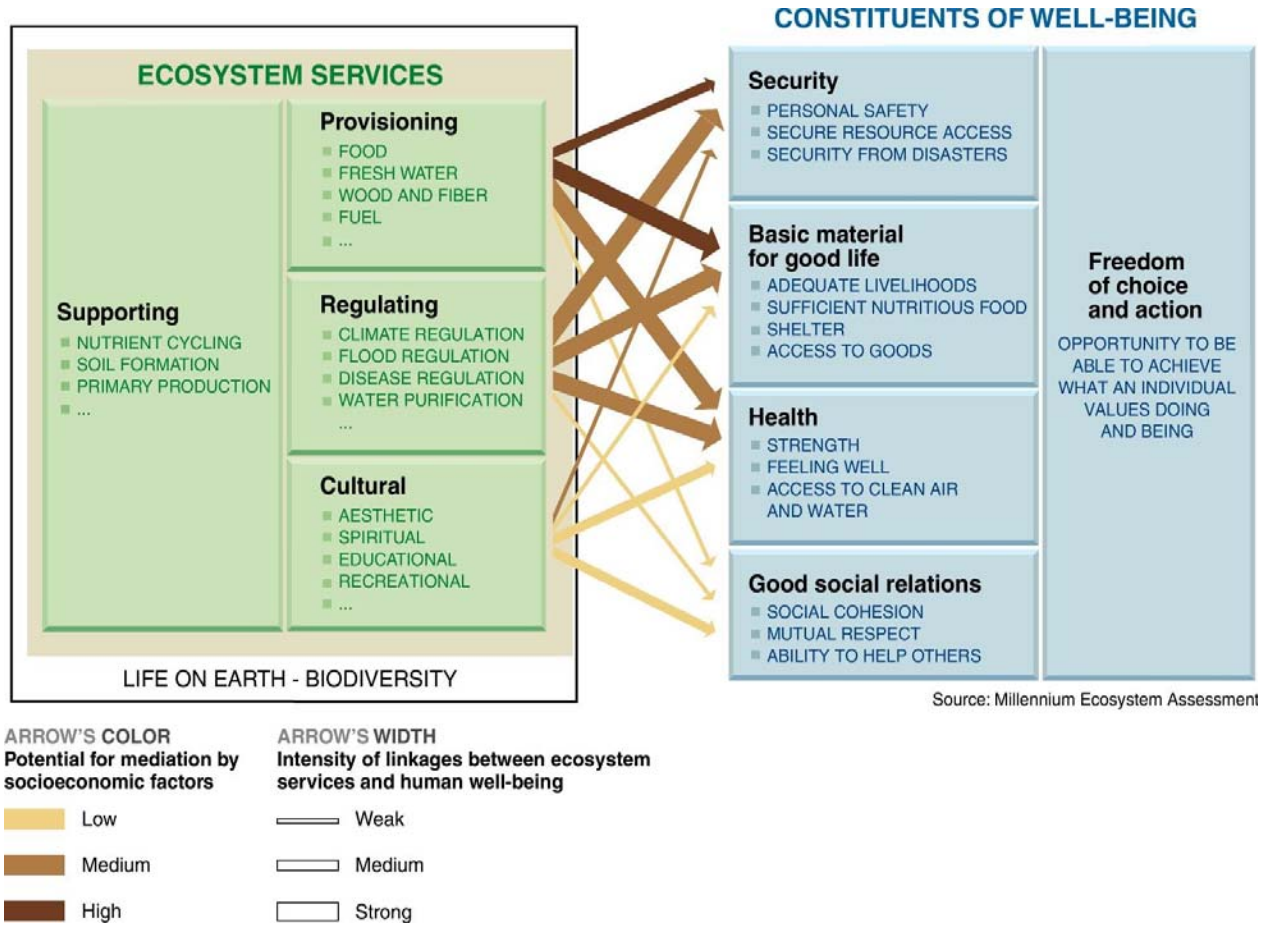

Figure 1. Relationships among ecosystem services and human well-being

As such, it is ERP's mission to conduct innovative ecological research that provides the information and methods needed by decision makers to assess the benefits of ecosystem services to human well-being, and to shape policy and management actions at multiple spatial and temporal scales.

