National Reporting on Ecosystem Condition:

Priority Data Needs and Key Management Challenges

Volume I: Summary and Findings

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The Heinz Center
State of the Nation's Ecosystems Project

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THE HEINZ CENTER

Executive Summary

Introduction

This report recommends that urgent attention be given to filling high priority gaps identified in the Heinz Center's 2002 report: *The State of the Nation's Ecosystems: Managing the Lands, Waters, and Living Resources of the United States*. These data gaps preclude effective reporting on key indicators of the condition and use of U.S. ecosystems.

Highlighting these data gaps was viewed by many as an important contribution to the debate over management of the nation's environmental monitoring infrastructure. However, it also posed a challenge: to identify those gaps which should be treated as most urgent priorities, given the importance of the information they would provide and the cost and feasibility of filling them.

This report responds to that challenge by recommending ten areas as high priorities for providing new resources to fill gaps and enable expanded reporting on key indicators. Implementing these recommendations would more than double the number of indicators that could be reported nationally, from 32 in the 2002 State of the Nation's ecosystems to 68.

This report also identifies important challenges facing the nation's environmental monitoring infrastructure. These challenges are systemic and reduce the effectiveness of the nation's substantial public and private investment in data collection.

Caveat Regarding Tradeoffs

Implementing this report's recommendations will require increased funding. However, filling the gaps highlighted here should not be undertaken at the cost of reducing existing monitoring and reporting activities. Approximately twenty public and private entities provided data for the 2002 report and many others provide crucial data for other purposes. Until there are sound mechanisms in place to assess the relative importance of these and other monitoring efforts and to evaluate how each contributes to important national goals, we strongly recommend their continued maintenance, even as we recommend additional resources to fill the gaps described here.

We are keenly aware of the overall fiscal climate, in which increases in domestic discretionary spending outside of homeland security-related needs face particularly high hurdles. As a response, we have identified "high priority" data gaps that can be viewed not as isolated entities requiring separate independent monitoring systems, but rather as groups of closely related gaps whose filling might be accomplished in a coordinated – and thus efficient – manner.

Setting Priorities

The recommendations included here are based on consideration of the importance of obtaining the required information, the cost of obtaining those data, and the feasibility or practicality of doing so. The cost estimates provided here are not definitive, but are clearly adequate for understanding the scope and scale of required investments.

Highest Priority Data Gaps

The ten data gaps or clusters of closely related data gaps listed in the table and described more fully in Section II and Appendix B[1] should be treated as high priorities for improving the nation's ability to report on ecosystem condition and use.

Data Gap / Cluster	Costs	Feasibility
Extent / Location (Primarily Remote Sensing)		
Landscape pattern / remote sensing analysis	*Initial: $1.2-$1.5 million* *Ongoing: $50,000-$220,000 per year*[1]	*Highly and immediately feasible*
Extent of specific key habitat elements	*Initial: Full costs not available* *Ongoing: Full costs not available; individual gaps range from $0 to ~$2 million / year*	Variable: Most *highly* or *moderately feasible;* some *challenging*
Chemical Composition (Field Survey)		
Contaminants related to human exposure	*Initial: Not available* *Ongoing: Full costs not available: $3 million to $8 million minimum per year*	Variable: Most *highly* or *moderately feasible;* some *challenging*
Nitrogen loading in rivers, nitrogen yield	*Initial: Not available* *Ongoing: $6.5 million per year*	*Highly and immediately feasible*
Carbon storage in ecosystems (including soil organic matter)	*Initial: $1.5 million (over 3 years)* *Ongoing $10.45 million / year*	Variable: *Highly* or *moderately feasible*
Species, Communities (Primarily Field Survey)		
At-risk species and communities	*Initial: $1.5 million* *Ongoing: ~$ 100,000 per year*	Variable: Most *highly feasible; some moderately feasible*
Non-native species[2]	*Initial: $3.2 million minimum* *Ongoing: Minimum of $14 million to $16 million per year (some costs unavailable).*	Variable: Most *challenging;* some *highly* or *moderately feasible*
Biological community condition	*Initial: Not available* *Ongoing: $10 million per year (freshwater only; costs for terrestrial and coastal unavailable)*	*Variable: Moderately feasible to challenging*
Stream and riparian habitat condition	*Initial: $10 million* *Ongoing: $1-2 million / year*	*Challenging*
Human Uses (Field Survey)		
Groundwater levels	*Initial: $4.5-$8 million* *Ongoing: $0.4-$0.8 million per year*	*Moderately feasible*

Notes: 1. Presumes availability of remote sensing data.
2. Estimate to be revised based on ongoing work

Challenges to the Nation's Environmental Monitoring Infrastructure

Data about the condition and use of U.S. ecosystems is obtained by numerous federal, state, local, for- and non-profit entities. Each of these programs was developed to meet a certain set of needs, and their continuation is of interest to users ranging from national policy makers to field level decision makers in both public and private institutions.

This "system" – or a "system of systems" might be a better term – is facing important challenges as technology advances, and information needs and expectations evolve. Some of these challenges are facing many data collection and monitoring efforts, and relate to broad changes in

[1] All appendices referenced in this report are compiled in a separate Volume II, also available online at: http://www.heinzcenter.org/ecosystems/DataNeeds_Vol2.pdf

the social contract between government and the public. Others are specific to certain types of ecological monitoring.

Managing an enterprise with many independent elements, all with legitimate reasons for doing what they do, and doing it the way they do it, is a long term and large scale challenge. The Heinz Center and the State of the Nation's Ecosystems project are neither the first nor the only ones to recognize these challenges. In addition, our identification of challenges is not meant to belittle or ignore the many important efforts to address long standing concerns over the organization and management of the nation's monitoring infrastructure.

However, with the goal of encouraging and contributing to a larger dialogue about the management of this infrastructure, the following challenges observations are made:

Challenges Applicable to Environmental[2] Monitoring Efforts Generally

- *Expectations about the performance and products of the nation's environmental monitoring infrastructure are changing, with new requirements being added to existing systems.*
- *Systems designed for one purpose may not serve other purposes well.*

Monitoring programs have been created for specific purposes, such as management, regulation, environmental assessment, and program evaluation. Some of these purposes are focused and local; some are broad in scope and scale. Increasingly, monitoring programs are expected to provide data for *multiple* purposes – for example, when land management information systems are asked to provide program evaluation data. These new or expanded demands may require different technical methods, institutional organization, and scale of resources.

- *There is no overall mechanism to determine the most appropriate and highest priority investments in monitoring and reporting capacity.*
- *There are probably non-trivial opportunities for cost savings in the overall national monitoring system, but these opportunities are difficult to realize given the relatively fragmented nature of the system.*

Decisions about the current monitoring "system" are made independently of one another, by the multiple agencies and organizations that collect and report monitoring data. While wholesale integration is neither likely nor desirable, it would be beneficial to explore the potential for improved mechanisms for conducting system-wide evaluations, establishing priorities, assessing integration needs and the like.

Such evaluations could produce significant benefits for existing monitoring efforts if, for example, they enabled data collected by one program to be combined with data from other programs. It is quite likely that small changes in methods and definitions could produce large results.

[2] This report uses use the term *ecological* to connote those aspects of the environment that relate primarily to non-human living resources and the term *environmental* to connote a broader range of features, resources, and conditions, including those related to human health and environmental influences on it.

Challenges Applicable Especially to Ecological Monitoring Efforts

- *Important elements in the nation's ecological data collection and reporting system are operated by entities outside the federal government. In many cases, federal support is ad hoc, relatively small, and not coordinated across agencies*

Highlight: NatureServe and the state-based Natural Heritage program. The data these programs provide concerning rare and declining species and communities is relied upon by many public and private entities, but federal funding is project-specific and does not support the basic infrastructure needed to maintain the overall enterprise.

- *Important elements of the nation's ecological data collection and reporting system are operated through ad hoc interagency arrangements.*

Highlight: The National Land Cover Data Set (NLCD) provides land cover data relied upon by a very large fraction of researchers, planners, and managers needing large scale land cover data. This important example of entrepreneurial interagency coordination would benefit from long term strategic planning and assured funding.

- *Research and development programs are fundamentally different from operational monitoring programs and it is important to ensure smooth transitions between the two.*

Research and development programs are a critical element of a sound monitoring system, but their objectives, personnel and cost structure, and general orientation is different from programs intended provide guaranteed, routine, and sustained delivery of established suites of monitoring data. Mechanisms for moving the best products from R&D into operational status are weak. Section III provides additional discussion of these challenges.

About The Heinz Center

Established in December 1995 in honor of Senator John Heinz, The H. John Heinz III Center for Science, Economics and the Environment is a nonprofit, nonpartisan institution dedicated to improving the scientific and economic foundation for environmental policy through multisectoral collaboration. Focusing on issues that are likely to confront policymakers within two to five years, the Center fosters collaboration among industry, environmental organizations, academia, and government in each of its program areas and projects. It uses the best scientific and economic analyses to develop viable options to solving problems, and its findings and recommendations are widely disseminated to public and private sector decision makers, the scientific community, and the public.

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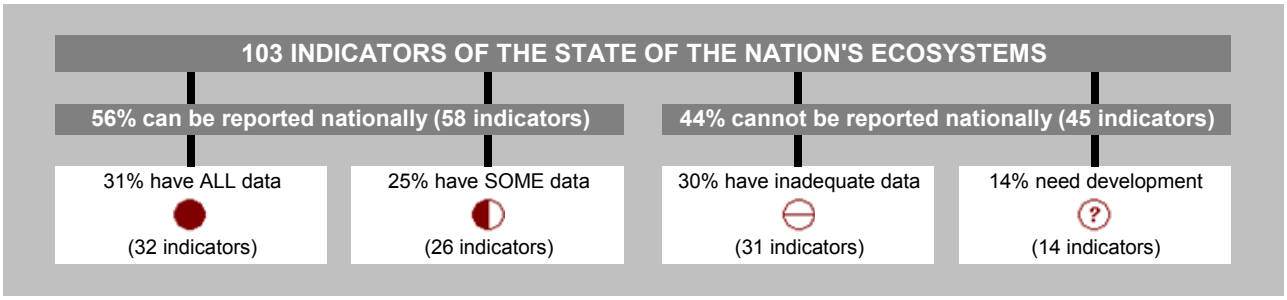
SECTION I: IDENTIFYING AND ASSESSING DATA GAPS

Data Gaps and the 2002 *State of the Nation's Ecosystems* Report

The 2002 edition of *The State of the Nation's Ecosystems* included 103 indicators describing ecological conditions in the nation's forests, grasslands, farmlands, urban and suburban areas, and fresh waters and coasts and oceans. While the identification of a set of key indicators was the primary purpose of the report, an important corollary objective was to identify and highlight those cases in which it was not possible, using currently available data, to report on an indicator at a national level. This is in keeping with the project's overall goal of helping to establish a long term process for reporting on ecological conditions and changes, using a set of consistent indicators.

