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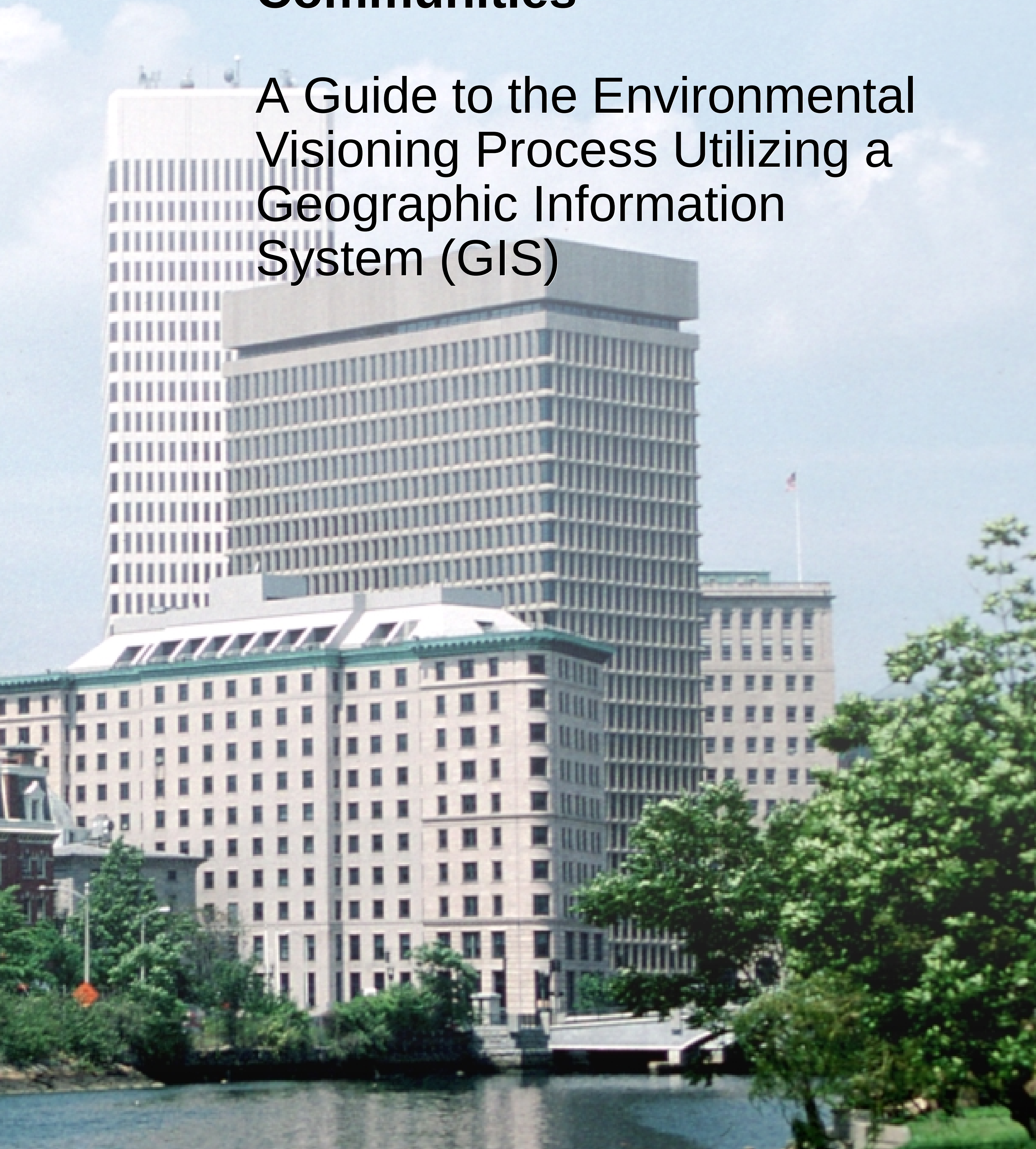
Technology Transfer

Environmental Planning for Communities

A Guide to the Environmental Visioning Process Utilizing a Geographic Information System (GIS)



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A Guide to the Environmental Visioning Process Utilizing a Geographic Information System (GIS)

Technology Transfer and Support Division
Office of Research and Development
United States Environmental Protection Agency
Cincinnati, OH

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Notice

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1 Introduction/Purpose of this Guide

1.1 Introduction

The U.S. Environmental Protection Agency (EPA) has shifted the focus of many of its ecosystem protection programs from command-and-control to the Community-Based Environmental Protection (CBEP) approach. In contrast to the previous regulatory approach, the CBEP approach emphasizes decision making by local stakeholders to address community-wide environmental issues. As an essential step in the CBEP approach, community leaders, citizens, and planners develop an environmental vision of their preferred "green" community. An environmental vision in its simplest form is a picture or a description of a preferred future state of the community, chosen from several alternative futures. The entire process of generation and selection of alternative landscape futures will be referred to as environmental visioning in this Guide. One of the important tools that can be used to develop and support such a vision is the geographic information system (GIS) technology.

A GIS, in its simplest form, is common off-the-shelf (COTS) computer software that can be run on desktop personal computers to produce simple maps. A complex GIS can support scientific what-if analysis and modeling, and has the power to depict environmental data in relation to the geography and the capacity to model the landscape as it may evolve over time. This guide explains how a GIS can be used for environmental visioning.

1.1.1 The CBEP Approach

CBEP is a comprehensive ecosystem management and planning approach promoted by EPA, to assess and manage the quality of air, water, land and living resources in an area in a "holistic context." The CBEP approach has been developed and employed to better reflect the unique needs and requirements of regional and local conditions and to stimulate and promote a more effective partnership with local communities.

The Key CBEP Steps

Establish Partnerships and Develop an Environmental Vision: Ecosystem protection projects often start at a grass roots level with small groups sharing a common interest in protecting or restoring their local environment. Ultimately, the small groups expand and align into larger groups of stakeholders, who develop partnerships by coming to agreement on issues, vision, and information. This naturally leads to the development of a set of community-derived goals and actions.

Assess Ecosystem: Once an organization has been developed and goals have been established, the next task is to assess the current condition of the local ecosystem. This can be achieved by defining the indicators of ecosystem such as human health, natural habitat and creating links between ecosystem, local economy, and quality of life.

Develop Ecosystem Strategies: After developing ecosystem indicators and environmental trends, strategies for ecosystem protection can be evaluated and implemented. The strategies usually involve voluntary initiatives, such as volunteer cleanups, land acquisition, or education programs. Legal strategies can also be considered, including local laws, zoning ordinances, property taxes and municipal fees, performance standards, and transfer of development rights and growth planning, in addition to enforcement of state and federal environmental laws. The selection of appropriate strategies includes the analysis of socioeconomic impacts and the ability to adapt the selected strategies to changing conditions and new information.

EPA has published a guide to the CBEP process **(*Community Based Environmental Protection: A Resource Book for Protecting Ecosystems and Communities, EPA 230-B-96-003*),** which contains detailed guidance on the implementation of CBEP initiatives.

