

Special Program - Acid Rain: Are the Data and Information Problems Solved?

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ABSTRACT

The topic, generally known as acid rain, presents a series of data and information challenges to researchers, policy makers, and librarians and information specialists. Acid rain became one of the first and at the time one of the largest and most vexing environmental problems of a global scale in terms of both its origins and in its solutions. The transport of air pollutants over long distances had been postulated as early as the 17th Century. Scientific study of the chemical composition of the Earth's atmosphere began in earnest in the later half of the 19th Century and continues today. This paper examines the challenges for the identification and acquisition of acid rain data and information and several trends related to research and policy aspects of acid rain.

INTRODUCTION

Like many of today's environmental problems the causes and sources of acid rain have no respect for political boundaries. The polluting sources of acid rain may be found hundreds or thousands of miles up-wind from the ecosystems suffering adverse effects. The long range transport of pollution in the Earth's atmosphere requires inter-regional and international cooperation and exchanges of research data and technologies to identify the causes, effects, remediation, and reduction or, hopefully, the elimination of the causes of acid rain.

In addition to the exchange of scientific and technical research data is the need to broadly disseminate the resulting data and information bases among all parties involved in the study of the problem of acid rain: the interdisciplinary communities of researchers, policy makers, managers, administrators, educators, and students. This dissemination of multi-disciplinary data and information is necessary to stimulate and sustain the exchanges across disciplines for the ideas and

proposals to reduce the causes and effects of acid rain.

There are four major data and information challenges revealed as a result of multi-disciplinary studies related to acid rain: the growth of the data and information base reporting the results of research on the topic; the rapid growth and dispersion of the information base among the multi-disciplinary communities generating and consuming this data and information base; the rapid changes in information technologies required to identify, acquire, archive, disseminate and utilize the data and information resulting from research and policy analyses; and the need to assure equity in the access to this data and information across disciplines, lines of work, corporate or individual lines of thought or need.

ACID RAIN INFORMATION: STUDY OF RESEARCH IN A HISTORICAL PERSPECTIVE BUILDS AN INFORMATION BASE

Scientific and technical information is derived from data and recording the results of research from laboratory and fields studies, monitoring campaigns, modeling strategies and other activities. The topic of acid rain has a rather long information trail and a rich history revealed in its literature.

Ellis Cowling (1) provided the first major historical review of the acid rain problem, tracing its origins to studies by Evelyn in 1661 and Graunt in 1662 noting the influences of industrial air emissions to plants and humans and the transboundary transport of air pollutants between England and France. Cowling attributes the first use of the term "acid rain" to R.A. Smith in an 1872 book *Air and Rain: The Beginnings of a Chemical Climatology* (London, Longmans, Green), who noted chemical variations in the chemistry of rainwater and the influence of the

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combustion of coal, direction of the wind, and proximity to the sea as affecting the damage to plant life and materials exposed to rainwater.

The early decades of the 20th Century saw a small number of scientific articles continuing to monitor the acid content of rain in Australia (2), the United States (3), Uithuizermeeden, Groningen (4), and Russia (5). These papers reflect an effort to record basic rain water chemistry with implications for variations due to natural (meteorological) or human (combustion of carbon-based fuels, e.g., wood and coal). Cowling (1) provides a chronology of increased monitoring of rainwater in Europe and increased studies relating the effects of acidification to biotic and abiotic components of the environment.

The decades of the 1950s and 1960s saw a continuation of research dealing with the chemical composition of rain and the atmosphere. Much of this research focused increased interest of the implications of acidification of rainfall as a result of industrialization and rain water predominantly in Europe (6-7). These European research initiatives lead to one of the first major general reviews of the phenomenon linking increased acidification of rain and other forms of precipitation attributed to the generation of sulfur dioxide in the industrialized regions of West Germany and England (8). John Reuss of the U.S. National Ecology Research Laboratory (Corvallis, Oregon) authored one of the earliest U.S. Technical Reports linking carbon dioxide—carbonate equilibrium and its relationship to the ecological effects of increased acidity of acid rainfall (9). In the same year F.B. Hill proposed the need for increased information to more accurately model the impacts of sulfur dioxide and ecosystem responses to environmental dosing of sulfur compounds in the environment (10). At the close of the 1960s Svante Oden described the effects of changing acidity of precipitation in Sweden as a result of industrial pollutants in England and their transport over space and time and their impacts to the environment (11). Cowling (1) notes that a series of lectures by Oden at the 1971 International Limnological Congress in Winnipeg, Manitoba stimulated both scientific and public scrutiny of acid rain and its effects on the North American continent.

The 1970s was marked by a rapid increase in the gathering of preliminary background information on the phenomenon of acid rain. As a result of this increase in research and investigation, it was during the decade of the 1970s that the first trends of a rapid growth in the literature related to acid(ic) rain and acid(ic) precipitation (12-17) was seen in 1976. Publication of the *1st International Symposium on Acid Precipitation and the Forest Ecosystem* (18) held in 1975 and the publication of a triple, special issue of the journal, *Water Air and Soil Pollution* (19) marked the beginnings of a period of rapid growth and accumulation of literature related to acid(ic) rain and acid(ic) precipitation. It was during this period that researchers such as Gene Likens, F. Herbert Borman, and Charles Cogbill (14-17) noted patterns similar to those cited by Oden in rainwater chemistry and the environments of North America, especially in the Northeast U.S. and Southeast Canada.

COORDINATED RESEARCH IN THE 1980s

In 1977 the President's Council on Environmental Quality began calling for the consolidation of the existing monitoring and research programs such as the National Atmospheric Deposition Program and the Multistate Atmospheric Power Production Pollution Study. President Jimmy Carter announced in August 1979 the creation of a 10-year initiative to study the causes and effects of acid precipitation in Title VII of the Energy Security Act (P.L. 96-264), the Acid Precipitation Act of 1980. A major provision of the Acid Precipitation Act was the creation of the National Acid Precipitation Assessment Program (NAPAP) to define an ongoing, 10-year research initiative to provide a solid scientific understanding for the development of sound environmental policies that were needed to address the issues related to acid rain.

It was during this period that an era of coordinated interdisciplinary research was started and took on its own transboundary aspects with conferences focusing on the international exchange of ideas, resources, and research results. The media increased its news coverage of the phenomenon of

acid rain, which until the late 1970s had remained more of an academic or scientific curiosity. As media coverage increased so did public concerns and demands for answers to the issue of acid rain.

