2.0 INTRODUCTION TO THE DELAWARE RIVER BASIN PILOT STUDY

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2.1 Objectives of the Study

The past 20 years of environmental research have shown that the environment is not made up of discrete components acting independently, but rather it is a mosaic of complex relationships among air, land, water, living resources, and human activities. The data collection and analytical capabilities of current ecosystem assessment and monitoring programs are insufficient to measure how multiple components of the ecosystem interact. Since the mid-1990s, resource managers have been called upon to adopt "ecosystem management" practices for land stewardship, but seldom have had the multicomponent, ecosystem-level information needed to achieve this goal. Much of the information currently being collected is fragmentary and incompatible because it is collected through programs designed and conducted at different scales or for different objectives, because data confidentiality issues can limit data sharing and field collaboration, and because protocols for sampling and data management are inconsistent. Similarly, much of the information currently collected cannot be used to answer regional ecosystem-level questions because the scale of process-based research is incompatible with the larger scales of typical monitoring and assessment. Science capabilities must be expanded to increase our capability for drawing connections between processes taking place at intensively studied research areas and trends in the resources typically monitored at larger scales (Gosz and Murdoch 1999).

To be effective, ecosystem management, environmental assessment, and monitoring of environmental health must take into account the mosaic of complex relations among air, land, water, living resources, and human activities, making connections between processes occurring at multiple spatial and temporal scales. Narrowly targeted monitoring programs based mainly on observations and empirical analysis are poorly suited to developing an understanding of these complex relationships.

One suggested solution to the problem of multiple, nonintegrated monitoring programs is to create a single Federal agency in charge of monitoring the Nation's natural resources. This scenario would ensure integration but would require significant resources to establish and could not completely replace the issue-specific monitoring required to meet current agency missions. This scenario also fails to address the scientific and analytical capability required to take full advantage of the myriad data types that must be collected for a full understanding of ecosystem-level processes at multiple scales. An alternative proposal endorsed by the Committee on Environmental and Natural Resources in 1997 (Committee on Environment and Natural Resources 1997) was to develop a concept for "virtual" integration in which existing monitoring programs would fill specific niches in a monitoring hierarchy, the sum of which could be used for tracking environmental problems in a more holistic manner than currently possible (CENR 1997). By supplementing and adjusting existing monitoring and research strategies, those programs could continue to meet specific agency missions while also contributing to a national multiscale, multiresource tracking system, and they could do so for the least additional expense relative to the other scenarios being proposed. A test of this latter concept is the subject of this report. In developing this concept, we focused on key issues that express themselves at a larger scale and demand integration among researchers not only for understanding the causes and consequences of the ecosystem processes taking place, but also for monitoring the status and trends of those processes at the landscape scale.

During the first 4 years of the new century, the U.S. Geologic Survey (USGS), the U.S. Forest Service (USFS), the National Park Service (NPS), and the National Aeronautics and Space Administration (NASA) tested strategies for multiagency collaboration by establishing a Collaborative Environmental Monitoring and Research Initiative (CEMRI) in the Delaware River Basin (DRB). The goal of the initiative was to test potential collaborative strategies for multiagency monitoring and research networks that could be applied throughout the United States. The Delaware CEMRI followed a 1-year test of integrating regional probabilistic survey programs in eastern Oregon by the USFS and the USGS (Goebel et al. 1998). The Delaware CEMRI expanded on the results of that study by testing a framework for integrating environmental data collected across a range of temporal and spatial scales, from process-level research sites such as the Hubbard Brook Experimental Watershed in New Hampshire to regional surveys and remote sensing programs such as those tested in the Oregon demonstration project (Goebel et al. 1998).

The objectives of this report are a) to describe the applicability of existing monitoring programs, monitoring data, and scientific analytical capability to assess five environmental issues of critical importance in the DRB and b) to describe a proposed network design based on those assessments for the collaborative monitoring and research effort. These descriptions clarify gaps in existing data and highlight data comparability issues that currently limit our ability to gather appropriate information for effective detection and monitoring of cross-resource environmental trends at appropriate spatial scales. The report also recommends actions that could be taken in existing programs to improve data comparability.

Further information on CEMRI can be obtained at http://www.nrs.fs.fed.us/pubs/.