CBEP emphasizes a collaborative approach to environmental protection instead of the traditional "end-of-pipe" approach EPA has employed historically. The CBEP approach tailors environmental programs to address the particular needs of individual communities, watersheds or other planning units. In some cases, CBEP activities may go beyond achieving national environmental standards by enacting more strict standards and policies that reflect local concerns.

CBEP is designed to maximize the use of scarce resources, encourage local support, consider the economic well being of communities, and allow EPA to work in partnership with residents to solve environmental problems. CBEP partnerships may include representatives from all levels of government, public interest groups, industry, academia, private landowners, concerned citizens and others. The active integration of all of these interest groups fosters a better understanding of environmental problems, as well as producing more achievable, effective, and popular solutions. Improved environmental protection results are achieved by focusing activities on issues unique to specific geographic boundaries, and by identifying overall environmental improvements and trends. CBEP success is measured by examining environmental improvement over an entire area of concern, instead of looking at facility-by-facility progress.

1.1.2 Evolution of Media-Based/ Command-Control Approach to CBEP

The traditional approach to pollution control has been a media-based, command-control process, where air, water and land resources have been addressed separately through regulations, criteria and standards. This process has been effective in significantly reducing the release of pollutants to the environment from point sources. A point source, such as combined sewer discharge, is a discharge whose location can be exactly pinpointed on a map. In contrast, a non-point source (NPS) of pollution, such as agricultural runoff, occurs over an entire geographic area. The reductions have been accomplished through the development of regulations, criteria, and standards, directed largely at point sources, which can be easily identified and regulated.

The environmental problems that many communities now face are more complex and difficult to define. In order to deal with these environmental problems, EPA is promoting the CBEP approach. The CBEP approach proactively involves all social, economic, and political issues from different interest groups into the environmental decision-making process. CBEP recognizes that environmental decisions cannot be made in a vacuum, independent from the other societal demands—jobs, fire protection, education, etc.—that impact the use of the communities' material, financial, and human resources. When environmental issues are openly addressed in a CBEP process, local constituents have an opportunity to take a more active role. If the process includes consensus and negotiation, the local constituents can extend their support for the implementation of the selected environmental management strategies more aggressively.

1.1.3 Environmental Visioning as It Relates to CBEP

Environmental visioning is a step in the CBEP process that develops a picture of a preferred future environment. The question "Where do we want to be" is the central theme of any visioning process and the environmental vision statement for the community becomes the driving force for implementation of CBEP efforts. Preferred communities often are called "Green Communities," and the term refers to sustainable communities with healthy environments, vibrant economies and a high quality of life for residents (*http://www.epa.gov/region03/greenkit)* Sustainable communities combine residential, commercial and industrial development while maintaining local ecosystems.

1.1.4 GIS as a Tool to Support Environmental Visioning

A GIS is a computer software tool that supports a variety of purposes, including map-making and scientific analysis. A GIS has the inherent ability to generate graphical and tabular displays, and the capacity to support "what-if" analyses by modeling different scenarios that are important building an environmental vision. Color-coded GIS maps can either be viewed on a computer screen, or printed as hard copy.

Several vendors provide off-the-shelf GIS software that can run on a variety of platforms, ranging from desktop personal computers to high-powered computer workstations. GIS data generally consist of two components: graphical data about the geography, and tabular data about each feature in the geography. For example, the graphical component may include display of county boundaries on the screen, whereas the tabular database component keeps track of the county population, average income, and other relevant attributes. The values from the database can be used to color-code the geographic areas, thereby providing a visual representation of the conditions. A GIS can also be used to display and manipulate satellite images of a geographic area to perform analyses of the environment.

GIS capabilities can be applied no matter what the size of the geographic area under consideration. In addition, the geography being depicted, as well as the database values used for color-coding the maps, can be based on reality or imagination (e.g., the environmental vision). Therefore, a GIS becomes an ideal tool to support the environmental visioning step of the CBEP process. In addition, a GIS can be used as valuable tool for ongoing ecosystem management (Sumner and Kapuscinski, 1998). By using a GIS, community members become familiar with the mapped information and gain an appreciation of the community's dependence on the ecosystem. This process is fueled by the availability of relevant knowledge bases on the Internet.

1.2 Purpose of This Guide

The purpose of this Guide is to explain how a GIS can be used by communities as a tool to support environmental visioning as part of the CBEP process. Although significant reference material exists on CBEP and on GIS applications, the use of GIS in the CBEP process has not been presented in a comprehensive document. A few case studies have shown how a GIS can be used effectively during environmental visioning, but a general discussion of that theme has not been prepared.

This Guide to the Environmental Visioning Process Utilizing a Geographic Information System (GIS) has been developed consistent with the requirements of CBEP. In this framework, the guide can be utilized to meet the needs of individual media issues (e.g., the watershed management approach to water quality issues) and to support integrated ecosystem analyses, embodying the multiple impacts on air, water, and land resources.

1.2.1 Where Does This Guide Fit Into EPA Programs?

For more than 25 years, EPA and its associated state and local agencies have achieved significant strides in protecting all aspects of our environment. The air, water, and land resources, which have supported the social and economic growth of this nation, have been reasonably protected and preserved for future generations through the application of national, technology-based standards. While these technology-based standards for individual media have been successful, new approaches, such as CBEP, are now required to ensure the long-term health and welfare of ecosystems and the population.

In this process, the singular objectives of environmental control and management cannot be viewed exclusive of the other societal demands, such as police and fire protection, and schools. Planning processes require a balanced approach to community, environmental, and ecosystem management within an open, public decision-making framework.

The ability to effectively and efficiently address and display these complex issues requires utilization of tools, such as GIS technology. A GIS integrated with models and other display software, allows the evaluation of a myriad of alternative management strategies and presents them in a manner in which community stakeholders can evaluate them in decision-making processes. Use of GIS in this manner will permit a more inclusive decision-making process, conducted in a rational, objective, meaningful, and understandable way to all participants.

1.2.2 Relationship of This Guide to Other CBEP and Environmental Visioning Products

EPA has produced several products relating to environmental visioning and CBEP, including a "Storefront of Community Environmental Tools" on the EPA home page on the Internet *(www.epa.gov).* Many of these products reference the value of GIS in environmental visioning and CBEP, but do not include any details on how to develop a GIS or what to include in an effective GIS program.

The Environmental Protection Agencies in several states have published guidebooks for environmental planning, although focused more towards water quality. For example, the Ohio EPA (OEPA) has published a guide for watershed-based approach to the development of a water quality protection plan (OEPA, 1997).

This Guide supplements the above products by addressing the technical and organizational aspects of GIS. For example, the guide discusses what type of data should be collected, and how to arrange the data into map layers that can be used to envision future environmental conditions. References to data and tools available through EPA are provided throughout this Guide, which also discusses previous studies on evaluating alternative futures.

1.2.3 Audience for This Guide

This Guide is meant for everyone who is interested and wants to participate in the CBEP process. The Guide provides introductory material for newcomers to the GIS technology and advanced material for the more technically oriented GIS users. Although not targeted as a 'how to' manual for the sophisticated GIS professional, the Guide discusses both the technical and nontechnical issues involved in using a GIS for environmental visioning that should address the needs of a broad audience.