This period of coordinated scientific research had a unique feature in providing the scientific and technical underpinnings for the development of policies that would ameliorate, reduce, or otherwise eliminate the threats to the Earth's ecosystems resulting from the effects of acid precipitation. The coordination of research clearly focused on the need for interdisciplinary initiatives that involved not only the physical and life sciences, but also included the social and policy sciences as well. The relationship between scientific research and policy developments took on new meanings as a debate over science-driven policies or policy-driven science emerged amid the political climate of the 1980s in the U.S. and elsewhere.

It is also noted that during the early 1980s attempts were made to develop specific information services and programs for acid rain. The Center for Environmental Information (CEI, Rochester, New York) secured funding for the development of the Acid Rain Information Clearinghouse (ARIC) in 1982 and developed a series of reference and referral services, conducting regional and international multi-disciplinary conferences, the development of a dedicated research library collection for acid rain literature, and began publication of the highly acclaimed current-awareness publication, the *Acid Precipitation Digest*. ARIC also served as the New York component of the New York-Quebec Acid Rain Documentation Center, which facilitated the development of the *ACIDOC* bibliographic database, which is still a viable information database operated by the Quebec Ministry of Environment.

CONTINUATION OF A RESEARCH AGENDA AND IMPLEMENTING RESULTING POLICIES

Authorization of the Clean Air Act Amendments of 1990 coincided with the end of the 10-year mandate of NAPAP. Implementation of the provisions of the Clean Air Act, a continuation of

the long-term monitoring and research programs established by NAPAP, and further refinements of research agendas would become the driving forces of acid rain study at the close of the 20th Century.

During this period the growth of acid rain information continued as projects initiated during the NAPAP era publish the results of their research and monitoring programs. While a majority of this current information base remains in the physical and life sciences (biology, chemistry, ecology, geology, physics), it is during the 1980s and 1990s that we see the emergence of a solid literature base developing in the social sciences (economics, education, geography, information and data management, law, management, policy science, psychology). There appear two rather distinct clusters within the social science research. The first cluster of social science literature published in the 1980s begins to formulate the economic aspects of the effects of acid rain to ecosystems and materials. To a larger extent is the emergence of policy and legal strategies required to address the precursor pollutants causing acid rain, most notably sulfur dioxide and oxides of nitrogen. A second clustering of social science literature in the 1990s and continuing into the first decade of the 21st Century are articles discussing the effectiveness of various abatement strategies outlined in the Clean Air Act Amendments of 1990 <<http://www.epa.gov/airmarkt/arp/reggs/caaa.html>>, and the effectiveness of emissions trading scenarios to reduce the overall generation of sulfur dioxide.

A SURVEY OF ACID RAIN LITERATURE, PART 1. GROWTH OF INFORMATION

To examine the scientific literature base of acid rain, the *Chemical Abstracts* portion of the CAS database, *SciFinder Scholar*, which was used to collectively gather bibliographic data on the concepts of acid(ic) rain (rainfall, rain water, etc.) and acid(ic) deposition. *SciFinder Scholar* was selected as one of several bibliographic data bases from which to examine the simple search strategy of "acidity of air pollution or acid rain" provided the most direct and comprehensive retrieval of related information. Selection of the *Chemical*

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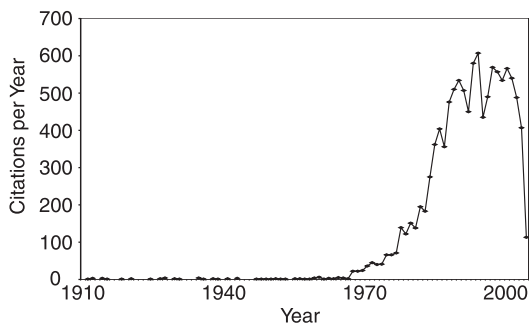


Figure 1. Growth of acid rain literature, 1907-2002 (June), Chemical Abstract and SciFinder Scholar.

Abstracts portion of SciFinder Scholar was for its abilities to sort and analyze components of the bibliographic data retrieved and the comprehensive treatment of the scientific aspects of the subject matter covered by Chemical Abstracts. Figure 1 shows the growth of the literature base of 11,206 citations retrieved on these topics from 1907 to June 2002.

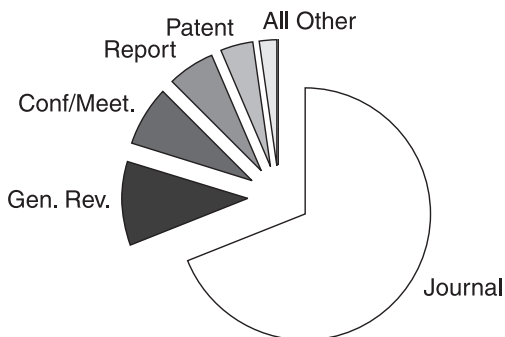


Figure 2. Types of acid rain literature published 1907-2002 (June), Chemical Abstracts and SciFinder Scholar.

Of this total, 8,841 citations were published as journal articles (79%). Figure 2 shows the distribution of published acid rain literature from the SciFinder Scholar database, and clearly shows the dominance of the journal article as the primary source of information and the primary vehicle for

Table 1. List of the 20 journals most frequently publishing articles about acid(ic) rain or acid(ic) precipitation. Data retrieved from the Chemical Abstracts portion of the SciFinder Scholar database from 1907 to June 2002.

<u>Number of Articles Retrieved</u>	<u>Journal Name</u>
611	Atmospheric Environment and Atmospheric, Part A
461	Water, Air, and Soil Pollution
276	Proceedings of the Annual Meeting of the Air and Waste Management Association (and the Proceedings of the APCA Annual Meeting)
203	Environmental Science and Technology
149	Environmental Pollution
122	Journal of Geophysical Research (Atmosphere)
106	Science of the Total Environment
83	Studies in Environmental Science
77	Journal of Atmospheric Chemistry
73	Geophysical Research Letters
64	Journal of the Air and Waste Management Association and the Journal of the Air Pollution Control Association
64	Kinky Jujutsu
58	Keening Exude Xebio
56	Journal of Aerosol Science
54	Chemosphere
54	Journal of Environmental Quality
52	Haunting Kexue
51	Zhongguo Huanjing Kexue

disseminating information on the topic. The journals publishing the most number of articles are listed in Table 1.