2.2 The Framework Concept behind CEMRI

In 1995 an interagency working group of scientists and program managers was established by the National Science and Technology Council's Committee on Environment and Natural Resources (CENR) and directed to "recommend a framework for an integrated monitoring and research network that allows evaluation of the Nation's environmental resources (e.g. air, water, soil, plants, animals, and ecosystems)." The conceptual framework articulated by the working group (hereafter called the "framework") was designed to address limitations and capitalize on the strengths of existing monitoring programs to build a national ecosystem monitoring system based on collaboration among Federal, State, local, and nongovernment programs (Committee on Environment and Natural Resources 1997).

The premise of the framework is that an effective national environmental monitoring strategy can be assembled largely by creating a conceptual structure within which independent monitoring and research programs can take advantage of their complementary activities to address environmental questions across multiple scales and multiple resources (Fig. 2.1). In general, the committee concluded that existing programs fit into three broad categories of spatial and temporal monitoring:

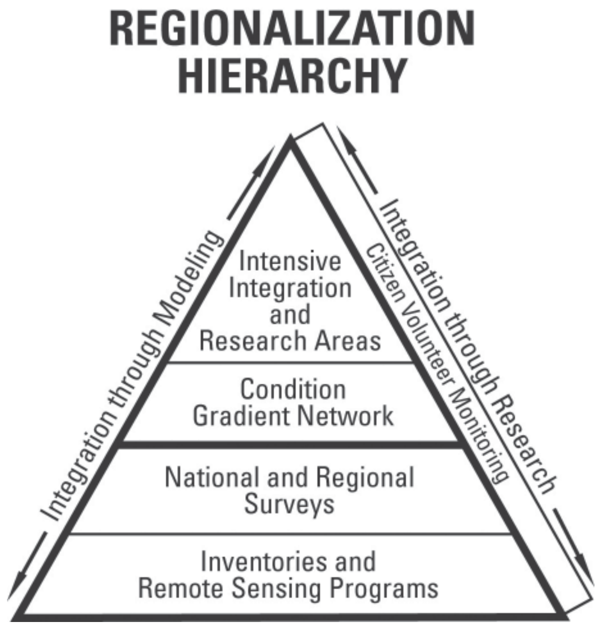

Figure 2.1.—Conceptual framework for achieving the multiple goals of environmental monitoring and research. (Committee on Environment and Natural Resources 1997)

- Tier 1 - Frequent monitoring and indepth research on processes, cause and effect, and trends at a limited number of intensively monitored sites within relatively small areas; these sites are referred to in the CEMRI as intensive monitoring and research areas (IMRAs)
- Tier 2 - Infrequent multipoint ground monitoring (such as national and regional resource probability surveys) and inventories
- Tier 3 - Temporally and spatially continuous monitoring and analysis (such as satellite remote sensing, aerial photointerpretation, and mapped data developed from fixed site networks)

After the framework exercise was completed at CENR, a refinement to the second monitoring tier was proposed to differentiate two distinct methods of extrapolating process-level information to the regional scale. The proposed additional data-collection tier represents gradient networks of monitoring stations that are deliberately selected to represent a range of conditions for a specific environmental issue and that are monitored at a range of temporal intensities for parameters specific to that issue. The framework ultimately used for the CEMRI study is a conceptual structure for a systematic linkage of existing inventories and remote sensing with national and regional resource surveys, gradient-based studies, and whole-ecosystem, intensive monitoring and research sites, using modeling as a tool for integrating data across temporal and spatial scales. As a general guide for this integrated work, we developed specific goals for research and monitoring at each of the four tiers.

At Tier 1 IMRAs, the goal was to conduct process studies to define relationships among key ecosystem parameters and processes. For example, in the DRB we combined program resources to conduct collaborative, ecosystem-level research studies at common study sites to determine the effects of pest infestation on soil nitrogen (N) cycling rates, to relate rates of forest carbon (C) sequestration to factors such as forest type and soil nutrient capital, and to investigate the relationship of tree health to soil nutrient status. Also at this scale, an explicit goal of the project was to link measurements of terrestrial and aquatic ecosystems to develop better strategies for integrated monitoring at larger scales. Process studies such as these typically require detailed site-specific information that is too costly to collect over a broad region. Process research involves substantial investments of time and money, and the number of such research sites nationwide is therefore limited. However, to be relevant to environmental policy for a given region, the process-level understanding developed at these IMRAs must be extrapolated to the regional scale.