1.3 Organization of This Guide

Following this Introduction (Chapter 1), the Guide has been organized to provide users with a framework for incorporating a GIS into the CBEP process and for initiating efforts to implement such an approach for their area. Examples are provided to gain a better understanding of the 'real world' applications.

1.3.1 Overview of CBEP (Chapter 2)

The details of the components of CBEP programs are discussed in Chapter 2. Topics addressed include how to organize community groups, how to set goals for CBEP projects, how to assess community conditions, and how to define, evaluate and choose strategies for ecosystem protection and restoration. The Steinitz framework (Steinitz, 1990) for landscape planning is also discussed.

1.3.2 Overview of Environmental Visioning (Chapter 3)

Chapter 3 presents the history of environmental visioning; its advantages as a guide for setting goals in ecosystem management and the processes that affect it. Examples of recent visioning activities are also presented.

1.3.3 GIS-Based Environmental Visioning (Chapter 4)

An overview of GIS and a discussion of its primary components (e.g. software, hardware, and databases) are presented in Chapter 4. Also GIS-based environmental visioning and the advantages and limitations of GIS applications are discussed.

1.3.4 Creating a GIS to Support Environmental Visioning (Chapter 5)

Chapter 5 provides guidance on how to establish a GIS for environmental visioning. GIS data needs emphasizing the scope and usage of data (extent, type, quality, resolution and accuracy) for environmental visioning are discussed. Some basic GIS products used for effective communication are also presented. Helpful information on what to consider when establishing a GIS is presented along with methods for acquiring GIS data.

1.3.5 Appendices

A bibliography of referenced material is attached as Appendix A, followed by glossary of terms (Appendix B).

1.4 Reference

Ohio Environmental Protection Agency, A Guide to Developing Local Watershed Action Plans in Ohio, Ohio EPA, 1997.

Steinitz, Carl; A Framework for Theory Applicable to the Education of Landscape Architects (and Other Environmental Design Professionals), *Landscape Journal,* October 1990, pp. 136-143.

Sumner, R. and J. Kapuscinski. Building the Vision for Ecosystem Management. U.S. Environmental Protection Agency, National Health and Environmental Effects Research Laboratory, Corvallis, Oregon (submitted for publication).

2 Overview of Community-Based Environmental Protection (CBEP)

2.1 Introduction

Since EPA was formed over twenty-five years ago, its regulatory focus has emphasized a media-based approach towards pollution control. However, EPA is now in the process of shifting the focus of its regulatory program to CBEP. CBEP emphasizes a geographic focus, development of partnerships among stakeholders within the ecosystem, and a focus on environmental results (EPA, 1997b). An important step in this process for a community is the development of its vision of a preferred environmental state (Figure 2-1). This preferred environmental state has been defined by EPA as a “green community.” Figure 2-1 illustrates an example of a CBEP progression. A small group alerts potential stakeholders about their concerns; the stakeholders discuss the issues and develop their vision of preferred community; goals and strategies are set for achieving the vision; and the strategies are implemented.

2.1.1 History of CBEP

In a sense, environmental protection has its roots in a community-based movement. On the first Earth Day (April 22, 1970), 20 million people turned out to show support for environmental causes. The momentum of Earth Day and other influences led to the formation of EPA. As discussed earlier, EPA subsequently developed regulatory programs, which have significantly reduced the effects of pollution. However, the work is ongoing and the efforts are far from complete.

EPA is emphasizing a CBEP approach to improve the effectiveness of federal environmental regulations and programs. The CBEP approach tailors programs to address the environmental conditions of a particular watershed, ecosystem or other area of concern. The goal of CBEP programs is to assess and manage the quality of air, water, land, and living resources in a place as a whole. In this manner, environmental management strategies will better reflect local conditions and will more effectively promote and establish partnerships for environmental protection.

However, CBEP does not represent the only approach to the integrated evaluation of environmental issues. A strong watershed management context was established for water quality issues in the Clean Water Act of 1972 (as embodied in the 303(e), 208, and 201 water quality planning processes). A new initiative of ecosystem and watershed management has been proposed, recognizing the continued need to reevaluate and manage the allocation of water resources to competing environmental demands. Ongoing efforts to manage the impact of pollution from point sources and non-point sources including, combined sewer overflows, storm water discharges, and agricultural runoff have been reinitialized and reemphasized.

The requirements for high-quality water that can support aquatic life and human uses have become increasingly more stringent. Similarly, increased emphasis on risk analysis techniques that require integration of many environmental factors, pollutant sources, costs, and economic variables, demands a more sophisticated and complete approach in evaluating environmental impacts and associated management strategies.

Commensurate with the above programs, it is essential to have interactive, public, decision-making processes that integrate all aspects of a community into environmental decisions, and that consider the environmental impacts of all activities in a community. For example, consider the following problems:

- Polluted runoff from non-point sources in areas that lack vegetation to absorb heavy rainfall or snowmelt. These sources include parking lots, streets and highways, heavily tilled farm fields, and clear-cut forest areas.

- Difficult-to-control environmental problems created by urban sprawl, including polluted runoff caused by the replacement of vegetation with paved surfaces, poor air quality from increased vehicle miles per person due to longer commutes, and habitat fragmentation for animals and plants.

To address these complex issues, CBEP has been employed as a holistic approach to environmental protection that is sensitive to local conditions and employs multilevel, cross-sector partnerships to achieve results. CBEP efforts sometimes go by other names, such as ecosystem management or place-based and/or geographically targeted environmental protection. An important factor in these efforts is that the people who live and/or work in the community (the local stakeholders) have a common interest in protecting an identifiable, shared environment and quality of life.

The role of EPA in the implementation of the CBEP will vary from place to place and from one issue to another. In