The research Agenda set forth by NAPAP provided a fertile environment for the publication of resulting research results and helped to sustain the proliferation of literature for more than 20 years. A closer examination of the impacts of NAPAP on the generation and subsequent publication of scientific and technical information is found in the production of U.S. Federal technical reports and output of graduate research measured by the production of doctoral dissertations and theses on the topics related to acid rain. Again, the data was extracted from the pool of bibliographic data obtained from the SciFinder Scholar database and are presented in Figure 3. It appears that NAPAP funding and support stimulated graduate research and as the overall quantity of NAPAP sponsored research declined, so did the number of technical reports and scholarly dissertations.

DISPERSION OF ACID RAIN ACROSS DISCIPLINES

An analysis of the output of literature searches done in the Institute for Scientific Information Web of Science database allows users to review the contents individually or as the combined three resources comprising the Web of Sciences: the Science Citation Index, the Social Science Citation Index, and the Arts and Humanities Citation

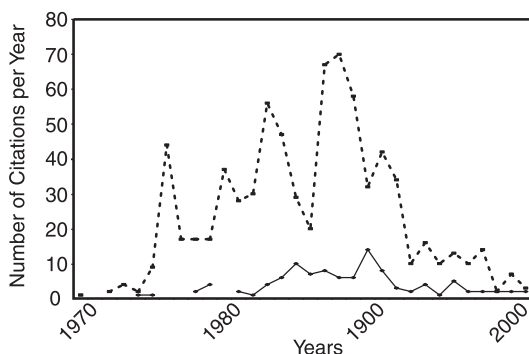


Figure 3. Growth of technical reports (top) and dissertations (bottom) in Chemical Abstracts, SciFinder scholar, 1970-2002.

Index. A total of 5,224 items were retrieved from a combined search of terms acid(ic) rain, acid(ic) precipitation, or acid(ic) air pollution(tants) from 1977-2002 (the period to which access was limited). Of this total, 4,968 citations are found in the *Science Citation Index* (covering the physical, applied, and life sciences), 418 citations in the *Social Sciences Citation Index* (covering legal, policy, business/economic, and education aspects), and 27 citations in the *Arts and Humanities Citation Index* (including articles on ethics, effects to art works and statuary, contribution of poetry and prose, history and philosophy of science). A more exhaustive survey of the acid rain literature can be constructed by use of the bibliographic databases described in the next section.

BIBLIOGRAPHIC CONTROL OF ACID RAIN LITERATURE

The environmental literature from various multi-disciplinary research agendas around the world appears in a very large number of bibliographic databases (20-22). The major bibliographic utilities from which acid rain literature can be identified and accessed are described here.

ABI/Inform covers the business, management, policy and regulatory compliance aspects of scientific issues and topics, including those related to acid rain. This database also provides good coverage of the various trade publications in the energy, environmental, and regulatory segments of business and industry.

ACIDOC covers all aspects related to acid precipitation from its source to its control. General works; environmental effects: effects on aquatic ecosystems, effects on terrestrial ecosystems, human health effects, ecosystem sensitivity, effects on materials, monitoring; air and atmospheric processes: emissions, meteorology, transportation, deposition, monitoring; socio-economic aspects; political aspects: law, regulations, government policy, international relations, economic effects, education, public participation; mitigative and corrective measures: emission reduction, chemical treatments, liming, biological methods.

AGRICOLA is the U.S. National Agricultural Library's AGRICulture OnLine Access database covers the literature of agriculture, including

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agricultural and forest ecology, environmental quality and impacts associated with agriculture (including aquaculture) and forestry practices, environmental and human health aspects of environmental change (including the causes and effects of acid rain to agriculture and forestry).

Aquatic Biology, Aquaculture & Fisheries

Resources is a combination of the world's premier databases covering fisheries and aquatic sciences. It combines all relevant portions of *Aquatic Sciences & Fisheries Abstracts* with the FISHLIT, CABI and AGRIS Fisheries & Aquaculture databases' subsets, and resources from *Fisheries Review*, Fish & Wildlife Reference Service.

ASCE's Civil Engineering Database is a Web-based database produced by the American Society of Civil Engineers that provides citations to all ASCE publications, including those devoted to environmental engineering, including acid rain and air pollution control.

Biological Abstracts/BIOSIS Previews provides the full range of topical coverage related to the biological and life sciences, including biological and biochemical aspects of ecology, effects of biological and chemical agents on biological systems, biological impacts of climatic changes, environmental biology, pollution biology (water, air, and soil). The effects of acid rain to biota and ecosystems are covered in a comprehensive manner.

Chemical Abstracts (see *SciFinder Scholar*)

*Compendex*Plus* covers over 2,600 journals and conferences as well as non-governmental reports in all areas of engineering including environmental engineering. Environmental topics covered include the physical and chemical aspects of pollution, environmental restoration and remediation, risk assessment and management, health and safety, hazardous waste management and impact analysis, and energy exploration, delivery, use, and management.

Current Contents Connect (ISI) provides multi-disciplinary bibliographic coverage of the contents of over 8,000 major journals and scholarly reviews including the literature of ecology, environmental science (biology, chemistry, engineering, geology, physics), and environmental management and policy (sociology, business, economics). (see also *Science Citation Index*, *Social Science Citation Index*, and the *Web of Science*)

Digital Dissertations (*Dissertation Abstracts/Index*) indexes doctoral and masters theses from all disciplines including those related to scientific, technical, policy, social, and legal aspects of air pollution, acid rain, and related studies.

DOE Reports Bibliographic Database contains citations for Department of Energy (DOE) sponsored scientific and technical reports. Environmental coverage is directed primarily to ongoing DOE-sponsored research in ecology and ecological restoration, global environmental change, acid rain and the ecological and environmental aspects of energy science and policy.

DOE Information Bridge is a publicly accessible website that provides access to the full-text and bibliographic records of DOE research and development reports in the sciences with multi-disciplinary coverage of environmental and energy sciences. The database includes over 2 million searchable pages in over 27,000 reports produced by the DOE and the extended DOE contractor research community released to the public since January 1996. An expanded and enhanced version of this database is available for DOE contractors.

Dow Jones Interactive provides access to the full text of current and retrospective news stories, periodical articles, and financial data from several thousand sources covering virtually every subject. Although often associated with business information, Dow Jones Interactive is much more than a business database, with coverage of environmental issues such as hazardous waste remediation, regulatory compliance, health and safety issues, and environmental policy.