Only thirty two of the 103 indicators had all of the required data for national reporting. For twenty four indicators, there were enough data to provide an overall national perspective, although some of these indicators still had some significant data gaps. See Figure 1.

Figure 1. Data Gaps Prevented Full Reporting on Most Indicators in 2002[3]



For thirty one indicators, data were not aggregated or were sufficiently spotty that they were designated as having "inadequate data for national reporting." The box on the following page describes the criteria for inclusion of data sets in the 2002 report. By far, more data sets were excluded from the report because of inadequate geographic coverage than for any other reason. Many excellent data sets exist that describe conditions in only a portion of the United States. In other cases, data may be available (for example, from state agencies) but these data have not been aggregated and made consistent to allow national reporting.

While these data sets may be quite valuable, and in some cases may provide the basis for future national reporting, The Heinz Center and the project's guiding Design Committee wished to avoid creating an impression that data were available for many or all indicators. A strategy of including "sample" or "illustrative" data sets was employed in the project's 1999 prototype[4], and it was clear from reviewer's reactions that this created the impression, to the quick or casual reader, of far greater data availability than was actually the case.

[3] The numbers in Figure 1 differ slightly from Figure 3.2 in the 2002 Report, from which it is derived because, in 2002, one indicator was mistakenly classified as having all required data when this was not the case.

[4] The Heinz Center. 1999. Designing a Report on the State of the Nation's Ecosystems: Selected Measurements for Croplands, Forests, and Coasts &Oceans. The H. John Heinz III Center, Washington, DC.

Finally, there were fourteen indicators identified as "needing further development." For these indicators, it was possible to identify a target for reporting, but not a specific quantifiable metric. Despite the lack of specific indicator definitions, it is possible to say that data for most of them is not currently available for national level reporting.

In all, the 2002 report identified seventy one individual data gaps, including those for indicators for which only partial data are available, indicators for which adequate national data are not available, and undefined indicators.

Response to the report's highlighting of data gaps came in two forms. The first was a recognition of the profound importance of highlighting gaps in the infrastructure used as the nation's "eyes and ears" to understand ecological conditions and change. The second was a request for information on the scale of funding that would be required to fill the gaps, and an ordering of priorities – which gaps are most important to fill first.

Criteria for inclusion of data in the 2002 *State of the Nation's Ecosystems*

In order to be included in the report, data sources had to meet the following criteria:

Scientific credibility. Based on the professional judgment of the members of each ecosystem work group, data needed to meet the highest standards of the appropriate discipline; judgments of the work groups were extensively peer-reviewed.

Provide information on a substantial majority of the resource or issue in question. Only data sources that cover a majority of states or a significant fraction of coastline were included.

Measurements will be repeated at regular intervals in the future. Although all monitoring and reporting programs are subject to changes in funding and priorities, established programs are clearly different from one-time studies conducted by individual researches or groups. One-time efforts do not necessarily form a solid foundation for periodic reporting and were not included.

See: State of the Nation's Ecosystems, 2002. Appendix, page 199

The process leading to production of the 2002 *State of the Nation's Ecosystems* report did not include consideration of either cost or priority for filling the data gaps. The primary reason for this was to identify those aspects of the nation's ecosystems that were most important to track – not simply to report on those already being monitored. Working groups did eliminate possible indicators for which it appeared technically infeasible to collect data or for which the potential costs were clearly "beyond the pale." However, our goal was to look to the future rather than being constrained by existing resource constraints.

In this effort, we made every effort to identify "high priority" data gaps that can be viewed not as isolated entities requiring separate independent monitoring systems, but rather as groups of closely related gaps whose filling might be accomplished in a coordinated – and thus efficient – manner.

Assessing Priority, Cost, and Feasibility of Filling Data Gaps

This report provides recommendations about which of the data gaps identified in the 2002 *State of the Nation's Ecosystems* report are the highest priority for filling in order to improve the nation's capacity for broad scale reporting on ecosystem conditions and trends.

Ten gaps or clusters of closely related gaps are identified as being of the highest priority for near term action. In addition, all other gaps identified in the 2002 report are identified and described, and assigned a rank of *high, medium,* or *lower* priority.

Three related caveats apply to these recommendations.

First, it would be inappropriate to assume that gaps not included in the *highest priority* category are irrelevant or unimportant. All of the indicators identified in the 2002 *State of the Nation's Ecosystems* report were identified as highly relevant to achieving a broad and comprehensive understanding of the important conditions and trends in the nation's ecosystems, and thus are worthy of future action. This report simply identifies, based on a series of factors described below, those that should be addressed with most urgency. Additional data gaps identified in the 2002 *State of the Nation's Ecosystems* report are briefly described in Appendix C.

Second, these recommendations, and indeed the *State of the Nation's Ecosystems* report as a whole, focus on *national* reporting. There are numerous other reasons for collecting environmental data, including regulatory compliance assessment, land management planning, and the like. Simply because an environmental parameter is not included in the *State of the Nation's Ecosystems* report or in this data gaps report does not mean that collection of these data are not crucial for these other valid and important reasons.

Third, while recommending that the gaps identified here be treated with urgent priority, the Center and the Design Committee believe that it would be inappropriate to reduce funding for existing monitoring programs in order to meet the needs identified here. We base this recommendation on concerns that reducing existing efforts might create data gaps where none exist now, and because many existing programs provide crucial data for uses other than national reporting.

Our priority assessments were based on national reporting needs and assume that the programs relied upon to support national reporting will be continued. Reducing existing efforts could easily produce newly gathered data for one indicator at the expense of the loss of data for another. Table 1 identifies the agencies and programs from which data were included in the 2002 *State of the Nation's Ecosystems* report.

In addition, we did not ascertain whether data for other uses could safely be discontinued, nor did we balance the priority of those other needs against provision of data for national reporting. While we believe that systematic assessment and management of the nation's environmental monitoring infrastructure can provide efficiencies and potential cost savings, until and unless such a large scale assessment is needed, we believe existing programs should be maintained and additional resources provided to fill these critical gaps.

Table 1. Many Programs – Both Public and Non-profit – Contributed to the 2002 *State of the Nation's Ecosystems Report*

Department / Agency	Unit / Bureau	Program	Number of Indicators
US Department of the Interior	US Fish and Wildlife Service (FWS)		2
	US Geological Survey	National Water Quality Assessment (NAQWA)	10
		Water Resources Discipline (WRD)	4
		Biological Resources Discipline	3
		EROS Data Center	11
	Total US Department of the Interior		**30**
US Department of Health and Human Services	Center for Disease Control (CDC)		**1**
US Department of Commerce	Bureau of Economic Analysis (BEA)		1
	Census Bureau		1
	National Oceanic and Atmospheric Administration (NOAA)	National Marine Fisheries Service (NMFS)	4
		National Ocean Service (NOS)	1
	Total US Department of Commerce		**7**
US Department of Agriculture	Economic Research Service		5
	Farm Service Agency (FSA)		1
	Forest Service	Forest Inventory Analysis (FIA)	10
	Forest Service	National Surevey on Recreation and the Environment (NSRE)	1
	National Agricultural Statistics Service (NASS)		3
	Natural Resources Conservation Service	National Resources Inventory (NRI)	2
	Total US Department of Agriculture		**22**
Non-Federal	Nature Serve		**5**
Joint -- DOC / NOAA and NASA	National Oceanic and Atmospheric Administration (NOAA) / National Aeronautics and Space Administration (NASA)		**2**
Environmental Protection Agency	Office of Air and Radiation (OAR)		1
Environmental Protection Agency		Environmental Monitoring and Assessment Program (EMAP)	6
	Total Environmental Protection Agency		**7**

We considered three factors in setting priorities.

Our primary consideration was the utility of the information. Which indicators, for which data are not currently available, are the most "important"? Clearly, this is a value judgment, and the process we have used, which is described below, was intended to reflect the input from a broad spectrum of professionals and decision makers.

An additional factor was the cost of filling individual gaps. Clearly we cannot have all that we might want, and some notion of "cost per unit of importance" must enter into any such recommendations. (We did not, however, attempt to quantify or explicitly define such a relationship.)

The final factor we considered was feasibility – can this indicator be implemented immediately (given adequate funding) or are other technical or institutional steps required first?

Identifying Priorities. Priorities recommended in this report were developed in a multi-stage process. The first, basic input was a survey that asked respondents to rank each gap on a 1-5 scale, with 1 being highest and 5 being lowest priority[5]. This survey, conducted in 2003, was sent to about 1300 individuals, including past and current participants in *The State of the Nation's Ecosystems* project, organizations and individuals who had requested copies of the 2002 Report, agencies that had provided data to the project and/or had provided funding to the project, members of EPA's National Advisory Council for Environmental Policy and Technology, and assorted other contacts maintained by the Heinz Center with an interest in ecological monitoring. In addition, notices of the survey were sent electronically to several relevant listserves (e.g., Ecolog).

We received 278 responses, with 45% of respondents from government agencies[6], 21% from academia, 18% from environmental non-governmental organizations (NGOs), 8% from the business/industry sector, and 8% from people that did not fall into one of these four sectors[7].