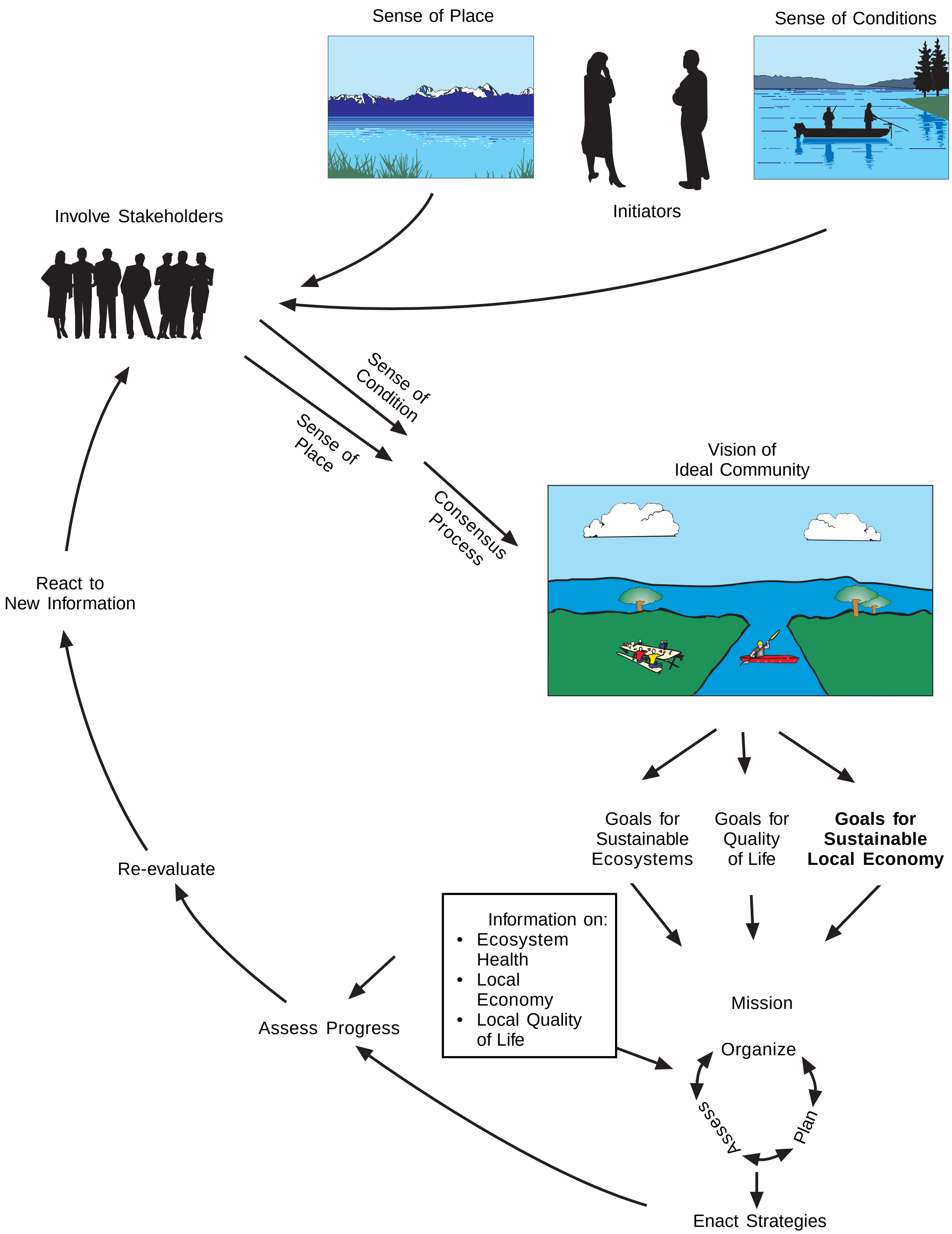

Figure 2-1. Community-based environmental planning (source: USEPA, 1997b).

many places, EPA will be an active partner in designing and implementing effective environmental solutions. In most places, EPA will support and assist the efforts of others by providing environmental information, monitoring systems, scientific analyses and other types of assistance.

2.2 Key Components of CBEP

While there are no prescriptions for CBEP, EPA has defined the following key components of an effective CBEP program: *(http://www.epa.gov/reinvent/notebook/)*

- Partnerships and stakeholder involvement from all levels of government, public interest groups, industry, academia, private landowners, concerned citizens, and others. EPA anticipates that these relationships established with regional and community organizations will bring about a better understanding of environmental problems and effective solutions.

- A geographic focus, which allows for a more comprehensive approach to environmental protection. Environmental protection efforts become more effective when they are directed towards specific watersheds or other ecosystems.

- A focus on environmental results over an entire area of concern, looking beyond facility-by-facility progress. Environmental programs that have integrated multimedia approaches, are now emphasized over the traditional end-of-pipe regulatory approach.

Some examples of CBEP Projects that include these components and are already underway include:

Clear Creek, Colorado—A partnership of local organizations, private citizens, industry and several agencies to protect the Clear Creek Watershed which covers roughly 600 square miles. Actions taken to restore the river include:

- Superfund remedial actions
- Voluntary cleanups
- Wetlands planning
- Mapping of endangered species
- Land use plans
- Water quality projects
- An emergency dial-down system to inform water users when spills have occurred in the creek.

St. Louis, Missouri, and East St. Louis, Illinois—An effort to enhance communication and coordination among the many agencies involved in environmental issues in the St. Louis Metropolitan area. The goal is to promote creative solutions to environmental problems such as hazardous and radioactive waste sites, poor air quality, wetland and riparian management issues. Actions taken include creating multimedia teams within EPA to work on issues in the area, as well as hiring an on-site liaison in response to community requests for more regular contact.

Brunswick, Georgia—An initiative to use regulatory and non-regulatory approaches to assess the environmental condition of the area and respond to environmental problems. Issues include mercury and polychlorinated biphenyl contamination in creeks, hazardous waste and potential problems in air quality. Actions taken include a strategy to reach across media-specific programs in a coordinated ecosystem protection manner; expanded site assessments; and sampling of surface water, sediments, fish tissue, private wells, and marshes in the area.

Henryetta, Oklahoma—A partnership with city and state agencies and a citizens' advisory group to address concerns about: the redevelopment of an abandoned mining and smelter site owned by the city; solid waste collection and recycling issues; and drinking water and wastewater delivery systems.

2.2.1 Establishing Partnerships

The first step in any CBEP initiative is to develop partnerships that include as many community stakeholders as possible. CBEP initiatives often begin at the grassroots level, when friends and neighbors share a common interest in protecting or restoring the local environment. These initiatives may be spurred by noticeable air or water pollution, a development that causes ecosystem damage, some obvious ecological effect such as a fish-kill, or some other symptom of an underlying ecological problem. Ideally, a community might come together to protect local ecosystems before they become threatened.

A concerned citizen, local official, or other project initiator may have some idea of desired outcomes or may have identified ecosystems or ecosystem components to improve or protect. Project initiators in other communities have found it useful to reach out early to other stakeholders. Potential stakeholders include anyone with an interest in what the initiator is thinking about—to begin an exchange of ideas about the desired outcomes or conditions that sparked their interest. Ultimately, stakeholders develop partnerships by coming to agreement on issues, vision, and information, leading to the development of a set of community goals and actions.

Possible stakeholders include anyone in the community who takes a natural interest in environmental protection. Groups that might be affected by changes in commercial activity resulting from ecosystem protection strategies are also potential stakeholders. Other stakeholders include businesses or labor unions. Local elected officials and

How to Establish Partnerships

Start at a grass roots level with friends and neighbors as initiators.

Identify stakeholders – anyone with a natural interest in the environment is a potential stakeholder.

Involve key decision makers from local government, environmental regulatory agencies, industry, and local citizens groups.

Develop partnerships by agreeing on issues, which lead to a set of community goals.

Communication is vital to maximizing stakeholder involvement – such as public presentations to local community groups or publishing newsletters.

community leaders can help identify potential stakeholders, in addition to participating themselves.

Potential stakeholders might include the following organizations and individuals.

1. Members of existing organizations that use or are concerned with the environment or land-use issues, such as the Audubon Society *(http://www.audubon.org)* and the Sierra Club *(http://www.sierraclub.org).*

2. Private landowners whose property includes habitat areas that the community wants to protect, including farmers, ranchers, timber companies, and private residents.

3. Local chapters of relevant national professional organizations, including ecologists, biologists and landscape architects.

4. Local governments, including, local watershed organizations and conservation districts, local parks and recreation departments, and state departments of environmental protection, agriculture, fish and game, transportation, and commerce.