Ecology Abstracts focuses on the interactions of organisms with their environment and provides detailed coverage of the impacts of natural and human interactions with ecosystems and the environment, including environmental change and destruction.

Energy Science and Technology Database abstracts and indexes basic and applied scientific and technical research literature. It was designed for use by government managers and researchers at the national laboratories, and other technical/research efforts sponsored by the U.S. Department of Energy and includes coverage of ecology,

including the assessment of energy technology on the environment.

Environment Abstracts/Environmental Universe covers a broad range of issues and topics related to the environment and the management and use of natural resources. Coverage includes: air pollution, acid rain, environmental education, environmental law and policy.

EPA National Online Library System (OLS) consists of several databases with information on books, reports, and audiovisual materials on a variety of topics. OLS contains the holdings for most of the 28 EPA libraries at the EPA Headquarters (Washington, D.C.), the ten EPA Region offices, and EPA laboratories. It also contains records for EPA documents distributed through the National Technical Information Service (NTIS).

ERIC, the database from the Educational Resources Information Center, is the largest education database in the world with coverage of over 800 periodicals and non-journal publications (research papers, guides, government reports, speeches and more). Topics range across all aspects of educational research and practice and cover conservation, energy, environmental, nature, and outdoor education with ample coverage related to acid rain.

GeoArchive is a major geoscience database covering more than 5,000 serials, books from more than 1,000 publishers, conferences, doctoral dissertations, and technical reports as well as over 15,000 geological maps. Provides coverage of geoscience, hydroscience, and environmental science topics.

GeoRef, produced by the American Geological Institute database, is the most comprehensive database in the geosciences, covering all aspects of geology and geography including the earth sciences and the environment.

GPO Monthly Catalog is a comprehensive listing of federal government publications. It attempts to index all the unclassified publications of federal government agencies. These include reports (policy, assessments, technical), booklets, popular publications, and Congressional documents related to ecology and the environment (Senate and House hearings, committee reports).

The legislative chronologies related to acid rain are found in this database.

InfoTrac OneFile covers articles from more than 1,500 scholarly, trade, and general-interest periodicals, and provides access to articles for the most recent six months of the *New York Times*. Subject coverage includes humanities, social sciences, general sciences, and current events including broadly defined coverage of ambient, home, and workplace environments. *OneFile* was formerly known as *Expanded Academic Index*.

Marine, Oceanographic & Freshwater Resources is a bibliographic database on marine, oceanographic, and related freshwater resources. Providing coverage on international marine and oceanic information, as well as substantial coverage of estuarine, brackishwater, and freshwater environments,

MEDLINE database produced by the National Library of Medicine provides comprehensive coverage of the biomedical literature including all aspects of environmental health and medicine related to acid rain and its precursor air pollutants, sulfur dioxide and oxides of nitrogen.

NOAA Library Catalog is a searchable interface to the holdings of the National Oceanic and Atmospheric Administration's library network. Collections consist of reports, special datafiles and datasets, documents, articles, and audiovisual resources related to ocean science and atmospheric sciences.

NTIS is the National Technical Information Service, the U.S. government's central source for reports written on scientific, technical, engineering, and related business information produced by or for the U.S. government.

Pollution Abstracts is the leading resource for environmental engineers and scientists, hydrogeologists, geologists, chemists, industrial engineers and hygienists, corporate regulatory affairs managers, waste managers, and government officials concerned with pollution.

SciFinder Scholar is a bibliographic and reference research tool based on an enhanced compilation of Chemical Abstracts and MEDLINE. Users explore this collection by research topic, substance identifier, chemical structure, chemical reaction, or author's name. It includes materials on the chemical aspects of earth

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sciences and geology, ecology, environmental impact, pollution, and toxicology.

USGS Online Catalog is the online catalog of the USGS library and includes over 200,000 records for books, periodicals, maps, microforms, videocassettes, CD-ROMs, and pamphlets. Online citations describe items that have been added to the library since 1975 plus all of the publications of the USGS. To find information about maps and related data for geology, natural hazards, earth resources, geophysics, geochemistry, geochronology, paleontology, and marine geology, look at this resource site.

Web of Science is comprised of the Science Citation Index, Social Sciences Citation Index, and Arts & Humanities Citation Index. The database covers journal articles in all subject areas including environmental science and engineering.

ACID RAIN AND THE INTERNET

The topic of acid rain emerged before the popularization of the Internet and the creation of the World Wide Web (WWW). This does not mean the topic of acid rain is not found in the Internet or the WWW. While it is completely beyond the scope of this present paper to provide a comprehensive inventory of the acid rain-related online sites, it is possible to highlight several of the more useful sites.

An analysis of the raw retrieval of information retrieved by several major Web search engines provided the results listed in Table 2. Table 3 shows the breakdown by domains for the 257,900 matches made by the HotBot search engine

Clearly, there is an abundance of resources on the topic of acid rain on the Internet. A primary

Table 2. Search results for acid(ic) rain, acid(ic) precipitation, or acid(ic) air pollution(tants) on the Internet.

Search Engine	Number of matches
AltaVista	1,261
Google	8,000
HotBot	257,900
Northern Light	13,254

Table 3. Domain breakdown for Hot Bot search engine results.

Domain	Number of Matches
.gov	17,400
.org	45,200
.edu	59,700
.mil	<500
.com	5
.us	8,100
.ca	12,900
.uk	9,200
.se	>900

feature of the Internet is the ease with which scientific and technical data can be brought to the individual, classroom, library, or organization. There are, however, many words of caution about the Internet and the WWW, all of which can be summarized as, "Buyer Beware!" and "Sorting the Wheat from the Chaff." It is not nearly as easy to delineate what is "good" data or information or what is "bad" data or information on the Internet.

The University of South Carolina's Beaufort Library has a very good tutorial for searching the World Wide Web for relevant resources, "Bare Bones 101: A Basic Tutorial on Searching the Web" <http://www.sc.edu/beaufort/library/bones.html>. Librarians at the University at Buffalo created "How to Find What You Want on the World Wide Web" <http://ublib.buffalo.edu/libraries/search/searchint.html> as an interactive tool for locating and evaluating resources obtained on the WWW.

Provided below is a short and *representative sample* of a few dozen of the hundreds of high-quality acid rain web sites available for researchers, policy makers, educators, students, librarians, managers, and administrators to use when looking for data and information resources on the topics related to acid rain.