On a broader scale, ERP's goal is to have decision-makers regularly apply information and methods developed by ORD's Ecological Research Program to make proactive policy and management decisions that ensure human well-being by conserving and enhancing ecosystem services over time and at multiple scales. In other words, the outcome of the research must be the use of the information by those who make the decisions.

ERP's vision, mission, and goal are part of a coordinated effort throughout EPA to adhere to the Agency mission of protecting human health and the environment.

The logic model (Figure 2) provides a complete overview of the program strategy. The first column represents the human and financial resources of the program, the second column

describes the major categories of research activities, and the third column identifies a portfolio of research products and outputs. These outputs provide the core ecological information and methods needed by decision makers to assess the benefits of ecosystem services to human well-being, and to identify strategic management options needed to secure the integrity and productivity of our ecological systems over space and time.

The outputs for the ORD Ecosystem Research Plan, in greater detail, are as follows:

Measures and dynamic maps of ecosystem services - Spatial representations of ecosystem services are central to communication, outreach, planning, assessment, and resource management. We are developing biophysical measures for a suite of ecosystem services (e.g., nutrient uptake, recharge rate, cooling, and flood mitigation) that can be portrayed in maps, either individually or as "service bundles" associated with specific locations in the landscape. These measures will be selected for their role as "final" services valued by society, or because they are a critical intermediate step in maintaining these valued services. Where appropriate, these measures will also identify the quality of the service provided. In addition, these maps will be dynamic so that they can reflect changes in the distribution of service measures in response to alternative scenarios for stressors and management options.

Predictive models relating to the response of stressors - These models are the foundation of our ability to forecast change and to proactively assess how ecosystem functions and services are likely to respond to natural and human stressors. We will build on ERP's extensive background in a variety of forecasting and modeling techniques -- including statistical models, landscape ecology models, process models, ecological threshold models, and hybrid approaches -- to develop and test new ways to forecast how ecosystem services will change over space and time, and at multiple scales of analysis.

Management Options - We will use predictive tools, singly and in complex arrays, to develop alternative future scenarios. These scenarios will be developed to reflect stakeholder needs as well as to illuminate the range in trajectories for ecosystem services associated with different management strategies. In particular, we will apply principles of landscape ecology and optimization to explore and create new ways to restore, retain, and enhance ecosystem services under scenarios of increasing human populations and intensified resource use.

Decision Support Platform - ORD is developing a decision support platform to serve as a focal point for enabling managers and decision-makers to explore how various policies affect the likely distribution of ecosystem services, and human health and well-being outcomes, both now and in the future. This platform will be designed to support the varying information needs of different clients, including the public, the scientific community, industry, regulators, economists, financial investors, and elected representatives. The overall goals of the decision support platform are to enable decision-makers to evaluate trade-offs among alternative resource management strategies, to avoid unintended consequences of their actions, and to better manage for sustained ecosystem services and human health and well-being.