Many diverse ethnic, religious, or other groups might be interested in sharing their points of view and participating. Often, a community's ecosystem protection effort will interest people who live in distant places. For example, environmental projects in rural vacation areas often draw the interest of city-dwellers that visit them. Similarly, a river restoration effort may affect many downstream communities.

Engaging people from all key stakeholder groups as soon as possible produces many benefits. People are much more likely to work together successfully if they are involved from the beginning rather than after decisions are made. For example, developers may be more willing to discuss alternative development schemes if they are invited to help plan ecosystem protection strategies. Many community members gain a sense of well being from volunteering their time to create a better community; involvement in the effort can be a source of personal enrichment.

Most communities have found that communication is vital in getting stakeholder involvement. For example, visiting some of the groups noted above at one of their meetings and speaking for five minutes might successfully draw stakeholder participation. Likewise, establishing a name for the group and developing a newsletter to document decisions made and activities undertaken, keeps everyone engaged and keeps the public abreast of the latest developments.

2.2.2. Defining Geographic Boundaries

As CBEP partnerships evolve, their geographic boundaries will evolve as well. A key step in the CBEP process is clearly defining the geographic boundaries of the effort. Determining these boundaries isn't always straightforward. In particular, it involves an understanding of the complex interactions between people and their environment.

The boundary-drawing exercise is complicated by the fact that most ecosystems are not wholly self-contained. A lake, for example, may be a component of a larger natural system of rivers and streams within a watershed. Therefore, runoff, spills, flooding, and other problems affecting related water bodies might affect the lake. Some ecosystems are so complicated that it may be difficult to address the entire system. River deltas, with their networks of fresh and saltwater marshland and rivers and lakes, and large urban air sheds are examples of such a system. Furthermore, most communities and their attendant ecosystems, such as forests or lakes, do not coincide with city, county, and even state boundaries.

These considerations may tend to discourage communities from going forward with ecosystem protection plans. The community may feel that its ecosystems are so interconnected with the larger environment that whatever small steps it takes locally will be overwhelmed by events occurring in related ecosystems in other towns or states. Alternatively, the community may keep increasing the area of interest to incorporate as many ecosystem features as possible, then realize that it will need to reach out to other communities for their cooperation.

Some communities have found it useful to start small. Considering ecosystems in the context of the larger environment of which they are a part, doesn't require tackling the entire system at once.

Sometimes, however, retaining a small geographic scope may not be feasible or desirable. For example, expanding the scope could help to include the following:

A Critical Locale—A project may be more effective if it covers an important tributary to a river or woodland that contains a crucial nesting site for birds.

A Critical Stakeholder—A large landowner may be able to make a significant contribution to the health of local ecosystems through land management techniques.

Special Skills or Resources—The community may want to expand boundaries, for example, to make the project relevant to a nearby university or to include endangered species habitat that will capture the interest of federal agencies.

Special Constituencies—The community may want to expand boundaries in an explicit effort to include, for example, groups who historically have been overburdened by environmental degradation or have been systematically left out of other community decisions. One community can use the boundary-drawing exercise to help in thinking about other communities with which to cooperate. If a community is considering making a river swimmable, for example, the effort will be affected by what goes on upstream. For this reason, communities often work closely with the watershed association and state entities, and may involve other towns.

Communities often start with the most obvious ecosystem unit and enlarge the area of interest by considering related ecosystems. If a community is focusing on a small pond, for example, it may also consider including wetlands, marsh, or wooded areas around the pond. Outlining the area on maps clearly shows topography (e.g., elevation and water bodies), as well as political features (e.g., roads and state, county, and city boundary lines).

How to Define a Geographic Boundary

Start small and progress to larger and more complex ecosystems

Define critical locale, stakeholders, resources, or special constituencies

Select an area which has achievable goals

As partnerships overlap with other communities, boundaries should overlap as well

One way to define natural ecosystem boundaries is to define watersheds. A watershed is an area where rain and other water drain to a common location such as a river, lake, or wetland. This collection of water may occur naturally (as with rain running down a hillside) or with the influence of drainage infrastructure such as ditches and storm sewers. Watersheds range in size from a few acres that drain to a farm pond to thousands of square miles. Landscapes such as watersheds may contain many different and interrelated ecosystems (such as forests, streams, urban areas, and wetlands).

Ecosystem managers often use watersheds as a meaningful way to define areas of concern. Watersheds typically cut across political boundaries like neighborhoods, subdivisions, city limits, and state lines. Since watersheds are often drawn around sloping geographic features such as valleys and mountains, they are also meaningful with regard to air and land issues. Thus, watershed management often requires coordination among different governments and organizations. While such coordination can prove challenging, watershed-based efforts can ultimately establish a seamless network of environmental protection across large regions.

In drawing boundaries, projects may consider whether to include a buffer zone around special features in the ecosystem. Such a zone absorbs the effects of human activity around the core of the ecosystem, preventing damage to the system itself. For example, for a seacoast, a zone of non-marsh, non-sandy terrain between the water's edge and development can prevent erosion and protect delicate tidal ecosystems.

2.2.3 Achieving Environmental Results

An essential step in the CBEP process is for the region of concern to develop an environmental vision. This environmental vision will address the current condition of the local environment; will address all of the actions and issues that will affect the environment in the future; and will define the community environmental goals in the future. **Environmental visioning can be thought of as the picture of where the community wants to be, and CBEP is the overall process of developing and implementing that vision and moving the community towards the preferred state.**

Various methods of goal setting such as visioning—forming a concept of what the preferred state of the community's ecosystems should be—can help a community develop goals. The environmental visioning process involves all interested community members from the start. Using environmental visioning as a means to develop community

Geographic Boundary and Partnerships

A group of individuals becomes organized around a perceived problem or issue (e.g., deteriorating water quality or lost fishery). On further examination, the group assesses the appropriate geographical boundaries within which ecological and social processes affect that issue (watershed). Given the chosen boundary, the group may need to increase or otherwise adjust its membership to generate sufficient capacity for addressing the stated issue. After further consideration, the group can decide the efficacy of the originally perceived problem. In the esoteric terms of "risk assessment," the group moves from problem recognition" to "risk definition." This point is important because the group may originally perceive a problem, e.g., a fishery problem, only to later realize that the real issue is water supply. They may not be able to fix the local fishery problem until they fix, or concurrently work on, the broader water supply problem.

goals takes advantage of the breadth and depth of ideas within the community and ensures that all affected members shape the initial proposals.

The question "Where do we want to be?" is the central theme of the environmental visioning process. Environmental visioning enables community members to express their shared values to invoke an image of the future. Environmental visioning is the process which focuses on where a community wants to be within a specified timeframe, whether it be 5, 10 or 20 years into the future. The environmental visioning process will result in an environmental vision statement with one or more alternative futures proposed. These futures should represent variations on a theme aimed at achieving sustainable solutions for the environment, economy and social well being. It has been suggested that a community should develop a set of rigorous measures for evaluating its commitment to the future (Sumner, 1998). These benchmarks can be a set of community attributes, such as number of viable businesses, school class size, and amount of steam bank vegetation.