National Acid Precipitation Assessment Program (NAPAP)

<http://www.oar.noaa.gov/organization/napap.html>

NAPAP remains an interagency program to coordinate scientific research, environmental

monitoring, and integrated assessments for examining the effects of acid precursors, sulfur dioxide and oxides of nitrogen. NAPAP extends its network among individual states, universities, private sector interests in the energy industries, and among six Federal Agencies: Department of Agriculture, Department of Energy, Department of the Interior, the Environmental Protection Agency, the National Aeronautics and Space Administration, and the National Oceanic and Atmospheric Administration. NAPAP was reauthorized under Section 901, j of Title IX of the Clean Air Act Amendments of 1990 (P.L. 101-549), which also included Title IV, the Acidic Deposition Control Program. NAPAP's biennial reports provide the scientific underpinnings linking ongoing research and monitoring activities to policy initiatives. In addition to NAPAP's assessment documents and reports is the Tracking and Analysis Framework, a modeling framework developed to access, inform, and guide U.S. regulatory policies on emissions of acid rain precursors. The TAF Model can be navigated by going to its Web site at <http://www.lumnia.com/taf/start.htm>. Table 4 lists acid rain-specific Web sites maintained by federal departments of agencies participating in NAPAP.

The National Atmospheric Deposition Program/ National Trends Network (NADP/NTN)

<http://nadp.sws.uiuc.edu/nadpoverview.asp>

NADP/NTN was established in 1978 as a network of 22 monitoring stations in the U.S. Today, more than 200 stations are found in the continental U.S., Alaska, Puerto Rico, and the Virgin Islands. In addition to monitoring precipitation for hydrogen (acidity as pH), sulfate, nitrate, ammonium, chloride and base cations (e.g., calcium, magnesium, potassium, and sodium), more than 35 sites are now participating in the Mercury Deposition Network (formed in 1995 to collect weekly samples for mercury content). From

this site it is possible to link to a variety of NADP data products:

- Weekly and daily precipitation chemistry data
- Monthly, seasonal, and annual precipitation-weighted mean concentrations
- Annual and seasonal deposition totals
- Mercury deposition data
- Daily precipitation totals
- Color isopleth maps of precipitation concentrations and wet deposition
- Site photos, maps, and descriptive information
- Quality assurance data and information

Data are available for individual sites or as a series of isopleth maps (2000 data) as gif images and Adobe PDF (portable document format) maps (there are a total of 22 maps, one for each parameter).

The Atmospheric Integrated Research Monitoring Network (AIRMoN) is part of the NADP/NTN and provides a higher resolution of temporal acid rain data. A variety of AIRMoN data products can be retrieved at <http://www.arl.noaa.gov/research/programs/airmon.html>. Data provided includes daily wet and dry deposition and various inter-laboratory programs in the U.S. and Canada.

Man and the Biosphere Program

<http://www.mabnetamericas.org/>

As stated in the introduction from the Man and the Biosphere Home Page, "The MAB Program is an interdisciplinary research effort directed toward providing information for the solution of natural resources and environmental issues. As an intergovernmental program, MAB presents an opportunity for international cooperation and a focus for the coordination of related programs aimed at improving the management of natural resources and the environment."

Table 4. Acid Rain Web sites for Federal NAPAP or Acid Rain Departments and Agencies.

EPA	http://www.epa.gov/airmarkets/acidrain/
NOAA	http://www.oar.noaa.gov/organization/napap.html
USGS/DOI	http://bqs.usgs.gov/acidrain/

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MAB is an international cooperative of environmental research organizations operating in the following Regional Networks:

- AfriNet
- ArabNet
- East Asia
- EuroMAB
- MABNetAmericas
- IberoMAB
- USMAB

The Biodiversity Resources for Inventorying and Monitoring (BRIM) component of MAB is a major component of MAB and is a collaboration of U.S. MAB and the Information Center for the Environment to facilitate collection and dissemination of biological inventory and monitoring information derived from protected areas worldwide. Components of BRIM include the MABFlora and MABFauna software programs to standardize methods in the collection, storage, and retrieval of bioinventory information.

“The mission of the United States MAB Program is to explore, demonstrate, promote, and encourage harmonious relationships between people and their environments building on the MAB network of Biosphere Reserves and interdisciplinary research. The long-term goal of the U.S. MAB Program is to contribute to achieving a sustainable society early in the 21st Century. The MAB mission and long term goal will be implemented, in the United States and internationally, through public-private partnerships and linkages that sponsor and promote cooperative interdisciplinary research, experimentation, education and information exchange on options by which societies can achieve sustainability.” (Adopted by the U.S. National Committee MAB, July 26, 1995)

The U.S. MAB is operated by the Department of State, Bureau of Oceans and International Environmental and Scientific Affairs. A July 1, 1998 directive describes the main functions of biosphere reserves as:

1. conservation of important biological resources;
2. development of environmentally sound

economic growth;

3. support of environmental research, monitoring, education, and training;
4. as a framework to bring people together to accomplish the above three.

The United States has 47 biosphere reserves with 99 administrative units. The *protected areas* and *managed use areas* are owned/administered by the National Park Service; U.S.D.A.-Forest Service; state, county, or city governments; U.S. Fish and Wildlife Service; The Nature Conservancy; universities; private owners; U.S.D.A.-Agricultural Research Service; National Oceanic and Atmospheric Administration; Bureau of Land Management; Tennessee Valley Authority; and the Department of Energy. A list of U.S. Biosphere Reserves includes the following locations (and sponsoring agencies) is appended to this paper as Appendix A.

Each Biosphere Reserve maintains its own research and monitoring networks, programs, and services, and is responsible for its site's data and information management and sharing strategies.

Among the MAB Biosphere Preserves, the Adirondack Park Agency (APA), is one of the major acid rain data repositories in the entire U.S. The Web site for access to the APA acid rain data is <http://www.northnet.org/adirondackparkagency/>. The Adirondack Park Agency oversees the research and monitoring activities within the Adirondack Park, including a growing body of GIS Coverages, that now includes maps, land use data, legal jurisdictions and land designations, and wetlands designations. Much of this GIS data is now available from the APA in CD-ROM formats.

Influences on Wetlands and Lakes in the Adirondack Park of New York State – A Catalog of Existing and New GIS Data Layers for the 400,000 Hectare Oswegatchie/Black River Watershed is one of the specific Adirondack Park reports which includes access to data related to ongoing acid rain monitoring. The following data layers are divided into thematic groups as they appear on the final report poster. Links for each data layer lead to a graphic image of the data, to the topic in the final report, metadata when available, and to other related documents.