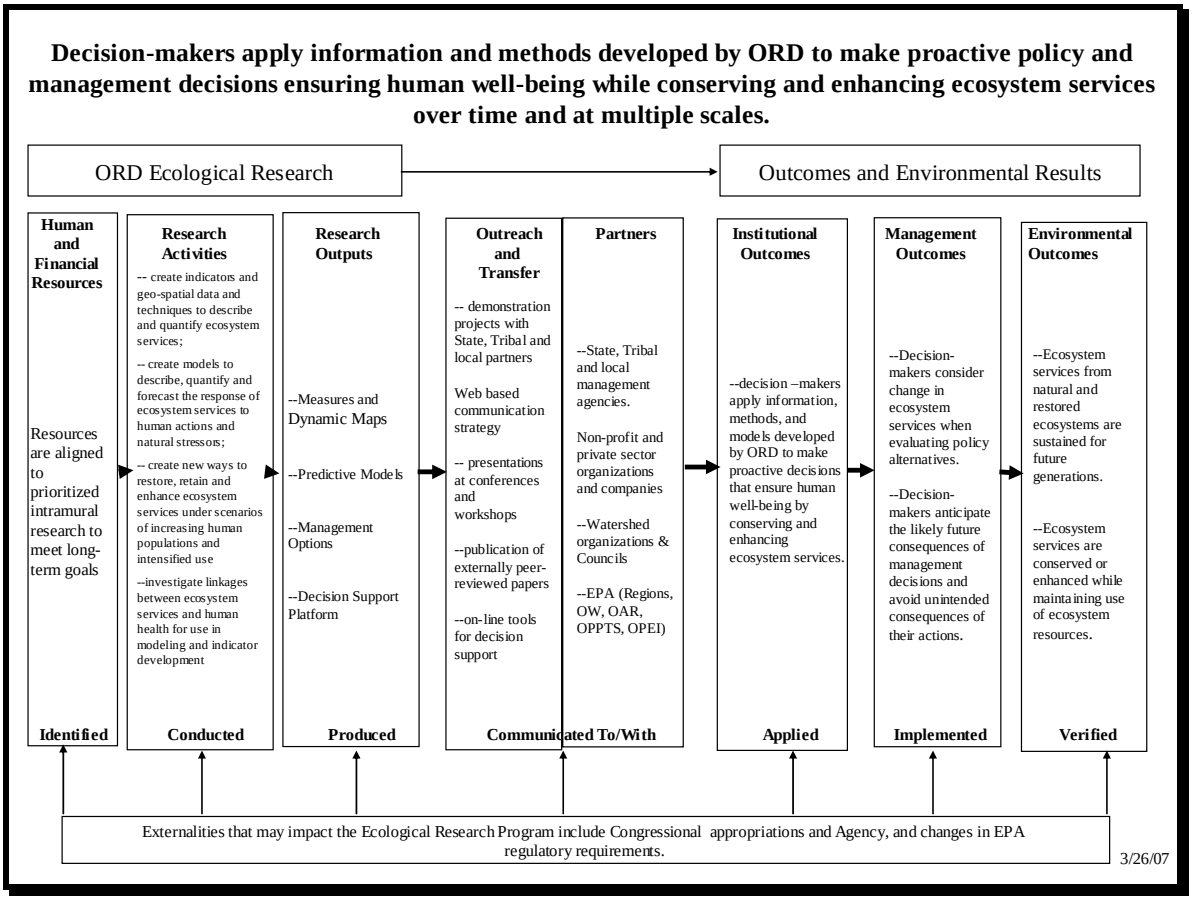

Figure 2. Program Logic Model

FEB MARA Research on Indicators of Ecosystem Services:

The shift in the ERP brings two new perspectives to ORD's research and eventually to EPA's approach to protecting human health and the environment. The first is a focus on ecosystem services as the endpoints of concern. This potentially differs from the current focus to which ORD has led program offices via EMAP, i.e., primarily an endpoint of ecological condition. The second new perspective is the use of and reliance on tools/models for forecasting the likely impact of human choices on the endpoints of ecological services. These tools will allow the Agency to evaluate various policy and management scenarios and their impact on the services provided by ecosystems. When the Agency adopts these perspectives, it will quickly be faced with the question: "How do we know if our choices achieved the desired results for sustaining ecosystem services?" In other words, the Agency will need indicators of ecosystem services quality that can be measured and monitored over time at a national and regional scale.

Research at FEB offers an opportunity to begin blending the ecosystem service perspective of the ERP with the current perspective on ecological condition and ranking of stressors with the preparation for the OW national survey and assessment of wetlands in 2011. The fundamental objectives of this wetlands component of the FEB research are to provide the cutting-edge science necessary to:

1) Identify, characterize, and assess the level of wetland services that contribute to human well-being at multiple spatial and temporal scales.

2) Produce the indicators needed to monitor and assess the quality of wetland ecosystem services at the national and regional scale.

3) Blend the indicators of monitoring wetland ecosystem services with the indicators for monitoring wetland condition and work to implement them in the OW national wetland survey in 2011.