With regard to environmental visioning, EPA Region III has introduced the concept of "green communities". Green communities are sustainable communities that integrate a healthy environment, a vibrant economy, and a high quality of life. EPA Region III has developed a green communities checklist which is presented below—*(http://www.epa.gov/region03/greenkit).*

How to Achieve Results through Environmental Visioning

- Establish an environmental vision
- Establish goals with sustainable economics
- Tie goals to specific indicators of progress
- Redefine goals and environmental vision as progress continues

When thinking about environmental goals and visions, many communities have considered not only ecological protection, but also the ways in which the environment interacts with quality of life and the local economy. These three endpoints can guide goal setting. For example, your primary ecological protection goal might be protecting streamside or woodland habitat. An associated "sustainable economy" goal might be working with landowners to preserve their woodlands by carefully planning and selecting the timber harvest to protect tree age, size, and species diversity, and replanting species native to the area. Improving the quality of life might combine protecting wildlife habitat with construction of nature trails to provide hiking and walking benefits. Goals to improve ecosystems can include both present and future generations—that is, the ecological legacy the community wants to leave its children and grandchildren.

Tying goals to indicators, or specific measures of how well the community is achieving its goals, is a concrete way to determine progress and to modify and adjust the process over time. For example, measuring community progress in protecting aquatic species might involve counting the number of wading birds in the area. Specifically, the community could seek to double the wading bird population by the year 2000. Measuring the economic health of the community might involve tracking employment in eco-tourism businesses with a goal such as 50 percent growth in local eco-tourist business by the year 2000.

By stating goals in concrete, measurable terms, the community ensures that it can objectively assess the project's progress. The use of such indicators is discussed in more detail in Chapters 3 and 5.

As more and more stakeholders join the effort, the community may need to go through the goal development process more than once. The period after the assessment, planning, and execution of a particular ecosystem protection project provides an opportunity to reevaluate whether the community is meeting goals, using indicators, and whether these goals indeed represent the priorities of the community. If not, then the strategies chosen may not be effective and the underlying goals may not be relevant and realistic. Ultimately, the community may want to undertake another goals development session.

Unless key community members participate in setting goals, the goals produced won't legitimately reflect the wishes of the community as a whole. Goal setting works best when participants are an inclusive group.

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U.S. EPA Home page: *http://www.epa.gov/epahome/general.htm*

Checklist for a Green Community

A Green Community Strives to:

Environmentally

- Comply with environmental regulations
- Practice waste minimization and pollution prevention
- Conserve Natural Resources through sustainable land use

Economically

- Promote diverse, locally owned and operated sustainable businesses (profitable, nonpolluting, socially responsible)
- Provide adequate affordable housing
- Promote mixed-use residential areas which provide for open space
- Promote economic equity

Socially

- Actively involve citizens from all sectors of the community through open, inclusive public outreach efforts
- Ensure that public actions are sustainable, while incorporating local values and historical and cultural considerations
- Create and maintain safe, clean neighborhoods and recreational facilities for all
- Provide adequate and efficient infrastructure (such as land, water, sewers, … communication and energy systems) that protects public health and the environment, and transportation systems that accommodate broad public access including bike and pedestrian paths.
- Ensure equitable and effective educational and health-care systems.

Source: *www.epa.gov/region03/greenkit/indicator.htm*

3 Overview of Environmental Visioning

3.1 Introduction

Environmental visioning is a set of steps by which members of a group or community gather their ideas about a preferred condition (e.g. environmental health), formulate goals and come up with strategies for achieving the goals. These steps are a part of the overall Community-Based Environmental Planning (CBEP), discussed in Chapter 2, that builds the environmental vision and takes the actions necessary to move the community towards its preferred state. The environmental visioning process brings together community stakeholders from public, private and civic sectors to discuss local concerns, layout alternative futures, and draw short and long term plans for the community. The success of environmental visioning projects depends on the participation and commitment of stakeholder.

Environmental visioning engages community members in assessing the current state of the environment, in visualizing a preferred state, and in proposing a practical methodology for moving towards the preferred state. A number of community meetings may be used for brainstorming, shaping ideas into goals, and setting strategies (EPA, 1994).

3.2 Evolution of Environmental Visioning

In many ways communities have always practiced some sort of forecasting to predict future trends and to allocate future resources such as demand for utilities. Traditionally, this process has been implemented by local government agencies, but it did not often reflect the context of problems across the entire community. With communities becoming increasingly diverse in every way and the decision-making power being more widely and thinly distributed, communities will be forced to employ inclusive approaches such as the process of environmental visioning.

The concept of environmental visioning is often thought of as relatively a new idea. However, one of the most successful environmental visioning projects was started in Chattanooga, Tennessee in 1969. In 1969, Chattanooga was named the most polluted city in the country with air pollution reducing visibility and increasing rates of respiratory illness. To address the problem, local leaders formed the Chattanooga-Hamilton County Air Pollution Control Board. The Board set pollution reduction goals and ensured that they were met. In 1990, Chattanooga was one of the few cities across the country in compliance with all national ambient air quality standards and on Earth Day was named "the best turnaround story" in the nation. The Chattanooga story is told in further detail in the "Chattanooga: A Sustainable Community" case study presented in this chapter.

More and more communities are employing environmental visioning to achieve a sustainable mix of residential, commercial and industrial development that ensures the long-term well-being of their communities. EPA has documented several case studies of ongoing community-based visioning efforts to support sustainable development. These studies include:

- *The Franklin Land Trust (Ashfield, Massachusetts)* has protected 11 rural and farmland sites through innovative partnerships with farmers, state agencies, and other farmland preservation groups.

- *Sustainable Urban/Rural Enterprise (SURE)* is a civic nonprofit corporation promoting the dual goals of economic development and environmental stewardship for the City of Richmond, Indiana and Wayne County.

- *Dunn, Wisconsin* implemented a land use plan in order to preserve the town's rural integrity, protect natural habitat, conserve resources, preserve open space and maintain farming as the town's primary economic activity. The plan included growth control measures through zoning restrictions, lot size limits, conservation easements and the purchase of development rights.

- *The Groundwater Guardian Program* is a project started by the Groundwater Foundation (Lincoln, Nebraska), which helps communities promote knowledge about groundwater issues and institute local groundwater protection programs.

These and other case studies are presented in further detail on EPA "Green Communities website" on the Internet *(www.epa.gov/region03/greenkit).*

3.3 Key Features of Environmental Visioning in the CBEP Context

A healthy environment, vibrant economy, and high quality of life are desirable goals. However, communities often approach these three goals separately. The CBEP process emphasizes all three simultaneously and addresses the following questions:

1. **Where are we now?**

   Before goals and objectives can be set, a community must assess its current condition. The first question in CBEP process—"Where are we now?"—is geared towards characterizing the current condition of the community and assessing its strengths and weaknesses. When reviewing the current condition of the community, it is important to look at economic, environmental and social conditions. Once an assessment is complete, community members can then rank the problem areas based on risk to the environment, quality of life, and economic sustainability.

   As discussed previously, the key to success in the community assessment phase is involving the right people. This effort will start small, as a planning team that seeks out local experts. The team leading the assessment should be representative of the entire community at large and include personnel knowledgeable on a variety of topics. Information on involving the entire community in the assessment phase is available in the CBEP resource book published by EPA on the Internet.