- Vegetative Cover

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- o Upland Cover from TM Data
- o Wetlands
- **Geology/Soils**
 - o Bedrock Geology
 - o Surficial Geology
 - o Bedrock Acid Neutralizing Capacity
 - o General Soils—Parent Material
 - o Elevation
- **Land Use**
 - o Adirondack Park Land Use & Development Plan
 - o 1989 Residential Areas
- **Hydrology/Atmospheric**
 - o Watersheds and Adirondack Long Term Monitoring Waters
 - o Mean Annual Precipitation (1951 to 1980)
 - o Total Nitrogen Deposition
- **Landscape Disturbance**
 - o State Forest Acquisition
 - o 1916 Fire Protection
 - o November 1950 Blowdown
 - o Forest Damage Assessment of July 1995 Blowdown
 - o Landscape Disturbance Composite (to 1950)

One of the major acid rain projects taking place in the Adirondack Park is the ongoing monitoring network established and continued by the Adirondack Lakes Survey Corporation (ALSC). The ALSC is a not-for-profit corporation established in 1984 as a cooperative agreement between the Empire State Electric Energy Research Corporation (ESEERCO) and the New York State Department of Environmental Conservation (NYSDEC) to determine the extent and magnitude of acidification of lakes and ponds in the Adirondack region. Presently, the ALSC is moving into the NYSDEC's Division of Air Resources and receives joint funding from the New York State Energy Research and Development Authority (NYSERDA) and the USEPA. Data available include physical attributes of wetland and watershed areas, data about the 1950 blowdown (resulting in excessive forest damage), the 1916 wild fires, the 1995 microburst wind storm that ravaged large portions of the western Adirondack region, various land use data, bedrock and surficial

geologic data, soil parameters, and atmospheric data (precipitation, nitrate and sulfate data). These data are provided in polygon and raster format for GIS coverages.

Their monitoring work began with an extensive baseline survey conducted from 1984 – 1987 that culminated with the 1990 Adirondack Lakes Survey Report <<http://www.adirondacklakessurvey.org/execsum.htm>>. Since that time acid rain monitoring surveys, fisheries and watershed projects have continued. The most intensive of these is the Long-Term Monitoring Project <<http://www.adirondacklakessurvey.org/ltmpage.htm>>, which began in June 1992 and continues presently. A special highlight of this website is the month by month chemistry update for two key monitoring lakes, Big Moose Lake and Willys Lake <<http://www.adirondacklakessurvey.org/monthly.html>>. The *Adirondack Lakes Survey: 1987 Report* is a 3-volume set of data collected in the Lower Hudson River region.

The original *Adirondack Lakes Survey* is a 19-volume set of the original 1985-1989 monitoring activities where extensive data were collected in hundreds of Adirondack lakes and ponds and select waters in the Hudson River watershed. The following data was collected for each lake tested: location and status, bathymetric map, morphometrics, macroinvertebrate macrophytes, fisheries, chemical/physical parameters, and management history arranged by numerical listing of lakes within each major Adirondack watershed. An additional 3 volumes were added in 1989 for watersheds of the Lower Hudson River. In all, these Adirondack data represent about 20 linear shelf-feet of loose-leaf datasheets. As mentioned above only small sets of these data have been converted into CD-ROM or digital formats.

Long Term Ecological Research (LTER) Network <http://lternet.edu>

LTER is another collaborative research effort that links more than 1100 scientists and students in ongoing investigations of ecological processes covering long-term temporal scales and broad geographic scales. The LTER was established in 1980 by the National Science Foundation to support dedicated, long-term ecological research in

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the U.S. There are 24 LTER Sites in the U.S.
<<http://www.lternet.edu/sites/>>:

- Andrews LTER
- Arctic Tundra LTER
- Baltimore Ecosystem Study
- Bonanza Creek LTER
- Central Arizona – Phoenix
- Cedar Creek LTER
- Coweeta LTER
- Harvard Forest
- Hubbard Brook LTER
- Jornada Basin
- Kellogg Biological Station
- Konza LTER
- Luquillo LTER
- McMurdo Dry Valleys
- Niwot Ridge LTER
- North Temperate Lakes
- Palmer Station
- Plum Island Ecosystem
- Sevilleta LTER
- Shortgrass Steppe
- Virginia Coast Reserve
- Florida Coastal Everglades
- Georgia Coastal Ecosystems
- Santa Barbara Coastal

As with the U.S.MAB Biosphere Reserves, each LTER site should be examined for its own research, monitoring, and data and information management activities. You will note that there is an overlap in the reporting jurisdictions of the LTER Network Sites and the U.S. MAB Biosphere Preserves, such as is the case with the Hubbard Brook Ecological Study site.

Among the LTER sites, The Hubbard Brook Ecosystem Study <<http://www.hubbardbrook.org/>> facility is, perhaps, the best known for its compressive and pioneering acid rain research. HBES is a long-term ecological research project located at the Hubbard Brook Experimental Forest (HBEF), a 3,160 hectare reserve located in the White Mountain National Forest, near North Woodstock, New Hampshire. The HBEF was established by the USDA Forest Service in 1955 as a major center for hydrologic research in New England. A large repository of “Research and Data” is available from their Web site and presents a

description of long-term data sets and the on-site research activities of the HBES:

- Stream Flow and Chemistry
- Atmospheric Inputs (precipitation and deposition)
- Vegetation
- Weather and Climate Data
- Watershed Budgets
- Soil Conditions and Chemistry
- Animals
- Lake Chemistry
- Paleoecology

Data are provided in both print/hard copy reports and publications as well as online data files and data sets. Images (photographs, aerial photos, and graphics), GIS coverages, and publications are also provided by the HBES.