Survey results were then statistically analyzed to identify five groups of gaps for which respondents ratings were strongly similar. Thus, the "highest" priority group had more "1" ratings and fewer lower ratings than other groups.

[5] In conducting this survey, our goal was to isolate, as much as is practical, considerations of the importance of the information from those related to the cost of obtaining that information, since more detailed cost information would be considered explicitly in later rounds. However, it is unclear to what extent this somewhat-artificial isolation was maintained by respondents. Essentially, we asked respondents to ignore the cost of filling a particular data gap when rating it. However, in order to provide some sense of scale, we provided very rough cost estimates for each gap; costs were described as being modest ("less than $100,000") or major ("a major addition to a national data monitoring program will be required").

[6] In most cases, the response from agencies were from individuals and in some cases multiple responses were received from the same agency although these appeared to be individual responses rather than multiple identical responses representing the opinions of the agency.

[7] Note that respondents were asked to identify themselves in terms of their sector (e.g., academia). In general, Center staff confirmed the accuracy of this information, and in very few cases made adjustments based on our interpretation of the different sectors.

This basic ordering of priorities was used as an informational starting point by the Center and Design Committee. All gaps, with associated cost and priority information, were reviewed, with the goal of identifying a very small number of highest priority gaps or clusters of related gaps. This process consisted of a first round of deliberations by a multi-sector working group of Design Committee members, with final review and ranking by the entire Design Committee.

[The following paragraph is written in anticipation of the completion of external reviews] It is important to note that many individuals and agencies reviewed this report and provided important comments, clarifications, and corrections, but that reviewers were not asked to comment on the priority rankings. The Heinz Center and the Design Committee accept sole responsibility for this decision.

Estimating Costs. Cost estimates provided in this report were developed in consultation with a wide range of agencies and individual experts. As is described in detail below, these costs estimates are not definitive and would need to be verified and made more detailed prior to implementation. However, it is our view that they are sufficiently detailed and sufficiently comparable to one another for the purposes of making overall priority decisions and understanding the scope and scale of recommended investments.

An initial review identified agencies or institutions that conduct monitoring activities similar to those required to fill each gap, and these agencies were asked to provide estimates of the cost of undertaking appropriate monitoring to address the specific data needs identified by our report (i.e., fill the gap). For example, the USGS provided data in the 2002 report on nitrogen yields in major river basins, but data were not available for significant areas of the country (see pages 46-47 of the report). In this case, USGS was asked to estimate the cost of providing the necessary data. These estimates have been reviewed on several occasions by the agencies / institutions that generated them, as well as by outside reviewers.

We are aware of several potential concerns with the cost estimates provided here.
Implied and Introduced Biases. By asking agencies that currently collect similar information to provide guidance on how to fill the gaps, we introduced several potential biases. These include an assumption that the method used by the agency we contacted is the "best" (e.g., most appropriate institutionally, least expensive, etc.) method. We asked agencies and reviewers to ensure that a broad suite of potential solutions was considered, but it remains possible that additional unexplored options might exist. A second bias is that, by asking federal agencies that conduct major monitoring programs, we imply that a federal solution (i.e., collection by federal agency staff) is necessarily the most appropriate means for filling the gap. We have attempted to avoid this trap, while recognizing that federal agencies, in many cases, have the institutional and technical capabilities that may not be available elsewhere. To counter this bias, in many cases the Heinz Center has outlined a non-federal approach, primarily involving collection by states or other entities, or aggregation of data that are already collected by such entities. It is crucial that the resources and creativity of states and other entities and their substantial interest in data collection for their own interests be considered in maintaining and enhancing the nation's overall infrastructure for environmental monitoring.

Uncertain Completeness and Comparability. The second significant concern surrounding these estimates is that they may include costs for different components of the "true" cost of

undertaking work, and thus may be not strictly comparable to each other. We asked agencies and institutions to provide estimates that covered the whole cost of undertaking the work – not, for example, just the direct salary or analytical laboratory expenses, but overhead, other support costs, major infrastructure costs (e.g., rental, leasing, or other payments such as for offshore "ship time" to conduct coastal monitoring). An additional consideration is whether estimates included both upfront or initial costs and long term annual estimates. Appendix A provides information on which cost components are included in each overall estimate, and these components are described separately in the indicator descriptions where they were included separately in the cost estimates. Given the breadth of our examination of gaps, and our limited ability to demand consistent accounting procedures from these agencies, it is highly likely that differing assumptions were used in these estimates. Such differences can create substantial inconsistencies in estimates.

A related issue is whether the cost estimates address all of the major elements required to collect, manage, and process environmental data. In broadly general terms, this chain requires data collection, data archiving and distribution, and data processing and analysis. In some cases, additional methods development or testing may be required prior to implementing a collection regime. We compared the estimates provided by agencies; see Appendix A for details. Most estimates explicitly dealt with one or two of these categories of activities. This implies that other activities – commonly archiving and distribution, but sometimes including data collection or processing – were assumed to be undertaken using existing agency / organization channels (e.g., data archives or collection mechanisms), and that the new activity did not overtax these resources or require additional funding. This assumption should be carefully reviewed as programs are implemented.

Piecemeal Estimates. The estimates provided here are for independent implementation of the activities required to address each data gap. In most cases, we believe the agency providing the estimates provided marginal costs for expanding their efforts to fill a gap. However, as is discussed in Section III below, it is possible if not likely that additional efficiencies might be obtained if, for example, the multiple federal field-based survey programs were more closely coordinated, or remote sensing data acquisition and processing were strategically integrated.

Available Technology. Finally, the estimates provided here are based largely on currently available technology. New techniques and methods, ranging from improved remote sensing to miniaturization of sampling technology linked with GPS and satellite telecommunications have the potential to decrease the cost or increase the scope of available data. It is, however, difficult to predict such advances.

However, the purpose of these estimates is not to serve as the basis for immediate implementation. Rather, they are intended to provide a relative indication of the magnitude of resources required to address gaps. We are confident that these estimates are sufficiently accurate to distinguish between very low cost and very high cost initiatives and provide rough, order-of-magnitude information useful for placing these recommendations into context.

Assessing Feasibility: Based on the input from agencies and organizations that provided cost and technical-solutions information, the Center provided an initial feasibility rating for each gap. The rating categories are:

Highly and immediately feasible gaps are those for which sufficient funding is the primary obstacle – the technical approaches are well developed and there is clear institutional capability to undertake the work, given adequate resources.

Moderately feasible gaps are those for which there are either technical or institutional issues that require resolution – and as a result funding is not the only obstacle to implementation. For these gaps, however, the impediments are not major or substantial (as is the case with "challenging" gaps; see below).

Challenging gaps are ones for which technological development is needed (e.g., which method works best for monitoring seagrasses in turbid waters), for which substantial uncertainty exists about the coverage, and comparability of data collected by many disparate entities (primarily states), or for which it is not obvious that there is any institution with the mandate and institutional capability to undertake the work. (This latter concern is especially relevant to gaps related to urban and suburban areas. There are few instances in which data are collected so as to be able to identify conditions in urban / suburban areas, and few institutions with the geographic, legal, and institutional capability to conduct much of the recommended monitoring.)

Evolution of *The State of the Nation's Ecosystems* and Its Effect on These Recommendations

Readers may be aware that the 2002 *State of the Nation's Ecosystems* report was the first in what will hopefully become a long running series of scientifically sound, non-partisan reports on the condition and use of U.S. ecosystems. The next edition is currently in development, with an expected release during 2007. The 2002 report was intended to be an initial statement about the suite of key indicators that should be tracked through time, with each successive version of the report representing continued refinement of that suite. Thus, a number of indicators are being revised and improved as the process evolves toward producing another report in 2007.

As a general matter, the indicator refinements currently underway will not substantially change the requirements for data, methods, and processing capabilities that are described as gaps in this report. Clearly, the ways in which specific indicators are calculated or reported may change, but in many cases the underlying data requirements are similar if not identical. The work underway now will likely identify some additional gaps, although at this time they do not appear to be major in nature.

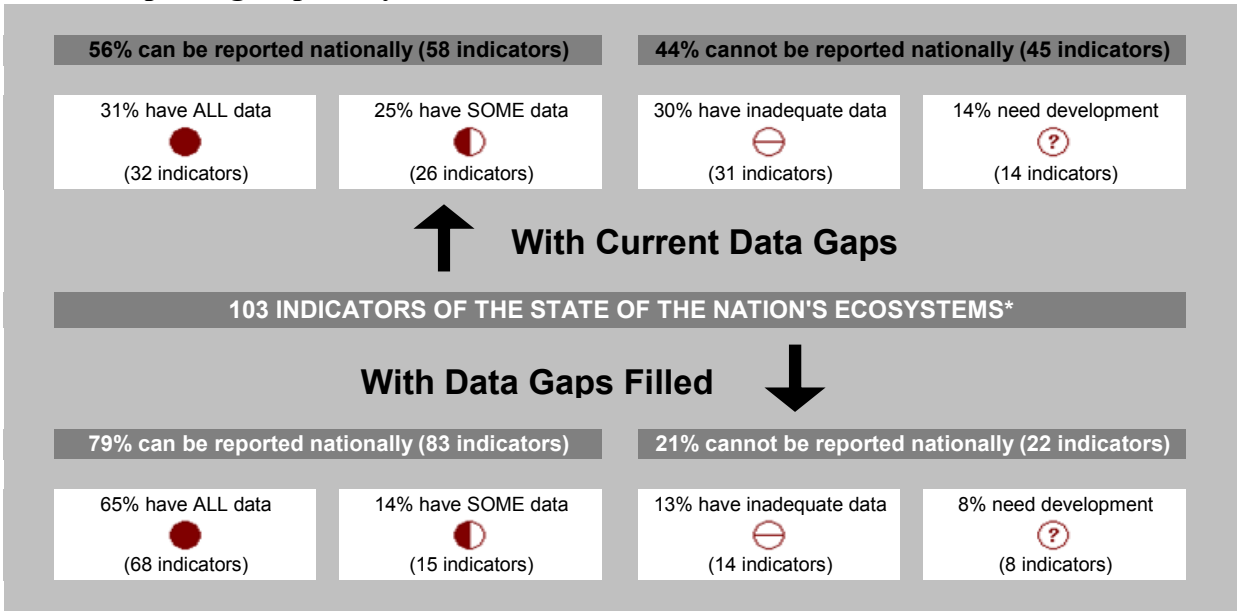
Additional detail concerning the specific areas in which refinement is currently underway and the extent of changes to data requirements is provided as the final component of Section II of this report, at page 30.