At Tier 2 (gradient study sites), the goal was to extrapolate the relationships from the Tier 1 process studies to the regional scale through regression of critical response variables against parameters that can be regionally mapped. In this tier, a number of monitoring stations representing the range of conditions for a given environmental issue are sampled with sufficient frequency or detail to use the combined data from all sites to correlate ecosystem response to a range of disturbances from a specific stressor. For example, an experimental manipulation at the IMRAs may determine that forest removal and development result in higher stream runoff, streambank erosion, and water quality decline. A gradient network of watersheds representing a range of deforestation and development could be sampled in Tier 2 to determine thresholds of fragmentation above which stream degradation occurs, and the regional extent of degradation could then be determined through mapping of forest fragmentation and development. The USGS and the USFS collaborated through CEMRI in establishing gradient networks for forest fragmentation and ecosystem calcium (Ca) depletion in the DRB. A final goal of work at Tier 2 was to conduct ground verification of remotely sensed parameters defined at Tier 4.

At Tier 3 (probabilistic regional surveys), the relationships from the Tier 1 process studies to the regional scale condition are extrapolated through random or stratified, probability-based surveys of environmental conditions or of responses related to a specific stressor. For example, research at the IMRAs may determine that tree species composition in a forest stand is an important driver of forest productivity. Using this relationship in conjunction with species composition data collected from ground surveys at Tier 3, we can estimate forest productivity at the regional scale. If a survey of soil nutrient status is also done, regional patterns of productivity (response) in relation to soil Ca depletion (stress) can also be mapped. These data can allow for the spatial identification of special cases where additional information may be needed to understand regional ecosystem processes.

At Tier 4 (spatially and temporally continuous remote sensing and mapping investigations), the primary objective was to develop spatially continuous information. Atmospheric N deposition, land use, and forest species distribution are examples of spatially continuous information that may help to define the regional extent of relationships described in Tiers 1, 2, and 3. Also, investigations at Tier 4 may be used to interpolate between survey points at Tier 3. Geostatistical techniques for interpolating tree species composition from ground survey points are an example of one such study. A final goal of investigations at Tier 4 was to develop methods to quantify indicators of interest for research studies at Tier 1. For example, through CEMRI we developed methods for quantifying forest fragmentation from remotely sensed imagery for small research areas that have extensive field observations (ground truth), and these findings will in turn be used to provide information for studies on the regional relationship between fragmentation and water quality.

This tiered approach to monitoring and assessment, using extensive inventories to link intensive sites with wall-to-wall measurements, has been adopted and modified by other national-scale monitoring efforts. For example, the North American Carbon Program (Wofsy and Harris 2002), used this approach for measuring and monitoring C stocks and fluxes in the Nation's forested ecosystems. The CEMRI application sought to integrate terrestrial and aquatic information for whole-ecosystem assessments.

In summary, intensive research studies at Tier 1 are used to define key ecosystem process relationships, and these relationships can be extended to the regional scale using ground-based gradient studies from Tier 2 and survey data collected at Tier 3. Information from Tier 4 can be used to interpolate between survey points, develop maps that help define the regional extent of relationships revealed at Tier 1, and develop methods for quantifying indicators of interest for study at both Tiers 1 and 2. Tier 2, the ground-based regional extrapolation tier, should be seen as a key link between the Tiers 1 and 3; this nested approach to our monitoring strategy allows us to span multiple spatial scales with confidence.

2.3 Unique Characteristics of the CEMRI Framework

To date, cross-tier linkages have been attempted by few programs because each program lacks the resources to provide a comprehensive approach, and robust methods for linking site-specific and regional data have not been fully developed. The multi-tier framework approach used collaboration among multiple programs to create the comprehensive, indepth, cross-resource monitoring impossible with a single program and yet required to understand complex environmental problems and thus make better informed policy decisions.

The framework concept also differs from other environmental monitoring and assessment programs in the following ways:

- The framework concept is not a new monitoring program; rather it is an organizing structure for conceptualizing how data from existing programs can be integrated through cross-agency collaboration. New funding would be used to fill gaps in existing programs, not to develop entirely new monitoring systems.
- It is not a single-issue or single-resource-driven monitoring scheme; rather, it calls for the development of collaborative strategies among existing monitoring programs to assess, evaluate, and forecast trends in the condition of whole ecosystems. It can, however, also be used to organize existing programs around a single issue in a scientifically rigorous manner.
- It provides a scientifically rigorous method for scaling ecosystem process information between single study sites and larger landscapes, and was the first such strategy to be tested explicitly in a pilot region.

The DRB study described here was the first attempt at using this framework approach.