Additional Internet Web Sites and Resources

US CURRENT pH MAP: You can view a map of the most current data (latest is for Nov. 26 through Dec 23, 2001) at: <http://water.usgs.gov/nwc/NWC/pH/html/ph.html>

US pHMAPS—1994-2000: You can view a map of the US pH averages for 1995 (change the date in the html to 1994 and that year is also available) at: <http://nadp.sws.uiuc.edu/>

CANADA: Canadian data can be viewed at <http://www.ns.ec.gc.ca/aeb/ssd/acid/index.html>

EUROPEAN FORESTS: Maps showing damage to European forests can be found at <http://www.soton.ac.uk/~engenvir/environment/air/acid.how.big.problem.html>

NORWAY: Maps showing increasing damage to Norway's rivers are at: <http://www.grida.no/soeno95/acidrain/effects.htm>

CONCLUSION

The information base related to acid rain will continue to grow in future decades. This growth most likely will decrease in magnitude over the years as research initiatives begun more than a quarter of a century ago come to a close and as monitoring programs are incorporated into more broadly defined global environmental change programs. Access to real-time, on-demand data

related to all aspects of acid rain science and policy will continue to be rigorously pursued and the growth of such data repositories will increase and become more organized. Digitization of historical data will continue at its present painfully slow pace unless funding and technical support is provided for such print-to-electronic conversions to take place.

A glimmer of hope resides in the summary statement on Information Systems presented in *Recommendations for Improving the Scientific Basis for Environmental Decisionmaking*, a report from the first National Conference on Science, Policy, and the Environment, held by the National Council for Science and the Environment (December 7-8, 2000, Washington, D.C.). Among the recommendations was the call for the creation of a National Environmental Information Infrastructure to support “intensified public information programs and environmental education and training initiatives (K-Adult). The NCSE recommendation for Information Systems is as follows:

“The United States should develop a National Environmental Information Infrastructure (NEII) that crosses scientific domains (i.e., applied, physical, information, natural and social sciences, engineering), sectors of the economy (i.e., private, academic, government), and lines of work (i.e., research, education, advocacy, communication, information).” <http://www.cnie.org/2000conference/13.cfm>

This recommendation is based on six components:

1. National Environmental Information Infrastructure

The NEII should be an open architecture for network development, with appropriate computer power [data, information, and knowledge management], and user interface.

2. Ensure Data

The federal government and its partners should work to ensure data (information) availability, quality, and preservation through this architecture.

3. Tool Development

The federal government should promote the development of tools to make information available to a multiplicity of users at varying

geospatial scales and time frames.

4. Data Evaluation

Creation of the NEII should begin with a comprehensive analysis to evaluate the many data and information repositories and data support systems at global/international, national/federal, state/provincial, and local levels. They should be evaluated in regard to:

- acquisition of data (and information)
- management of data
- integration and analyses of data
- dissemination of data
- examination of cross-cutting issues to examine organizational roles of data producers, providers, and users.

5. Multi-Stakeholder Advisory Board

There should be a multi-stakeholder advisory board (e.g., data producers/providers, data/information managers, data/database vendors/providers, librarians and other information providers, and various user communities) to examine the creation of a central, comprehensive environmental information infrastructure that would:

- coordinate efforts across scientific domains, industries, and institutions
- provide access to and communication of data and information for multiple categories of end users
- promote the use of environmental indicators and methods of advanced environmental accounting
- emphasize the need for a U.S. commitment to support environmental data and information systems and management
- identify environmental decision areas that currently lack robust supporting data and information resources
- examine educational opportunities and training in scientific, policy, and information technology (including librarians)
- examine policies for discussion of publication, dissemination, and “digestion” of data and information
- identify and network among repositories of human and organizational expertise and resources.

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6. Outcome

Completion of these tasks would serve to:

- define an environmental information infrastructure that is timely, adequate, and comprehensive
- address the need to develop services, products, and programs that are efficient, economic, and equitable.

This recommendation would certainly address nearly all of the data and information challenges that currently envelope the issues related to acid rain (and a host of other global environmental problems and concerns). Further refinement of this recommendation is needed and might include the expansion of the geosciences-topical framework of the existing World Data Center complex to include the creation of individual WDCs for Ecological Data. Programs such as the National Biological Information Infrastructure in the Department of the Interior's U.S. Geological Survey (already an active partner in the WDC-A complex in the U.S.) would seem to be well-suited to carryout this much needed ecological data coordination and management function. The next step in this process may have been undertaken at the Second National Conference on Science, Policy and the Environment, whose recommendations for Information Systems Interoperability in Support of Effective Environmental Decisionmaking was featured in *Recommendations for Achieving Sustainable Communities: Science and Solutions, A Report from the second National Conference on Science, Policy, and the Environment* <http://www.cnie.org/NCSEconference/2001Conference/report/page.cfm?FID=1692>, and appended to this paper.

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APPENDIX A. U.S. MAN AND THE BIOSPHERE PRESERVES AND THEIR SPONSORING AGENCIES

Key:

NPS – National Park Service, Department of Interior

NOAA – National Oceanic and Atmospheric Administration, Department of Commerce

FWS – U.S. Fish & Wildlife Service, Department of Interior

FS – Forest Service, Department of Agriculture

ARS – Agricultural Research Service, Department of Agriculture

DOE – Department of Energy

BLM – Bureau of Land Management, Department of Interior

Private – Denotes Some Form of Private Ownership

Complex – Denotes Multiple Ownership

U.S. MAB Sites:

- Aleutian Islands National Wildlife Refuge (FWS)
- Beaver Creek Experimental Watershed (FS)
- Big Bend National Park (NPS)
- Big Thicket National Preserve (NPS)
- California Coast Ranges Biosphere Reserve (8 Units)
 - o Elder Creek Area of Critical Environmental Concern (BLM)
 - o Heath and Marjorie Angelo Coast Range Preserve (University of California)
 - o Jackson Demonstration State Forest (California Department of Forests)
 - o Landels-Hill Big Creek Reserve (University of California)
 - o Redwood Experimental Forest (FS)
 - o Redwood National Park (NPS)
 - o North Coast Redwoods District State Parks (3 Units)
 - o Del Norte Coast Redwoods State Park and Alternate Site (California Department of Parks and Recreation)