SECTION II: HIGHEST PRIORITY DATA GAPS

The Heinz Center and the Design Committee for the *State of the Nation's Ecosystems* project recommend that the data gaps or clusters of closely related gaps identified below be filled as a matter of urgent priority.

The implications of filling these data gaps on the Nation's ability to report on ecosystem use and condition are profound. As shown in Figure 2 and Table 1 below, the number of indicators that could be reported nationally rises dramatically, and these expanded reporting capabilities extend across all major ecosystem types.

Figure 2: Implementing This Report's Recommendations Would Dramatically Improve Overall Reporting Capability



* The "With Data Gaps Filled" portion of this graphic and Table 2 below include 68 "All Data" indicators for a total of 105, reflecting the addition of two new core national indicators. The final 2007 indicator total may be less than this amount, since other indicators may be dropped or combined.

Table 2. Implementing This Report's Recommendations Will Dramatically Improve Reporting in All Ecosystems.

	Indicators with Full National Data – 2002	Indicators with Full National Data – As Recommended in This Report
Core National	2	8
Coasts & Oceans	2	6
Farmlands	9	14
Forests	7	12
Fresh Waters	3	10
Grasslands & Shrublands	4	9
Urban & Suburban Areas	5	9
TOTAL	**32**	**68**

In addressing these needs, there are two general strategies that might be considered – increased funding and reprioritized funding. We are keenly aware of the overall fiscal climate, in which increases in domestic discretionary spending outside of homeland security-related needs face particularly high hurdles. As a response, we have identified "high priority" data gaps that can be viewed not as isolated entities requiring separate independent monitoring systems, but rather as groups of closely related gaps whose filling might be accomplished in a coordinated – and thus efficient – manner. As a general matter, we believe that efficiencies might be created through more coordinated management of the nation's overall environmental monitoring infrastructure (see Section III). However, the 2002 *State of the Nation's Ecosystems* identified a large number of key data gaps, for national reporting alone. It is likely that many similar gaps exist for other monitoring purposes such as regulatory compliance, land management. Thus, while we believe that identifying efficiencies through more integrated management of the overall environmental monitoring enterprise is a wise thing to do, because it optimizes the amount of data collected with available funds, absent such an integrated capability for assessment and priority setting, it would be inappropriate to reduce funding for other existing monitoring programs.

These high priority gaps can be considered according to the type of information they provide and by the nature of the systems that provide the data necessary for reporting. See Table 3. This distinction is important because – as is discussed in greater detail in Section III below – greater integration of the management of data collection systems with similar technologies and data collection endpoints could yield important benefits for the overall national monitoring "system".

Table 3. Ten High Priority Data Gaps Hinder National Reporting Capabilities

HIGHEST PRIORITY DATA GAPS	
Extent and Location of Ecosystem Elements *(Primarily requiring collection, aggregation, or analysis of remote sensing data to fill gaps)*	○ **Landscape Pattern / Remote Sensing Analysis** ○ **Extent of Specific Key Habitat Elements**
Chemical Composition of Ecosystems *(Requiring collection, aggregation or analysis of field survey data to fill gaps)*	○ **Contaminants Related to Human Exposure** ○ **Nitrogen Yield and Load in Rivers** ○ **Carbon Storage / Soil Organic Matter**
Condition of Species and Biological Communities *(Primarily requiring collection, aggregation or analysis of field survey data, or research and development to fill gaps)*	○ **At-Risk Species and Communities** ○ **Non-native Species** ○ **Biological Community Condition** ○ **Stream and Riparian Condition**
Human Uses of Ecosystems *(Requiring collection, aggregation or analysis of field survey data to fill gaps)*	○ **Groundwater Levels**

In addition, we have provided information on the nature of the activities required to fill these gaps. See Table 3. In most cases, new data collection or aggregating of existing data is required. However, we have included several indicators for which additional research – development of technical methods for monitoring or definition of specific metrics to be monitored – is needed. These indicators are considered very high priority, despite the fact that the path to their implementation is perhaps longer and less clear.

Brief summaries are provided below; more detailed descriptions are in the appendices.

Descriptions of Data Gaps Begin Following Tables 4,5, and 6.

Table 4: Initial Estimates Are Available of the Initial and Ongoing Costs and Feasibility

Data Gap / Cluster	Initial / Startup Costs[8]	Ongoing Costs	Feasibility
Extent / Location (Primarily Remote Sensing)			
Landscape pattern / remote sensing analysis	*$1.2-$1.5 million*	*$50,000-$220,000 per year,* ***presuming availability of remote sensing data.***	All elements: *highly and immediately feasible*
Extent of specific key habitat elements	*Full costs not available*	*Full costs not available; individual gaps range from $0 to ~$2 million / year*	4 gaps: *highly and immediately feasible* 3 gaps: *moderately feasible* 1 gap: *challenging*
Chemical Composition (Field Survey)			
Contaminants related to human exposure	*Not available*	*$3 million to $8 million minimum per year (some costs unavailable)*	2 gaps: *highly and immediately feasible* 1 gap: *moderately feasible* 1 gap: *challenging*
Nitrogen loading in rivers, nitrogen yield		*$6.5 million per year*	*Highly and immediately feasible*
Carbon storage in ecosystems (including soil organic matter)	*$1.5 million (over 3 years)*	*$10.45 million / year*	1 gap: *highly and immediately feasible* 1 gap: *moderately feasible*
Species, Communities (Primarily Field Survey)			
At-risk species and communities	*$1.5 million*	*~$ 100,000 per year*	7 gaps: *highly and immediately feasible* 3 gaps: *moderately feasible*
Non-native species	*Depends on choices about program implementation.*		1 gap: *highly and immediately feasible* 1 gap: *moderately feasible* All others: *challenging*
	Costs for components range from ~$700,000 to $2.5 million	*Costs for component range from $240,000 to $10-12 million per year*	
Biological community condition	*Not available*	*$10 million per year (freshwater only; costs for terrestrial and coastal unavailable)*	*Moderately feasible to challenging*
Stream and riparian habitat condition	*$10 million*	*$1-2 million / year*	*Challenging*
Human Uses (Field Survey)			
Groundwater levels	*$4.5-$8 million*	*$0.4-$0.8 million per year*	*Moderately feasible*

[8] These are one-time costs for each effort. In some cases, project funding would begin in the first year, so it is not appropriate to assume the these one-time costs are the only costs in the first year(s) of a project.

Table 5. A Variety of Activities Are Required to Fill Data Gaps

Indicators	Aggregation of Existing Data From Disparate Sources	Analysis of Existing Data	Collection of New Data[1]	Research Into Methods
Extent / Location (Primarily Remote Sensing)				
Landscape Pattern / Remote Sensing Analysis		X		
Extent of Specific Key Habitat Elements	X[2]	X		
At Risk Species and Communities (remote sensing component)	X	X		X
Non-native Species (remote sensing component)		X		X
Chemical Composition (Field Survey)				
Contaminants Related to Human Exposure	X		X	
Nitrogen Yield and Load in Rivers	X[3]		X	
Carbon Storage / Soil Organic Matter	X[4]		X	
Species, Communities (Primarily Field Survey)				
At-Risk Species and Communities (field component)	X	X		X
Non-native Species (field component)	X		X	
Biological Community Condition	X		X	X
Stream and Riparian Condition	X		X	X
Human Uses (Field Survey)				
Groundwater Levels	X		X	

Notes:

1. For remote sensing applications, we have assumed that sufficient "data" are collected – in that there is a fairly large suite of array of sensors that gather large quantities of data on a regular basis. We assume further that the gaps identified here can be filled through analysis of these data, rather than requiring new sensors to be put into service. Clearly, the agencies conducting the analysis would have to acquire the relevant remote sensing data from the appropriate agency (e.g., NOAA, NASA, USGS).
2. In some cases, data may be available from existing, field-based sources (federal agencies, state agencies, research institutions). It may be possible to make early progress and provide important field verification of remote sensing information by aggregating these data.
3. Data for this indicator is currently provided by USGS and estimates provided in this report are based on re-establishment of USGS sampling networks that were eliminated in response to past budget reductions. It might be possible to provide some of these data using existing state networks.
4. Data on carbon storage / soil organic matter are collected, but not on a large scale or systematic basis, by many entities; for example, agricultural interests. It might be possible to integrate these data into a larger network that provided broad coverage.

Table 6. Key Data Gaps Affect All Ecosystems

Indicators	Primary Ecosystem Types Affected						
	Core National	Coasts & Oceans	Farmlands	Forests	Freshwater	Grasslands & Shrublands	Urban & Suburban
Extent / Location (Primarily Remote Sensing)							
Landscape Pattern / Remote Sensing Analysis	X	X[1]	X	X	X	X	X
Extent of Specific Key Habitat Elements		X		X[2]	X	X	X
Chemical Composition (Field Survey)							
Contaminants Related to Human Exposure	X	X			X		
Nitrogen Yield and Load in Rivers	X	X[3]	X[3]	X[3]	X[3]	X[3]	X[3]
Carbon Storage / Soil Organic Matter	X		X	X		X	
Species, Communities (Primarily Field Survey)							
At-Risk Species and Communities	X	X	X	X	X	X	X
Non-native Species	X	X	X	X	X	X	
Biological Community Condition	X	X	X	X	X	X	X
Stream and Riparian Condition					X	X	X
Human Uses (Field Survey)							
Groundwater Levels					X		

Notes:

1. The 2002 Report did not include an indicator of coastal landscape pattern, but the 2007 report will likely include such an indicator and it is likely that filling this gap will provide the capability to process data needed to enable reporting on it.
2. This indicator includes *total impervious area*, which was reported in 2002 as an "urban/suburban" feature. However, the 2007 report is likely to report on the overall extent of such surfaces, which occur in all the listed ecosystems, plus forests.
3. This indicator is reported as a "core national indicator" but it addresses freshwater flows, coastal discharges, and the source of these flows/discharges (irrespective of ecosystem type).