The Millennium Ecosystem Assessment produced a compelling synthesis of the global value of wetland ecosystem services to human well-being (Fig. 3). Wetlands deliver a wide range of ecosystem services (e.g., fish and fiber production, water supply support, water purification, climate regulation, flood regulation, coastal protection, recreational opportunities, and tourism) that contribute to human well-being. Although the most recent National Wetlands Inventory Status and Trends report showed a net gain in wetland acreage between 1998 and 2004, significant losses occurred in specific wetland types (e.g., 61% of freshwater wetland losses were due to urban and rural development). As human population continues to sprawl across coastal environments, wetlands worldwide are projected to suffer continued loss and degradation, thus reducing the capacity of wetlands to provide valued ecosystem services that contribute to human well-being. Rapid development and population growth concurrently increase the demand for many of these services (e.g., fish production, water purification, and flood and storm protection). Major policy decisions in the next decade must address trade-offs among current and future uses of wetland resources. Particularly important trade-offs involve those between agricultural production and safe water supplies; land use and biologically diverse terrestrial ecosystems; water use and biologically diverse and productive aquatic ecosystems; current water use for irrigation and future agricultural production; and coastal land use and human safety during floods or storm surges. Such decisions must also consider the full range of benefits and values to human well-being, which are provided by different wetland ecosystem services.

Many uncertainties and research needs have been identified as a result of conducting the Millennium Ecosystem Assessment. These include characterizing ecosystem services, linking ecosystem condition and function to services and human well-being, predicting the effects of changes in ecosystem services on human well-being, and improving the identification, quantification, and communication of uncertainty. Adapting the global research needs presented by Carpenter and others to wetland ecosystem services results in the following research questions:

- What are the current spatial extent and condition of wetlands?
- What are the functions and processes of wetlands?
- How are wetland condition and functions related to ecosystem services?
- Can wetland services be aggregated across the landscape at various spatial scales, while retaining important ecosystem heterogeneity and the ability to detect change?
- How can wetland services be linked to the maintenance and support of human well-being?

- How do changes in wetland functions and services affect future consequences for human well-being?

The MARA project in FEB will initially develop a research strategy for assessing ecosystem services of wetlands at regional scales and will work to blend these indicators with indicators of wetland condition for implementation in the OW national wetland survey in 2011. For other freshwater ecosystem types, the MARA project within FEB will evaluate existing indicators of