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- o Jebediah Smith Redwoods State Park and Alternate Site (California Department of Parks and Recreation)
- o Prairie Creek Redwoods State Park and Alternate Site (California Department of Parks and Recreation)
- o Western Slopes of Cone Peak, Los Padres National Forest (FS)
- Carolinian-South Atlantic Biosphere Reserve (11 Units)
 - o Blackbeard Island and Wolf Island National Wildlife Refuges (FWS)
 - o Cape Lookout National Seashore (NPS)
 - o Cape Romain National Wildlife Refuge (FWS)
 - o Capers Island Heritage Preserve (South Carolina Department of Natural Resources, Marine Resources Division)
 - o Cumberland Island National Seashore (NPS)
 - o Hobcaw Barony (North Inlet) (Complex Private)
 - o Little St. Simons Island (Private)
 - o Santee Coastal Reserve (South Carolina Department of Natural Resources)
 - o Tom Yawkey Wildlife Center (South Carolina Department of Natural Resources)
 - o Washo Reserve (The Nature Conservancy)
- Cascade Head Experimental Forest & Scenic Research Area (FS)
- Central California Coast Biosphere Reserve (See Golden Gate Biosphere Reserve)
- Central Gulf Coastal Plain Biosphere Reserve
 - o Apalachicola National Estuarine Research Reserve and Alternate Site (NOAA)
- Central Plains Experimental Range (ARS)
- Champlain-Adirondack Biosphere Reserve (3 Units)
 - o Adirondack Park Agency (Private)
 - o Green Mountain National Forest (FS)
 - o Mount Mansfield State Natural Area (Vermont Agency of Natural Resources)
- Channel Islands Biosphere Reserve (2 Units)
 - o Channel Islands National Marine Sanctuary (NOAA)
 - o Channel Islands National Park (NPS)
- Congaree Swamp National Monument (NPS)
- Coram Experimental Forest (FS)
- Denali National Park and Biosphere Reserve (NPS)
- Desert Experimental Range (ARS)
- Everglades National Park (with Dry Tortugas National Park) (NPS)
- Fraser Experimental Forest (FS)
- Glacier Bay-Admiralty Island Biosphere Reserve (2 Units)
 - o Admiralty Island National Monument (FS)
 - o Glacier Bay National Park and Preserve (NPS)
- Glacier National Park (NPS)
- Golden Gate Biosphere Reserve (13 Units)
 - o Bolinas Lagoon Preserve and Cypress Grove Preserve (Private)
 - o Bodega Marine Reserve (University of California)
 - o Cordell Bank National Marine Sanctuary (NOAA)
 - o Farallon National Wildlife Refuge (FWS)
 - o Golden Gate National Recreation Area (NPS)
 - o Gulf of the Farallones National Marine Sanctuary (NOAA)
 - o Jasper Ridge Biological Preserve (Coordinator) (Stanford University)
 - o Marin Municipal Water District (Marin County, California)
 - o Mount Tamalpais State Park (California Department of Parks and Recreation)
 - o Point Reyes National Seashore (NPS)
 - o San Francisco Peninsular Watershed (City of San Francisco, California)
 - o Samuel P. Taylor State Park (California Department of Parks and Recreation)
 - o Tomales Bay State Park (California Department of Parks and Recreation)
- Gray's Reef National Marine Sanctuary

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- (NOAA)
- Guanica Commonwealth Forest Reserve (Puerto Rico Department of Natural Resources)
- H.J. Andrews Experimental Forest (FS)
- Hawaiian Islands Biosphere Reserve (2 Units)
 - Haleakala National Park (NPS)
 - Hawaiian Volcanoes National Park (NPS)
- Hubbard Brook Experimental Forest (FS)
- Isle Royale National Park (NPS)
- Jornada Experimental Range (ARS)
- Konza Prairie Research Natural Area (The Nature Conservancy)
- Land Between the Lakes (Tennessee Valley Authority)
- Luquillo Experimental Forest (FS)
- Mammoth Cave Area and Barren River Area Development District, BRADD (NPS and Complex)
- Mojave and Colorado Deserts Biosphere Reserve (5 Units)
 - Anza-Borrego Desert State Park and Alternate Site (California Department of Parks and Recreation)
 - Death Valley National Monument (NPS)
 - Joshua Tree National Monument (NPS)
 - Philip L. Boyd Deep Canyon Desert Center (University of California)
 - Santa Rosa Wildlife Management Area, San Bernadino National Forest (FS)
- New Jersey Pinelands Biosphere Reserve (Pinelands Commission, Complex)
- Niwot Ridge Biosphere Reserve (University of Colorado)
- Noatak National Preserve (2 Units)
 - Gates of the Arctic National Park (NPS)
 - Noatak National Preserve (NPS)
- Olympic National Park (NPS)
- Organ Pipe Cactus National Monument (NPS)
- Rocky Mountain National Park (NPS)
- San Dimas Experimental Forest (FS)
- San Joaquin Experimental Range (ARS)
- Santee Coastal Reserve (South Carolina Department of Natural Resources)
- Sequoia-Kings Canyon National Parks (NPS)
- South Atlantic Coastal Plain Biosphere Reserve
- Southern Appalachian Biosphere Reserve (5 Units)
 - Coweeta Hydrologic Laboratory (FS)
 - Grandfather Mountain (Private)
 - Great Smoky Mountains National Park (NPS)
 - Mt. Mitchell State Park (North Carolina Department of Environmental Health and Natural Resources)
 - Oak Ridge National Environmental Research Park (DOE)
- Stanislaus-Tuolumne Experimental Forest (FS)
- Three Sisters Wilderness, Deschutes National Forest (FS)
- University of Michigan Biological Station (University of Michigan)
- Virgin Islands National Park and Biosphere Reserve (NPS)
- Virginia Coast Reserve (The Nature Conservancy)
- Yellowstone National Park (NPS)

APPENDIX B. INFORMATION SYSTEMS: INTEROPERABILITY IN SUPPORT OF EFFECTIVE ENVIRONMENTAL DECISIONMAKING.

A recommendation made at the National Conference on Science, Policy, and the Environment, December 6-7, 2001, Smithsonian National Museum of Natural History, Washington, D.C.

Introductory Remarks

Building on the recommendations of the first National Conference on Science, Policy and the Environment, the Information Systems Breakout Session confirmed that data and information are the transportation between science and decisionmaking for a sustainable environment.

The US is moving forward aggressively in

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building a national environmental information infrastructure, although many challenges remain. National borders do not limit many of these challenges.

Recommendations

The World Summit on Sustainable Development should advance the following approaches:

1. Global Environmental Information Commons – Nations need to work together to create a Global Environmental Information Commons as a cooperative venture among nations, including all sectors of society (government, non-governmental organizations, industry, academia and the public). The Commons would include data, tools and infrastructure.
2. Open Information Culture – Decisionmakers and scientists need to work toward creating an open information culture where the needs of the scientists and generators of data are valued. The culture needs to embrace the accessibility of scientific data to the many potential user communities including policymakers, resource managers, researchers, students, teachers and citizens. Stronger interfaces must be built among data generators, managers and users.
3. Common Data Definitions – Scientists and users need to work on globally common data definitions so compatible information can be