BRIEF SUMMARIES OF DATA GAPS

(For detailed summaries, see appendix[9])

Gaps Involving the Extent and Location of Ecosystem / Landscape Elements (Requiring Collection, Aggregation and/or Analysis of Remote Sensing Data)

- Extent of Key Habitat Elements
- Landscape Pattern / Remote Sensing Analysis
- At Risk Communities
- Non-Native Species
- Riparian Area Condition

The area of key ecosystem elements, such as wetlands, coral reefs, impervious surfaces, biological communities, and lands highly affected by non-native species provides fundamental information about the composition of the nation's ecosystems and can provide important clues to its condition. Knowing how individual components are intermingled can provide important information about the functioning of specific ecosystem types. For example, forests with housing or farmlands intermingled may provide habitat to different species than contiguous forest, and farmland areas with higher levels of suburban development may not support a robust agricultural economy.

- **Extent of Key Habitat Elements**: Reporting on the area of habitat components that are relatively small in area, but high in ecological significance, including coastal wetlands, coral reefs, seagrasses, impounded and channelized streams, altered wetlands, streambank vegetation, and impervious surfaces.

  The full costs for this cluster are not available. Individual items range from little or no cost to ~$2 million per year. In some cases, data may be available from existing, field-based sources (federal agencies, state agencies, research institutions). It may be possible to make early progress and provide important field verification of remote sensing information by aggregating these data. Some aspects of filling this gap would be *highly and immediately feasible*, others would be *moderately feasible,* and one is considered *challenging*; both new data collection and aggregation of existing data would be required. See detailed descriptions in Appendix B

- **Landscape Pattern / Remote Sensing Analysis**: Reporting on the extent and arrangement of land cover, requiring improvements to and analysis and processing of remote sensing data. These data would support indicators dealing with farmlands and residential development, forest and grass/shrub fragmentation and related patterns, land use change at the suburban/rural fringe, vegetation along streams and lakeshores, and extent of impervious surfaces.

[9] All appendices referenced in this report are compiled in a separate Volume II, also available online at: http://www.heinzcenter.org/ecosystems/DataNeeds_Vol2.pdf

This gap would require at least $1.2-1.5 million in initial costs and around $250,000 per year. Some costs were unavailable, so these should be seen as minimum costs. Filling this gap is *highly and immediately feasible*; doing so requires analysis of existing data (although see caveat below). See detailed descriptions in Appendix B.

A very important caveat is that the estimates here presume the availability, at little or no cost, of the underlying land cover data. There have been technical issues related to the sensors from which these data are derived, and costs for resolving these issues and completing the basic processing of the sensor data are not included here.

At-Risk Communities (part of larger At Risk Species and Communities; see below)**:** Reporting on at-risk community types. Two specific items identified in the 2002 report are reporting on declining forest community types and at-risk riparian and wetland communities. Costs for development of classification systems and initial methods are provided below (see full *At-Risk Species and Communities* entry below). Remote sensing should be utilized to the maximum extent possible in providing data on an ongoing basis. Filling this gap would be *moderately feasible* methods development, reconciliation of multiple data sources, and new data collection are all likely to be required. See detailed descriptions in Appendix B.

Non-native Species (portion of larger Non-Native Species gap; see below)**:** Reporting on non-native plant cover is an important priority in many ecosystems. In some systems, primarily grasslands and shrubland and potentially in farmland areas, it is possible to gather data on the extent of invasion using remote sensing. Costs are provided in the full *Non-native Species* entry below for field-survey-based approaches, but it is likely that future development of remote sensing can provide important contributions to this need. Filling this gap would be *challenging*; methods development and either analysis of existing data or acquisition of new data is required. See detailed descriptions in Appendix B.

Riparian Area Condition (portion of larger Stream and Riparian Area Condition gap; see below): Reporting on the condition riparian (streamside) areas. Techniques are being developed and tested that would allow monitoring of key riparian area characteristics from remote sensing. See full entry below. Filling this gap would be *challenging;* methods development and acquisition of new data are needed. See detailed descriptions in Appendix B.

Gaps Involving Chemical Composition of Various Ecosystem Elements (Requiring Collection, Aggregation and/or Analysis of Field Sampling Data)

- Contaminants Related to Human Exposure
- Nitrogen Yield and Loads
- Carbon Storage / Soil Organic Matter

Three aspects of the chemical makeup of the environment merit high priority attention. These include contaminants in fish and urban soils, because of their potential for human contact. The second is the amount of nitrogen discharged to coastal waters, because such discharges have been implicated in significant ecological damage (e.g., dead zones). The third is the amount of

carbon stored in U.S. ecosystem, which is important because carbon (as soil organic matter) is a critical determinant of ecosystem productivity and because the amount of carbon stored in ecosystems has particular relevance in discussions dealing with the mitigation of global climate change.

- **Contaminants Related to Human Exposure**: Reporting on levels of contaminants found in the edible portions of freshwater and saltwater fish and in fish sold for human consumption. The cost for assessing contamination in the edible portions of fish is between $3 million and $8 million per year; costs for assessing fish sold for human consumption or for determining levels in urban/suburban soils are not available. Some aspects of filling this gap would be *highly and immediately feasible*, whereas others would be *moderately feasible*.; collection of new data is required. See detailed descriptions in Appendix B.

- **Nitrogen Yield and Loads**: Reporting on the amount of nitrogen released per square mile of land, and the total resulting load in major rivers. Costs are estimated at $6.5 million per year. Filling this gap would be *highly and immediately feasible* if a federal data collection effort were used (new data collection); a state based effort would be *challenging;* this would probably require both new data collection and analysis of existing data. See detailed descriptions in Appendix B.

- **Carbon Storage / Soil Organic Matter**: Reporting on the amounts of carbon stored in forests and grasslands/shrublands (including above and below ground portions), and as soil organic matter in farmland areas. Filling these gaps is estimated to require approximately $1.5 million in startup costs and as much as $10.5 million per year. Some aspects of filling this gap would be *highly and immediately feasible*, whereas others would be *moderately feasible;* new data collection would be required, although some existing data may also be incorporated into a new system. See detailed descriptions in Appendix B.

Gaps Involving Understanding the Condition of Species and Biological Communities (Requiring Collection, Aggregation and/or Analysis of Field Sampling Data or Research and Development to Fill Gaps)

- At Risk Species and Communities
- Non-native Species
- Biological Community Condition
- Stream and Riparian Area Condition

The condition of species and biological communities is a crucial and central element to understanding the condition of the nation's ecosystems. The indicator gaps here focus on those elements of the nation's biological wealth that are most at risk of being lost, on non-native species, which are believed to be changing the nation's biological landscape in dramatic ways, and on broader techniques to assess the degree of change of overall biological communities.

- **At-Risk Species and Communities**: Reporting on at-risk plants for specific ecosystems, coastal and marine plants and animals, incorporating data on population trends into all at-risk

reporting, distinguishing between naturally rare and declining species, and improve reporting on at-risk community types. Costs are estimated at about $1.5 million initially and less than $100,000 per year thereafter. Some aspects of filling this gap would be *highly and immediately feasible*, whereas others would be *moderately feasible*; analysis of existing data, research into methods, reconciliation of existing data sources, and collection of new data are required. and See detailed descriptions in Appendix B.

Note: The *Remote Sensing* entry above includes a recommendation that ongoing data needs for the community element of this gap be provided by remote sensing to the greatest extent possible.

- **Non-native Species:** Reporting on non-native plant cover in forests, grasslands/shrubland, and farmlands, and on a wide array of species in freshwater and coastal systems. Startup costs are estimated at about $3 million, with annual costs around $15 million. **Note:** The *Remote Sensing* entry above notes that there is a reasonable likelihood that future advances in remote sensing technology will increase the amount and coverage of non-native plant cover data. Most of the activities required to fill this gap are *challenging*, although some elements are *highly and immediately feasible* or *moderately feasible;* collection of new data and aggregation of existing data are required. See detailed descriptions in Appendix B. **Note:** The Heinz Center is currently reviewing the suite of non-native species indicators to be included in the 2007 report. The revised suite will likely have different data requirements than are specifically outlined here, but the need for non-native species data is nonetheless considered high priority.

- **Biological Community Condition**: Reporting on the overall condition of the suites of species that inhabit and are adapted to specific geographic areas and ecosystem types. Techniques for freshwater assessment are well known and increasingly being implemented by states in cooperation with EPA. EPA provided estimates of as much as $50 million per year for full implementation (via its Environmental Monitoring and Assessment Program, EMAP) of a statistically valid sampling design, but this does not account for state contributions or efficiencies that might be obtained by combining this work with other ongoing state activities. Techniques for terrestrial (forests, grasslands, etc**.)** and marine systems[10] require additional development. Filling the freshwater portion of this gap would be either *challenging* (state based, requiring both collection of new data and aggregation and reconciliation of existing data) or *moderately feasible* (federal, requiring collection of new data). Filling the terrestrial gap would be *challenging*, requiring both methods development and data collection. See detailed descriptions in Appendix B.

- **Stream and Riparian Area Condition**: Reporting on the condition of in-stream habitat in freshwater streams and the condition of riparian (streamside) areas. There are multiple approaches for such assessment (especially for stream habitat), but none has been widely adopted. Reconciliation of methods so that consistent data can be collected in many areas and development of efficient riparian area assessment techniques are required. Filling this gap

[10] Techniques for assessing the condition of *benthic* communities (bottom dwelling worms, clams, snails and shrimp-like animals) are available (and were reported in the 2002 *State of the Nation's Ecosystems* report. However, these approaches assess only a relatively small fraction of marine communities.

would be *challenging;* methods development, aggregation of existing data, and collection of new data are required. See detailed descriptions in Appendix B.