   The boundaries of the study area can be defined in several fashions. It can be defined in terms of the problems to be addressed, a watershed boundary or municipal limits. The boundaries of the study are most critical in the data gathering process. If the area is too small, problems which affect the entire community may not be realized. Economic and environmental problems often don't lend themselves to political boundaries. Therefore, the study area should be chosen carefully so that issues to be dealt with are clear.

2. **Where are we going?**

   After completing the community assessment, the baseline knowledge necessary to evaluate trends and predict what is in store for the area of concern in the near future should be available. The task is to project the baseline data into the future and learn "Where are we going?" This projection includes evaluating socioeconomic trends, environmental trends, civic participation trends, and sustainability trends. Several case studies that explain trend analysis are available from EPA in the "Green Communities Tool Kit" on the Internet *(http://www.epa.gov/region03/greenkit/2tools.htm).*

3. **Where do we want to be?**

   After the community assessment has been completed and current trends have been established, the vision statement is established by answering the question "where do we want to be?" By proposing alternative futures and models of where the community wants to be in 5, 10, 20 or more years, the community can highlight its strengths and weaknesses. This process can promote ideas which will result in a vision statement. GIS is an effective tool, particularly, for its use in this phase of the environmental visioning process.

4. **How do we get there?**

   Once action plans have been developed that will direct the community towards a sustainable future, the momentum should be maintained by implementing 1 or 2 projects which will illustrate that all this time and effort was not wasted. Early success will bring long-term commitments and participation necessary to sustain more difficult and time-consuming projects.

5. **How do we know that it works?**

   Benchmark may be established as indicators of progress. They can be defined using the same information compiled for environmental visioning. For example, if the environmental vision includes cleaning stream banks in few phases, these phases would become benchmarks. Achieving one benchmark at a time is indication of progress. The environmental visioning process is summarized in EPA Region III's "Green Community Flow Chart" as shown in Figure 3-1.

3.4 Environmental Visioning Tools

Environmental visioning is a process of expressing a preferred state that a community hopes to attain. Some of the visual tools that are available to community members for illustrating their vision, as well as other future alternatives, are discussed below.

3.4.1 Graphic Tools

- General data display methods, such as graphs, charts, and tables, show trends and valuable statistical information. Also they are easily developed using personal computers.

- Maps of local cultural and natural resources. For example, land use maps provide information on current land use, which is basis for identifying potentially developable areas, and for estimating development impacts.

- Regional and local planning maps, such as site plans, renderings, and panoramas provide two- or three-dimensional perspectives on current and future landscapes.

- Drawings and illustrations. This tool is particularly useful for interactively changing illustrations and can be used to visualize a particular feature for discussion.

- Photographs such as digital mapping. For example, photographic images can be manipulated

Chattanooga: A Sustainable Community

Chattanooga, Tennessee, a mid-sized city located along the Tennessee River just north of the Georgia border, was not only voted the most polluted city in the United States in 1969, but faced the label of an "invisible" city with no real image. Job layoffs, deteriorating city infrastructure, racial tensions, and social division only compounded the pollution problems. Recognizing these serious problems, a few visionary community leaders created Chattanooga Venture – a nonprofit organization with the goal of full participation from the community in cleaning up their city environmentally, socially, and economically.

Chattanooga Venture designed and implemented a project called "Vision 2000" which brought together over 1700 people to take part in city planning over a four month period. The community participants were encouraged to dream of what they wanted their community to be and to organize these dreams into a formal list. Diverse groups of community members united and literally used brown paper and markers as they brainstormed, debated, categorized and organized their concerns.

The result was a set of 40 goals for the city to achieve by the year 2000. The goals were categorized according to future alternatives, places, people, work, play and government. The action led to 223 projects and programs with an investment in the community of over $800 million, that varied in scope but all worked to create a sustainable community. Chattanooga Venture has also compiled a step-by-step guide for other communities to use in the visioning process.

Environmental problems were the impetus for the community-wide actions that led to the creation of several public/private partnerships.

- The Environmental City Project – working for expansion or relocation of nonpolluting industries, retention of sound environmental businesses, and fostering environmental awareness.
- The Chattanooga Environmental Initiative - strives to make the city a national center for environmental information and business and create a zero emissions industrial park.
- The Tennessee River Gorge Trust - protects 25,000 acres of land.
- Electric bus technology – Chattanooga maintains the largest fleet of free electric buses in the country.
- The Greenways Planning Project, which is creating a network of protected space and linear parkways through eight counties.

More information is available on the Internet at *www.Chattanooga.net*

to show different design features or alternative developments in an urban (town center) or suburban setting These provide a means for highlighting features of interest in a community vision. Digital imaging, which combines emerging photographic technology with manipulations by computers, is a great tool for communities wishing to visualize alternative futures.

3.4.2 Software Tools

- Geographic Information Systems (GIS) software is a powerful tool that can gather, analyze, and integrate nearly any combination of data (e.g., census tract information, natural resources, and infrastructure) and print the data in maps or display them on computer screens.
- Multimedia software uses a combination of computer animation, video, and audio data, to create a highly sophisticated, computer presentation stored on a compact disc.
- Virtual Reality provides a visual experience using imaginary data, by using computer software, a head-mounted display with miniature screens, and movement-sensitive gloves.

3.5 Steinitz Framework for Environmental Planning and Evaluating Alternative Futures

Overview

Over the past decades, a number of researchers and practitioners have established protocols and frameworks for conducting ecosystem planning efforts. A large portion of the research has been devoted to the representation of the problem as a multi-objective mathematical optimization model, and the application of efficient solution techniques to obtain an optimal solution (Gershon and Duckstein, 1983). Instead of looking for an optimal solution, another body of research has focused on generating diverse alternatives within the planning constraints (Brill, 1979; Kshirsagar, 1983). An application of such techniques to land use planning has been discussed by Kshirsagar and Brill (1984).

Steinitz (1993) has developed and employed a technique, referred to as the 'Steinitz Framework,' which has proven successful in instituting the visioning process. The Steinitz Framework is provided here as a guide for structuring an environmental visioning effort. A similar framework in the context of watershed analysis has been proposed by Montgomery et al., (1995).

There are structural similarities among critical phases and milestones addressed in designing environmental, landscape, and ecological projects (Steinitz, 1993). Based on these similarities, Steinitz presented six project phases, known as the "Steinitz Framework" (Steinitz, 1993), through which ecological projects pass both during early stages in defining the project scope and methodology, and later towards implementation and project conclusion (Figure 3-2). The six phases of the Steinitz Framework are discussed below in the context of environmental planning. The name of each phase includes the word "models" to emphasize the fact that a variety of models (methods) is available to achieve the end-result of that phase. One or more of these models can be used in each phase. These phases together address the basic questions raised by the CBEP in Section 3.3.