2.4 Rationale for Selection of the Delaware River Basin as a Frame of Reference

The DRB in the Eastern United States was chosen as the framework's first pilot region because:

- The river basin hosts several existing agencies and programs that were willing to take on the integration challenge in designing and examining their monitoring strategies.
- The river basin-to-estuary landscape delineation was a logical conceptual unit for integrating environmental information on a regional scale because the water of the system serves as an integrated indicator of many environmental trends.
- The DRB is a relatively simple version of such a watershed system, with a single large river entering the estuary, as opposed to more complicated systems such as the Chesapeake Bay drainage where multiple rivers discharge freshwater into the bay ecosystem.

The primary focus of the CEMRI was not to complete a one-time comprehensive environmental assessment; rather, it used data collection and analyses targeted at specific environmental issues to illustrate the value of integrated monitoring among existing programs and to establish a scientifically rigorous long-term strategy for integrated monitoring in the DRB.

2.5 Collaborating Agencies

Lead Federal agencies on the DRB pilot included the U.S. Forest Service (USFS), the U.S. Geological Survey (USGS), and the National Park Service (NPS), with additional funding provided by the National Aeronautics and Space Administration (NASA). Explicit collaboration among these agencies allowed for planning data comparability, filling in data gaps, and integrating data among programs. The New York City Department of Environmental Protection also contributed to the CEMRI through their established collaborations with the USGS in the Delaware headwaters, the primary source of the New York City water supply.

2.6 Environmental Issues Addressed During the CEMRI Pilot

The CEMRI concept was tested at a regional scale by incorporating monitoring and research efforts at all four tiers of the framework to address the following five environmental issues specific to forested landscapes:

- Measuring and monitoring forest C stocks and fluxes
- Identifiying and monitoring forests vulnerable to non-native invasive pest species
- Monitoring recovery from Ca depletion and N saturation in forests of the Appalachian Plateau
- Measuring and monitoring forest fragmentation and associated ecosystem changes
- Integrating the effect of terrestrial ecosystem health and land use on the hydrology, habitat, and water quality of the Delaware River and Estuary

2.7 Objectives of this Report

This report provides the conceptual foundation for testing the CEMRI concept through addressing these five environmental issues, and presents background information that supplements research papers published or in process. Specifically, this report 1) describes the CEMRI integration concept and how it was used to test integration of several Federal monitoring programs, 2) provides an initial evaluation of the five issues listed above using data from the disparate, pre-CEMRI monitoring programs as a baseline for comparison with

CEMRI results, and 3) shows some of the initial results from the CEMRI study. This initial evaluation of the five issues highlights shortfalls and gaps in the pre-CEMRI monitoring programs and shows how the CEMRI approach to integrated monitoring can improve our ability to monitor ecosystem change across a range of scales, thus detecting and predicting environmental change earlier and more accurately.

2.8 Study Area Description

The DRB encompasses more than 12,700 mi^2 and includes parts of Pennsylvania (6,465 mi^2), New Jersey (2,969 mi^2), New York (2,363 mi^2), Delaware (968 mi^2), and Maryland (8 mi^2) (Fig. 2.2). About 7.2 million people live within the basin, and an additional 7 million people in New York City and northern New Jersey rely on surface water diverted from the DRB for their water supply (Fischer et al. 2004).

Topography varies from the relatively flat Coastal Plain Physiographic Province, where soils are underlain by unconsolidated sediments, to rolling lowlands and a series of broad uplands in the Piedmont Province where soils are underlain by metamorphic rock. North of the Piedmont, the New England Province and the Valley and Ridge Provinces consist of rock layers that have been deformed into a series of steep ridges and parallel folds that trend northeast-southwest. The Appalachian Plateau Province occupies the upper one-third of the basin and is characterized by rugged hills with intricately dissected plateaus and broad ridges. Bedrock in the Appalachian Plateau consists of interbedded sandstone, shale, and conglomerate. Elevation in the basin increases from sea level in the south to more than 4,000 feet in the north. During the last major glacial advance, the Appalachian Plateau and parts of the Valley and Ridge and New England Provinces were glaciated. North of the line of glaciation, valleys typically are underlain by thick layers of stratified drift and till (Fischer et al. 2004).

Average annual precipitation ranges from 42 inches in southern New Jersey to about 50 inches in the Catskill Mountains of southern New York; annual snowfall ranges from 13 inches in southern New Jersey to about 80 inches in the Catskill Mountains (Jenner and Lins 1991). Generally, precipitation is evenly distributed throughout the year. Annual average temperatures range from 56 °F in southern New Jersey to 45 °F in southern New York.