Gaps Related to Human Uses of Ecosystems (Requiring Collection, Aggregation and/or Analysis of Field Sampling Data)

- Groundwater Levels

Use of water for human activities, including agriculture, domestic use, power generation, and industry is one of the most direct human uses of ecosystems. While there are many anecdotal reports describing declining aquifer levels in response to human use, there is no overall assessment of the degree to which the amount of water stored in deep regional aquifers is changing over time.

- **Groundwater Levels**: Reporting on the fraction of the nation's major regional (drinking water) aquifers in which water levels are declining, increasing, or stable. Initial costs are estimated at $4.5-8 million, with annual costs about $0.4-$0.8 million. Filling this gap is considered *moderately feasible;* collection of new data and/or aggregation of existing data are required. See detailed descriptions in Appendix B.

Potential Changes to Data Requirements
Resulting from Refinements to the 2002 Report's Indicators

Landscape Pattern Indicators and Gaps

The 2002 *State of the Nation's Ecosystems* report included seven indicators describing various aspects of landscape pattern – a broad term that includes issues such as fragmentation of natural habitat, the degree to which different land types are intermingled, and expansion of development, often referred to as "sprawl." While many of these indicators described similar features, they were challenging to describe for our intended audience, were not consistent or comparable across ecosystem types, and some were undefined or "in need of further development."

The Heinz Center is currently working to reduce the differences in how this important ecosystem characteristic is reported. A Task Group, chaired by Dr, Norman Christensen of Duke University, is in the final stages of identifying a suite of revised indicators.

The landscape pattern data gaps described in this report generally highlight the need for:

1) Adequately funded capacity for processing existing, available land cover data, generally focusing on the National Land Cover Dataset (NLCD). This applies to the gaps for the core national indicator, farmland, forest, grassland/shrubland, and urban/suburban indicators.

   The revised indicators do not change the need for this capacity. They may identify additional analyses that would utilize such capability (see below), but this is not expected to materially affect the resources required.

   The work of the Task Group has emphasized the need for being able to do credible comparisons between multiple time points using the NLCD data. While this has been an implicit data need, we were unaware of the particular demands that such change analyses place on the NLCD data program. We understand that efforts are underway to reconcile the 1992 NLCD with the 2001 NLCD for some regions, however, it is unclear if such a reconciliation process is fully-funded for the entire dataset.

   In addition, the new suite of indicators is likely to identify the need for housing location in proximity to farmland areas. The NLCD currently identifies an estimated 50% of the housing in these areas, and since low-density housing / suburban development is a significant concern, one of the new indicators will focus on the proximity of housing to farm fields. In 2007, this indicator will likely be reported using NLCD data, but finer scale data would be desirable.

   In addition, data on our nation's road network is very likely to be necessary for one or more revised indicators (to be combined with land cover data), and we are anticipating a data gap dealing with the road network databases. Specifically, these databases have not been set up from a monitoring perspective, with one result being that data are not included that would

enable distinctions to be made between newly-constructed roads and those that had been in the database for years. An associated problem would be distinguishing a newly-constructed road from an older road that was just recently added to the database. Because this data need has recently emerged, we are unable to predict the cost to fill this data gap; we surmise, based on limited contact with this database, that this cost might be substantial.

2) Improvements to the National Hydrography Dataset (NHD) by reconciling this dataset with others that describe the location of dams (primarily the Army Corps of Engineers national dam dataset), and periodic comparisons of the NHD with the National Land Cover Dataset (NLCD).

   The revised indicators reinforce the need for this reconciliation. They will likely identify the need for analyses of the reconciled NHD-dam databases, which would utilize similar capabilities to those identified in item #1 above. It is important to note, however, that even when this reconciliation is complete, substantial analysis / processing is required to produce useful indicators. This work would require analytical capacity similar to that described in #1 above. Presumably, once this capacity were provided, the analyses described here could be undertaken without incurring major costs.

3) Identification of "total impervious area" – lands covered by pavement, buildings, and similar surfaces through which water cannot percolate.

   The revised indicators do not change the need for these data.

4) Identification of vegetation on stream banks (riparian vegetation). The National Land Cover Dataset, when combined with the National Hydrography Dataset, can provide estimates of the fraction of streams with vegetation (or development or agriculture etc.) on and around stream banks.

   The revised indicators do not change the need for these data

5) Finer scale data on stream bank vegetation for urban / suburban areas. In these areas, in which streams may be closely intermingled among developed areas, the resolution of the NHD is insufficient to track whether the stream bank and the riparian area immediately adjacent to the stream bank (i.e., within several feet to tens or at most one hundred feet from the water's edge) is vegetated.

   The revised indicators do not change the need for these data

Non-native Species Indicators and Gaps

As with landscape pattern, the 2002 *State of the Nation's Ecosystems* report included multiple indicators describing various aspects of the extent and distribution of non-native species. And similarly, while many of these indicators described similar features, they were not consistent or comparable across ecosystem types, and one was undefined or "in need of further development."

The Heinz Center is currently working to reduce the differences in how this important ecosystem characteristic is reported. A Task Group chaired by Dr, Ann Bartuska of the USDA Forest Service has identified a suite of revised indicators.

The non-native species data gaps described in this report generally highlight the need for:

1) Identification of the degree of non-native plant cover in multiple ecosystems (including forests, grasslands/shrublands, farmlands).

2) Identification of the occurrence of non-native species in freshwater watersheds (number of species in each watershed).

In addition, there was an undefined indicator for coastal and ocean areas that would likely have required information on both the number of species and the areas occupied. Because this was undefined, no cost estimates could be provided.

The revised indicators under consideration at this time focus on overall invasion levels (percent of species that are non-native), number of new invasions per unit time, non-native plant cover, degree of damage from non-native plant pathogens and pests, and extent of non-native animal diseases. We expect that the 2007 report will identify one of these foci for each of the six major ecosystems and one as a core national indicator.

However, while the specifics of these choices are unclear at this time, the level of importance attached to improving the information base on the extent, distribution, and impacts of non-native species is enormous, both in terms of national reporting and for on-the-ground management. Commitments to increased monitoring capability should not be delayed. The questions outlined here will be will be resolved within the period in which program planning and allocation decisions would be in progress.

Core National Indicators

The 2002 *State of the Nation's Ecosystems* report included ten "core national indicators" – a set intended to describe large scale trends affecting all lands and waters in the United States, as contrasted with the larger number of ecosystem-specific indicators in the other sections of the report (e.g., forests, farmlands, fresh waters, etc.).

Refinement of these indicators is a high priority for the 2002-2007 period.

None of the refinements to the core national indicators is expected to change the nature of the improvements to data collection and reporting methods identified in this report.

SECTION III: CHALLENGES TO THE NATION'S ENVIRONMENTAL MONITORING INFRASTRUCTURE

This report grew out of a specific challenge posed to The Heinz Center and its collaborators following release of the 2002 *State of the Nation's Ecosystems* report, namely to set priorities and estimate costs of filling key data gaps. Individual data gaps are not, however, the only type of challenge limiting the ability of the nation to understand the condition of its environmental and ecological resources.

This section of the report describes a series of challenges to the nation's ability to report on ecosystem condition and use – broad issues, concerns, or trends that appear to affect many major programs that provide national-scale monitoring information.

We did not set out to identify these larger-scale issues. Our examination of the details associated with filling specific data gaps also highlighted key challenges to the overall system that demanded some level of consideration.

The Heinz Center and the State of the Nation's Ecosystems project are neither the first nor the only ones to recognize these challenges. In addition, our identification of challenges is not meant to belittle or ignore the many important efforts to address long standing concerns over the organization and management of the nation's monitoring infrastructure.

We do not provide recommendations for addressing these issues, but rather offer them as the contribution to a larger discussion of the nature of the monitoring enterprise needed by the nation to meet a variety of agenda-setting, management, regulatory, and other needs. Our goal is to confirm that the challenges identified here are as important as we perceive them to be, and by stimulating dialog, contribute to the identification of potential solutions.

These challenges fall in two general areas. The first set describes factors that influence a wide range of *environmental* monitoring programs, not just those dealing with *ecological*[11] resources. (In fact, it may be true that data collection systems in other areas, such as health, crime, employment, etc. also face these challenges.) The second set is more targeted and specific, dealing with issues arising in the context of particular monitoring programs.

Challenges Applicable to Environmental Monitoring Efforts Generally

- **Expectations about the performance and products of the nation's environmental monitoring infrastructure are changing, with new requirements being added to existing systems.**

Data collection and reporting systems have been developed for a variety of reasons, including regulatory compliance and land management. These systems have been designed to achieve specific goals, with levels of geographic coverage, targets for where and what should be

[11] Although neither a hard-and-fast nor a universally accepted distinction, we use the term *ecological* to connote those aspects of the environment that relate primarily to non-human living resources and the term *environmental* to connote a broader range of features, resources, and conditions, including those related to human health and environmental influences on it.

monitored, targeted levels of accuracy, and other parameters appropriate for their intended uses. Many historical monitoring and data collection efforts have been designed to provide information needed for regulatory or management priority setting and decision making (e.g., locations of most troublesome pollution problems, status of lands or resources proposed for extractive activities, etc.). A second major thrust of legacy efforts is providing information on the implementation of programmatic activities – ranging from numbers of permits issued or acres leased to compliance with emissions reductions or other mandated conditions.

A newer set of expectations has arisen over the past fifteen year or so, and is grounded in both a strong, continuing, and government-wide emphasis on program assessment and accountability and broad national, regional, and sectoral efforts assess overall progress (or lack thereof) and to assess general trends for the nation[12] or specific places.