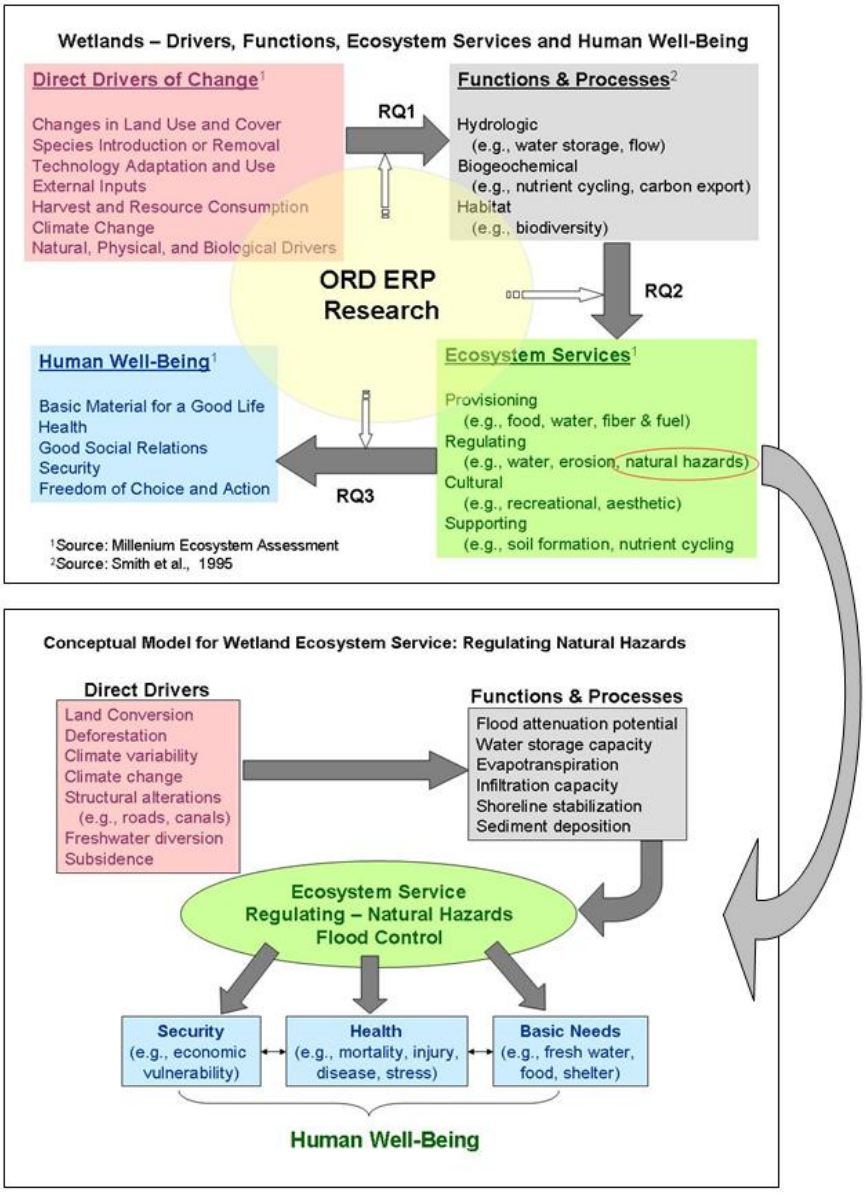

Figure 3. Conceptual model for wetlands showing the relationship between drivers, functions, ecosystem services, and human well-being

condition and stress and determine the extent to which they are applicable for assessing the quality of ecosystem services provided by rivers and streams as well as lakes and reservoirs. For indicators that are appropriate, FEB will promote the use of these indicators in OW national surveys which will result in a demonstration for the ERP of how to expand the site specific research and results to national scales.

Quality Assurance Statement for Focus Area IV: No new environmental data will be collected in this area of Focus. We consider this a Category 3 activity as it will be developing a proof of concept based on existing data. The collection of all data used has been covered by EMAP QAPPs or OW QAPPs.

V. Annual Performance Measures

The annual performance measures (APM) listed below are currently identified within the ORD Ecological Research Multi-year Plan. As each of the four sections of MARA and the ORD ERP mature, additional APMs will be added.

It should also be noted that the MARA research plan is the guiding plan for our overall work, there will be subcomponents that require more detailed plans to be developed as part of our efforts. Two examples of this exist now and are listed below for wetlands and monitoring. The wetlands and monitoring APMs below are ORD wide APMs with WED identified as the lead yet need to be coordinated across ORD. So laying out a full blown plan for them at this time is inconsistent with coordinating across ORD and is a key element of what we will accomplish within MARA.

APM #450 (FY08): Compile EMAP West Dataset to report on Western stream condition

APM #560 (FY08): Peer reviewed wetlands research/implementation plan including expectations of demonstration projects and nitrogen team

APM #341 (FY09): Report on the state of the science on linkages between wetland functions and ecosystem services at multiple scales

APM #xxx (FY10): Peer reviewed research plan for monitoring ecosystem services.

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VII. List of Acronyms

Acronym	Explanation
303(d)	Section of Clean Water Act requiring listing of impaired waters
305(b)	Section of Clean Water Act requiring reporting of condition of all waters
BCG	Biological Condition Gradient
CDFs	Cumulative Distribution Functions
CWA	Clean Water Act
EMAP	Environmental Monitoring and Assessment Program
EPA	Environmental Protection Agency
ERP	Ecological Research Plan
FEB	Freshwater Ecology Branch
GAO	General Accounting Office
IM	Information Management
MAIA	Mid-Atlantic Integrated Assessment
MARA	Methods for Aquatic Resource Assessment
MEA	Millennium Ecosystem Assessment
NCCA	National Coastal Condition Assessment
NRC	National Research Council
ORD	Office of Research and Development
OW	Office of Water
QA	Quality Assurance
QAPP	Quality Assurance Project Plan
QC	Quality Control
REMAP	Regional Environmental Monitoring and Assessment Program
SAB	Science Advisory Board
STAR	Science to Achieve Results – ORD Grants Program
STORET	Storage and Retrieval system for state data operated by OW
TALU	Tiered Aquatic Life Use
TM	Thematic Mapper
USDA	United States Department of Agriculture
USDOI	United States Department of the Interior
WQX	Water Quality Exchange
WSA	Wadeable Streams Assessment