From 1992 satellite-derived Thematic Mapper (TM) land cover data, it is estimated that about 60 percent of the DRB is forested land, 24 percent is agricultural, 9 percent is urban and residential, and 7 percent is surface water bodies and miscellaneous land uses. Eighty percent of the population of the study unit lives in the Piedmont and Coastal Plain Provinces in the southern part of the DRB, which cover only about 40 percent of the total area (Ritters et al. 2000).

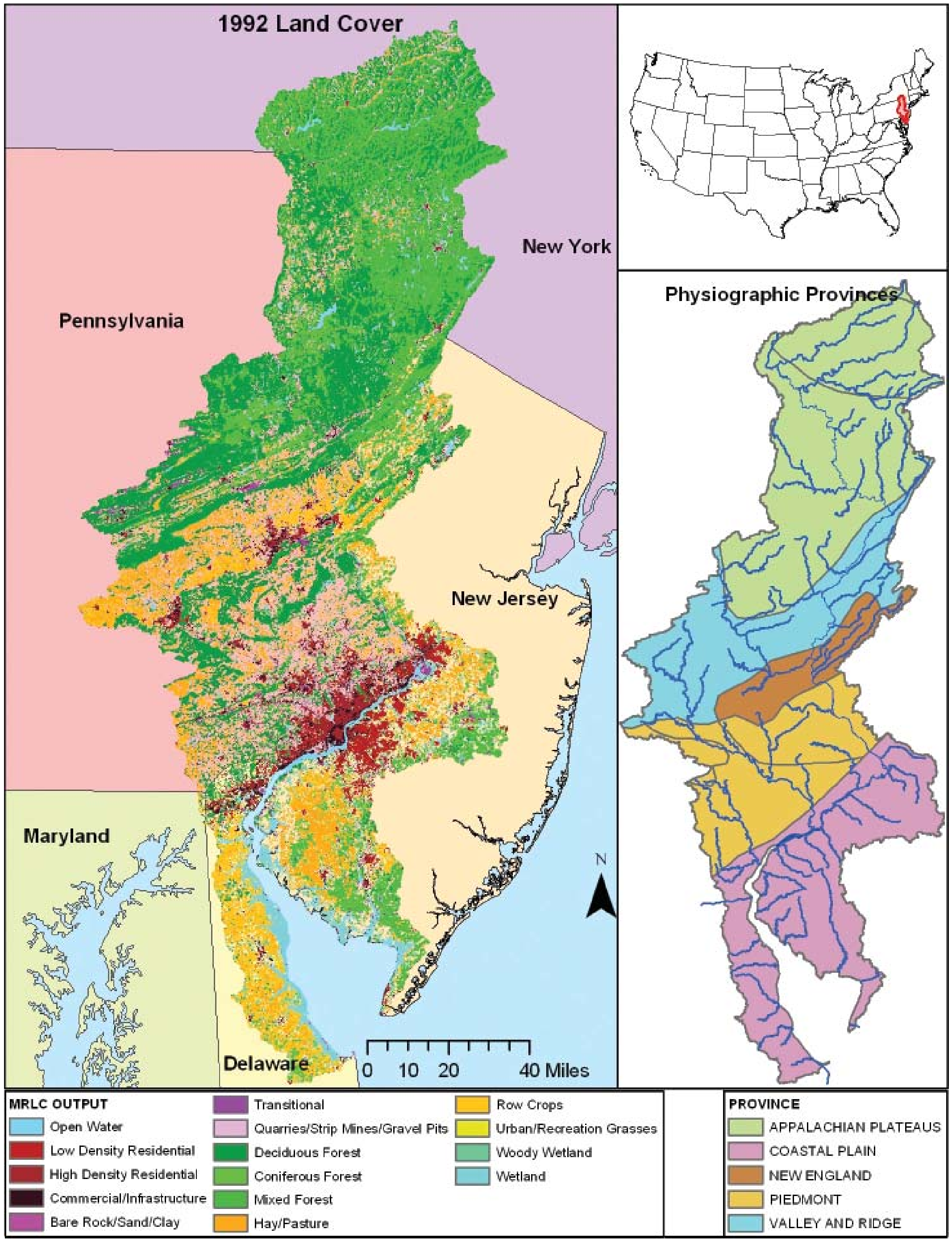

Figure 2.2—Land cover and physiographic provinces in the Delaware River Basin. (From Fischer et al. 2004.)