Program accountability measures are based in, for example, the 1993 Government Performance and Results Act, the administration's Program Assessment Rating Tool (PART), and related state-level programs, which are focused on assessing the degree to which individual programs have identified specific objectives and whether those objectives are being met. Broad-scale national reporting is embodied by *The State of the Nation's Ecosystems* and other indicator efforts such as those being undertaken by the multiple *sustainable resource roundtables,*[13] which are targeted at describing broad patterns and trends in the *state* or *condition* of America's ecological resources. These efforts are intended to inform dialogue regarding the management of the nation's resources, which generally includes consideration of whether current protection and management efforts are or are not meeting society's expectations.

The disconnect between the information provided by many existing monitoring programs and that needed to respond to these newer demands should come as no surprise, because the systems in place were not designed to answer this newer set of questions.

- **Systems designed for one purpose may not serve other purposes well.**

It is, of course, a truism to state that a tool designed for one purpose may not serve others well. However, this truism is nonetheless important in the management of the nation's overall monitoring enterprise. If the assets currently in place were not designed to deliver the kind of information now being demanded by society, it may be unrealistic to expect them to do so, or to do so well or efficiently.

[12] There are, of course, important exceptions to these generalizations. Both the USDA Forest Service's Forest Inventory and Analysis (FIA) program, which began in the 1930s, and the USDA Natural Resources Conservation Service's National Resources Inventory (NRI), which began in the 1980s, are examples of efforts intended to provide broad information on national status and trends. The US Geological Survey's National Water Quality Assessment (NAWQA) program and the Environmental Protection Agency's work toward creation of an Environmental Monitoring and Assessment Program (EMAP) are additional examples of large scale monitoring initiatives.

[13] Roundtable on Sustainable Forests: http://www.sustainableforests.net/; Sustainable Minerals Roundtable: http://www.unr.edu/mines/smr/; Sustainable Rangelands Roundtable: http://sustainablerangelands.cnr.colostate.edu/; Sustainable Water Resources Roundtable: http://water.usgs.gov/wicp/acwi/swrr. Roundtable Network: http://roundtablenetwork.cnr.colostate.edu/

For example, managers of regulatory programs have a legitimate interest in understanding whether their compliance efforts are successful. At their simplest, such systems might, for example, determine water quality conditions downstream from one or more discharge points to determine whether permitted discharges are causing water quality problems. Such a system would have no reason to monitor water quality conditions in areas in which there were no permitted discharges, and it is clear that broadening the question – *Are water quality conditions statewide improving or declining?* – would require a greatly different approach to monitoring.

Land management agencies face a similar situation. Clearly, Bureau of Land Management (BLM) staff responsible for activities such as grazing leases on public lands must have information on the condition of areas in which leases are contemplated, both to assess the appropriateness of the leasing request and to determine the effects of any permitted activities. Such efforts – necessarily targeted and non-random – do not, unfortunately provide the basis for broader statements about the condition of the nation's public lands – precisely the type of question now being posed to BLM.

- **There is no overall mechanism to determine the most appropriate and highest priority investments in monitoring and reporting capacity.**

Environmental monitoring and reporting programs have been developed in response to information needs in a wide variety of agencies and programs. Key federal agencies with operational or applied research roles include the Departments of the Interior and Agriculture, National Oceanic and Atmospheric Administration, Environmental Protection Agency, National Aeronautics and Space Administration, although agencies as disparate as the Centers for Disease Control and Food and Drug Administration have roles as well[14]. States collect significant amounts of data, sometimes with federal financial support or under federal guidance in delegated programs.

At the federal level, each of these programs is funded within their agency's overall budget, which means that investments in monitoring are considered in conjunction with all other issues *facing that specific agency*. So, investments in USDA Forest Service monitoring programs are considered first in light of the needs of the Service's own monitoring objectives, but also side by side with competing demands from the National Forest System and programs designed to support state and private forestry activities, then in a broader context that includes Food Stamps, commodity support programs, and technical assistance and outreach to the nation's farmers.

While this balancing and priority setting is clearly appropriate and not likely to go away, there is no mechanism for answering questions such as *Which are the most important / efficient / needed investments to help us ascertain compliance with the nation's environmental laws?* and *Is it more important to make new investments in compliance monitoring or regional / national indicator monitoring?* Such questions imply a different set of tradeoffs and priority considerations, which should not simply over-ride agency-specific priorities, but which currently are not part of the decision-making mix.

[14] Clearly, this list is not exhaustive.

It would be a mistake, however, to imply that tradeoffs are the only product from such cross-cutting efforts. More effective coordination and priority setting could and should benefit both the entire monitoring enterprise and individual programs. Individual agency investments could and should leverage investments by other agencies or entities. Such leveraging creates "win-win" opportunities that can improve both the quality of the data produced and the fiscal efficiency of the affected programs.

A variety of mechanisms have been used to ensure that topical issues crossing agency (and appropriations bill) lines are aired. These include major longstanding formal efforts such as the Global Change Research Program, now the Climate Change Science Program. This effort, designed (among other things) to set priorities for expenditures that total over $3 billion per year, involves multiple layers of scientific and policy assessment. At a different scale, the Office of Management and Budget frequently prepares "budget cross-cuts," which describe the fiscal profile of all programs within a specific topical area.

- **There are probably non-trivial opportunities for cost savings in the overall national monitoring system, but these opportunities are difficult to realize given the relatively fragmented nature of the system.**

We do not wish to downplay the difficulties that would arise in any scheme involving cross-program and cross-agency setting of priorities, or in reducing expenditures in one agency to support higher priority activities in another. Nonetheless, it is clear that, for example, there are instances in which multiple agencies undertake monitoring with similar or overlapping objectives and outcomes, and produce unreconciled estimates of the same environmental feature. As we have noted, improved coordination creates opportunities for efficiency and leveraging, with the potential to produce better data at equal or lower cost.

Estimating land cover provides a potentially useful example. Several agencies, including the US Geological Survey, USDA Natural Resources Conservation Service, and USDA Forest Service produce estimates of the extent of the nation's forests; at least four agencies provide data on the extent of the nation's farmlands; and three produce estimates of wetland extent. These estimates may be totally or partially overlapping (for example, NOAA collects data on wetlands in coastal areas while other agencies produce national estimates), and use different classification systems, and have different levels of accuracy and different reporting cycles.

Clearly, there is a need for a mix of remote sensing and field-based measurements, because field based measurements can serve as crucial cross-checks on remotely based observations. However, it is also possible that a coordinated approach to assessing the various needs for land cover data and development of an integrated system involving land based and remotely sensed data could produce equal or better results at lower cost.

Challenges Applicable Especially to Ecological Monitoring Efforts

- **Important elements in the nation's ecological data collection and reporting system are operated by entities outside the federal government. In many**

cases, federal support is *ad hoc*, relatively small, and not coordinated across agencies.

States and local governments collect large amounts of environmental monitoring data. Some of these activities result from delegated or mandated federal programs such as the Clean Air Act, Clean Water Act, or the new Comprehensive Wildlife Conservation Strategy Programs. Some are voluntary, such as Natural Heritage programs[15]; and yet others are state-initiated and state-specific, such as the programs of the state natural history surveys or efforts to track non-native species.

In some cases, as with air quality monitoring, conducted by state, local, and tribal entities under EPA guidance, this partnership has produced information that is generally viewed as useful for its intended purpose[16] and broadly comparable across the entire United States. In the case of water quality monitoring under the Clean Water Act, there is a general consensus on the part of EPA and others that the existing system is not adequate to provide the kinds of data now seen as important for state, regional, and national water quality decision making. In response to this recognition, EPA and the states have embarked on a series of efforts to expand the reliability and comparability of state-based data.

Natural Heritage programs are another case in which, despite weaknesses in some geographic areas and taxonomic groups, there is a general consensus that the data are far more comprehensive, comparable, and unbiased than any existing alternative[17] and that the data are important for a wide range of uses. This consensus is illustrated by the reliance on Heritage data by organizations such as

- The Sustainable Forestry Initiative (developed by the American Forest and Paper Association, an industry group)
- The Forest Stewardship Council (a forest practices certification effort having its roots in the environmental community)
- USEPA, both as a component of national-level reporting in its Draft Report on the Environment 2003 and in program management decisions such as those involving registration of pesticides
- The Heinz Center, as a data source in the 2002 *State of the Nation's Ecosystems* report

[15] State natural heritage programs are voluntary state efforts that collect, analyze, and make available data on rare, declining, and at-risk species and vegetation communities. Heritage programs exist in every state and are generally located within state agencies and supported with state funds. However, the basic data collection architecture was developed and is maintained and upgraded by a not-for-profit entity, NatureServe. (Until 2001, this program was a component of The Nature Conservancy. NatureServe, is now a free-standing, independent non-profit organization.)

[16] This does not imply that there are not improvements and enhancements to this system that have been identified as desirable. For example, a large portion of monitoring is focused on urban and suburban areas (where most people live), but this means that data on air quality in other areas – important for both rural residents and understanding air quality effects on ecosystems, and farmland and forest productivity – are not as rich.

[17] The primary alternative candidate for data on rare or declining species is the federal "endangered species list" – the record of all species formally listed as threatened or endangered under the Endangered Species Act. While this listing is certainly an accurate record of those species having undergone formal listing, it is not perceived as an adequate assessment of the number and types of species that are rare or declining. This is a consequence of the fact that the list is based on a process with enormous legal consequences, and which is subject to a wide range of litigation, budgetary, and other constraints and influences.

- Literally thousands of federal agency staff, local governments, state government agencies, conservation groups, and consulting organizations who make use of site-specific data provided by individual Heritage programs, or on broad regional, national, or species-specific assessments.

However, despite the recognition that these data represent an important national asset, federal support remains limited to projects in which agencies seek data or analyses for specific purposes. These *ad hoc* arrangements constitute approximately ten percent of NatureServe's annual budget, but do not provide core support for maintenance and enhancement of the overall enterprise, are not predictable from year to year, and are not coordinated by the originating agencies. In addition, these figures do not include the funding provided by states (which supports the majority of data collection); state support varies greatly, with the result being that, while he overall system is strong, there are areas of inconsistency in coverage between states.

- **Important elements of the nation's ecological data collection and reporting system are operated through *ad hoc* interagency arrangements**

Important assets of enduring utility should be managed and planned for in ways that are commensurate with their value and designed to ensure their periodic production and long-term continuity. Failure to do so makes multi-year program planning difficult, and leaves important choices to the vagaries of year-by-year funding. Statutory mandates provide perhaps the highest level of stability; such mandates carry weight with both administration and Congressional decision makers. Other programs, not specifically authorized, are nonetheless recognized in appropriations, through long-term program planning, and the like.

An apparent exception is the mechanism used for production of what is known as the National Land Cover Data Set. This dataset is a product of Landsat-based observations and provides information on land cover[18] across the United States. A full NLCD for the lower 48 states was produced using data from the early 1990s and a second is in preparation using data from 2000 and 2001.

The institutional mechanism underlying NLCD is both an enormous strength and a potentially major weakness. NLCD was originally developed by an interagency consortium (Multi-Resolution Land Characteristics, MRLC), whose members included U.S. Geological Survey (USGS), Environmental Protection Agency (EPA), National Oceanic and Atmospheric Administration (NOAA), the U.S. Forest Service (USFS), the National Atmospheric and Space Administration (NASA) and the Bureau of Land Management (BLM). EPA and USGS share primary administration of the consortium, which has undertaken other projects in addition to NLCD.

This consortium was initiated in 1992 in response to the escalating costs of acquiring satellite images, and resulted in significant savings for each agency and development of what is now viewed as a crucial element of the nation's environmental information infrastructure. The users of NLCD are legion, and anticipation of the second round (i.e., the 2000-2001 data set) is

[18] NLCD provides data on 21 land cover classes (e.g., deciduous, hardwood, mixed forest; pasture/hay, row crops, small grains, etc.). These data are at a 30-meter resolution, meaning that the smallest area characterized is a square "pixel" about 100 feet across. See http://landcover.usgs.gov/natllandcover.asp.

significant, because it has the potential to provide the most fine-grained, two-time-period[19] view of the nation's landscape ever available.

However, while the entrepreneurial development of this effort was crucial to its success, its lack of formal interagency existence, and its funding strategy – which relies upon contributions made available from a number of offices in different agencies, often on an annual basis – means that the program cannot plan for the long term, may not be able to meet expectations in a timely fashion, and may have to defer key elements of the effort.

For example, as of mid-2004, development of enhanced information on impervious surfaces, considered crucial for assessments of the effect of residential, commercial, and industrial development on water quality, was only partially funded, with commitments sufficient for only 40-45 of the nation's 66 mapping zones.

The fact that a full NLCD from the 2000-2001 period is not yet available would seem to be another consequence of the *ad hoc* funding strategy. Land cover data – and especially data that can show changes in land cover – are important because they point to important changes in landscape condition. If the data are five or six or more years old by the time they become available, their value is diminished. Indeed, many reviewers have noted that these data should be available every five years, not only once a decade, as with the current effort.

- **Research and development programs are fundamentally different from operational monitoring programs and it is important to ensure smooth transitions between the two.**

Research and development (R&D) monitoring programs have as their objective the expansion of basic knowledge about monitoring techniques, indicators, assessment, and interpretation, as well as development, testing, and demonstration of tools and methods. Operational programs on the other hand, have as their main goal the guaranteed, routine, and sustained delivery of established suites of monitoring data[20].

R&D programs are often the source of important improvements in monitoring practices. However, the management, design, and cost structure of R&D efforts is different from that of operational monitoring programs, and it is important to identify strategies to transform proven R&D programs into effective long term operation monitoring assets.

EPA's Environmental Monitoring and Assessment Program (EMAP) is an example of a high quality research and development program. This effort has pioneered the introduction of random,

[19] MRLC and the associated data sets (e.g., NLCD) were originally conceived of as a long-term research program in methods of land-cover monitoring. There remain many technical issues to be resolved, perhaps especially issues of how best to compare data from one time period to another, given the program's uses of both sampling and wall-to-wall data. However, it is important to remember that MRLC is a long-term research project, and there is not at this time a national commitment to transform it into a truly operational activity.

[20] The First Annual Integrated Ocean Observing System (IOOS) Development Plan, a report of the National Ocean Leadership Council (December 2004, prepared by Ocean.US) defines "operational" as "an activity in which the provision of data streams and data products of known quality is routine, guaranteed, and sustained (in perpetuity or until no longer needed) at rates and in forms specified by user groups."

statistically-based approaches for monitoring ecological conditions over large areas and has led the way in design and development of both specific indicators and overall assessment strategies. It is a powerful engine of intellectual contribution to the nation's monitoring capabilities.

It is, however, not an operational program. EMAP has neither the field capabilities nor the resources to undertake frequent nationwide monitoring efforts. Rather, ideas and modules initiated by EMAP must find a "home" – another EPA program or a similar institutional setting, enabling EMAP to move to other challenges, and ensuring a good match between institutional goals (i.e., ongoing monitoring versus research) and program needs. For example, EMAP contributed significantly to the development of techniques now being tested for potential nationwide implantation under the aegis of the Clean Water Act. In another example, the National Coastal Condition report, which brought together EMAP concepts and the skills and resources of several agencies, faces an uncertain funding future.

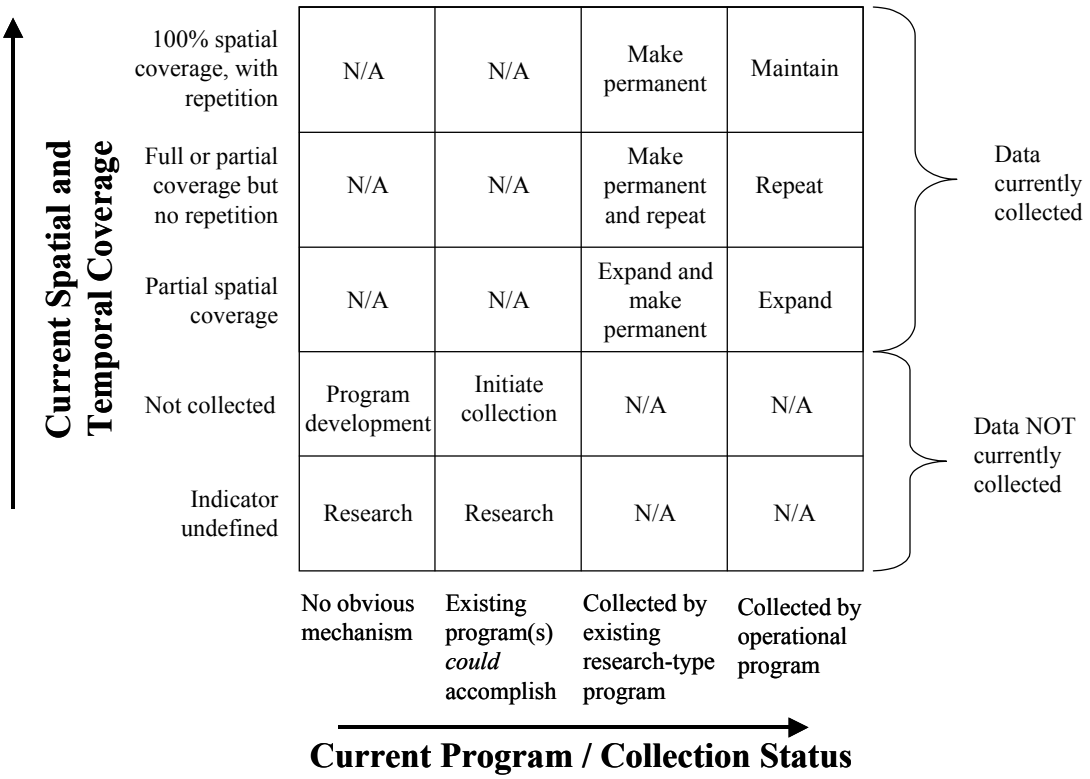
Simply put, there is no established mechanism to identify the most promising R&D products and craft strategies to transition these efforts into operational mode, even when the nation would be better off (i.e. save money, get better information). Such activities might include identifying funding and institutional locations, devising incentives for broad adoption, and the like.

The "R&D to operational" transition is in fact a simplification of the true needs for life cycle management for elements of the nation's monitoring infrastructure. As was demonstrated in the 2002 *State of the Nation's Ecosystems* report, data collection for key indicators exhibits varying degrees of completeness, repetition, and institutional setting. See Figure 1.

A challenge facing the management of the nation's monitoring infrastructure is to move promising and important elements toward the upper right corner of Figure 1 – toward a situation in which the data the nation seeks is collected periodically, with full national coverage, and by an institution whose management and orientation are operational in nature.

The recommendations for filling of data gaps presented in Section II above can be placed on this chart, with the appropriate "next step" easily outlined. For example, the need for full national coverage for *nitrogen yield and load in rivers* presents a situation in which some but not all data (i.e., the horizontal row labeled "partial spatial coverage") is collected by several elements of USGS, including the National Stream Quality Network, an operational program and the National Water Quality Assessment Program (NAWQA), an R&D-type program. Thus, the challenge for this gap is to "expand (geographically) and make permanent" those elements in the R&D program and "expand" those in the operational program. The *biological community condition* gap is more fundamental, and would be placed in the lower left corner, because there is no entity currently charged with similar monitoring, and the indicator required additional technical development and definition.

Figure 3: Monitoring Programs Should Be Consciously Managed Through a Predictable Developmental Cycle.



Additional Information located in Volume II: Appendices
available online: http://www.heinzcenter.org/ecosystems/DataNeeds_Vol2.pdf

The appendices provide additional information on these and other gaps identified in the 2002 *State of the Nation's Ecosystems* report, including:

- One page summaries of each of the ten key gaps highlighted here.
- Full descriptions of the individual elements that comprise the larger gaps presented in the report and one-page cluster summaries.
- A listing and brief descriptions of the gaps identified in the 2002 report that were rated as *High, medium, or low priority* in our survey, or which were not included in the survey because of definitional problems, and which were not selected to be highlighted as *Highest priority* for this report.
- Additional information on the types of costs considered in estimating the resources needed to fill gaps.