Basic Questions Addressed in Community-Based Environmental Planning (CBEP)

- **Where are we now?** - Develop a community profile based on a self-assessment.
- **Where are we going?** - Formulate a trend statement based on important economic, social and environmental trends.
- **Where do we want to be?** - Develop a community vision statement.
- **How do we get there?** - Develop community action plans.
- **How do we know if it is working?** - Establish benchmarks as indicators of progress

Advantages of CBEP-based Environmental Visioning

The primary advantages are:

- Greater depth and breadth of issues that are addressed
- Involvement of the full community
- Fostering of environmental stewardship in all local decisions

As communities work toward sustainable solutions, they realize that they can achieve a mix of residential, commercial, and industrial development that ensures the long-term well being of the community – both economically and environmentally. The environmental visioning process strives to be non-adversarial, to build constructively on differences, and to achieve a strong community-based consensus.

Representation Models

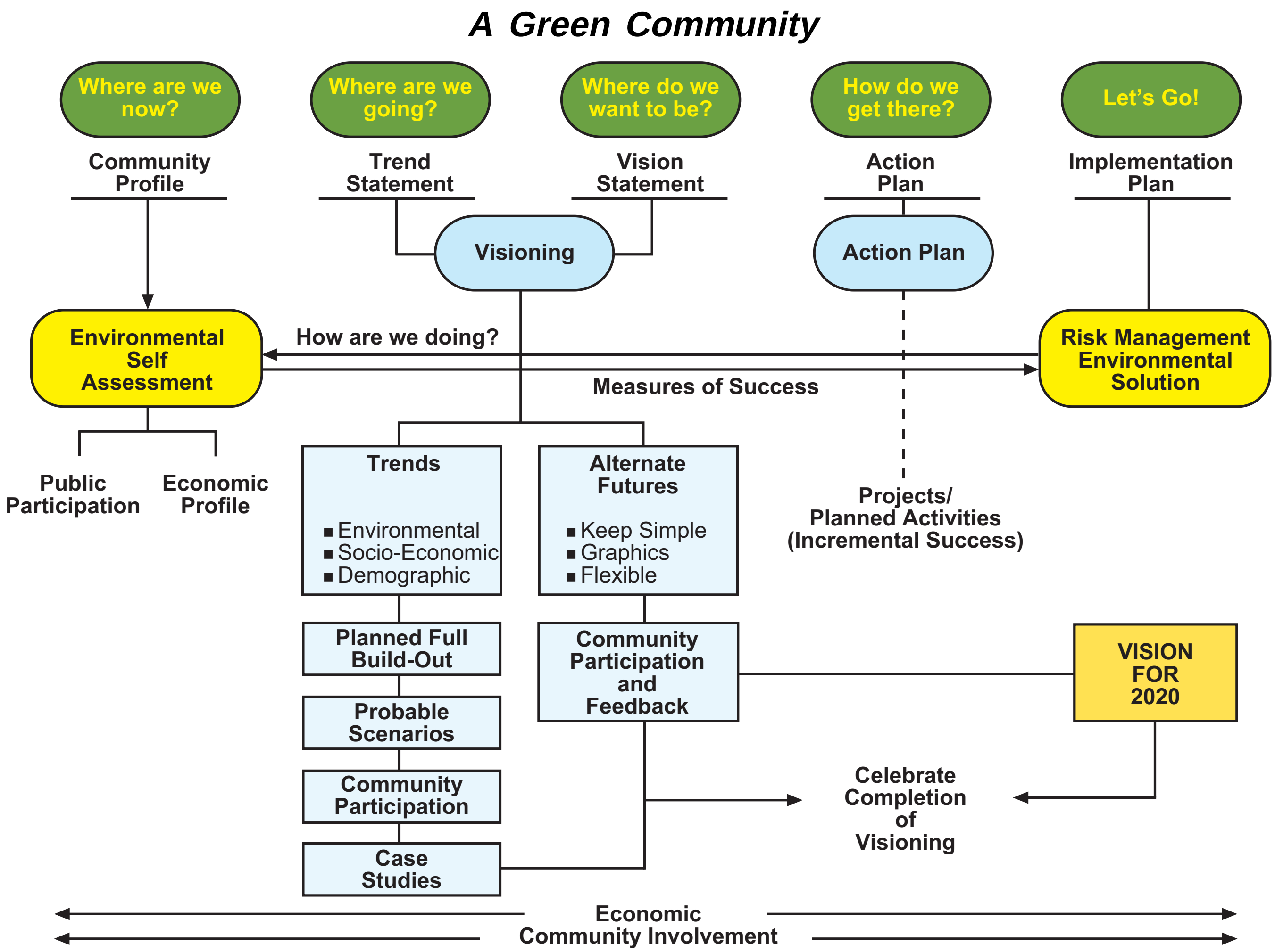
The first step in any environmental planning project is to characterize the initial or current state in content, boundary, space, and time. All natural and cultural systems are characterized during this phase. These include, but are not limited to, hydrology, geology, land cover/use, topography, biodiversity, fires, roads and public ownership. Representation of landscape is best done with visualization techniques. For example, maps and pictures give good visual sense of the landscape. GIS provides tools for putting together layers of information about the landscape's natural and cultural systems, and for displaying them visually on computer screens or on printed maps.

Process Models

Once the pertinent elements of landscape are characterized, their structural and functional relationships can be studied to describe how the landscape operates. This phase includes modeling key processes and their relationship with other interacting processes. Typical processes include physical, such as hydrology and geology; biological, such as vegetation and wild life; and cultural, such as land use and management practices.

Evaluation Models

This phase evaluates how well the current landscape is functioning. First, some measures of judgement are established for rating performance from least to most desirable, based on the benefits and pitfalls of each scenario. Then the current landscape and the state of its elements are evaluated using the performance standards. For example, a survey on visual preference could indicate how well the visual landscape is functioning. Alternatively, a study on the patterns of precipitation, stream hydrographs



Portions reprinted with permission of the Oregon Visions Project.

Figure 3-1. Green community flow chart (source: *http://www.epa.gov/region03/greenkit).*

and flooding, could be used to evaluate stream performance related to flooding.

Change Models

Predictable changes in landscape are based on current trends, such as demographic changes, urban development, and deforestation. Changes may also be proposed to reflect community needs. These changes can be modeled using cultural parameters, such as, growth and development plans; or natural process, such as hydrologic and drought cycles. Using several scenarios of land development policies, as well as other cultural and natural changes, produces a number of alternative scenarios.

Impact Models

Process models are used to simulate changes and predict the impacts resulting from such changes. This phase provides information about the alternative futures of the landscape. In any given area, the physical processes (e.g., hydrology, biology, and geology) affect each other. For example, high-density land developments traditionally increase pavements and contiguous hard surfaces resulting in high runoff from precipitation and less infiltration. This process results in a reduction of soil moisture, erosion of stream banks, and decline in vegetation growth. Thus, traditional land developments not only affect the hydrologic process, but also impact some biological processes that thrive on soil moisture and vegetation health. Thus, the impacts of land development and deforestation on biodiversity or hydrologic processes may constitute one aspect of the study. At this stage, the impacts from several change scenarios are studied to yield a number of alternative futures.

Decision Models

A comparative analysis of the predicted changes and their impacts on the landscape presents decision makers with the opportunity to make informed decisions on what changes should (not) happen in order to reach the preferred alternative future. Adequate information is required in order to reach healthy decisions.

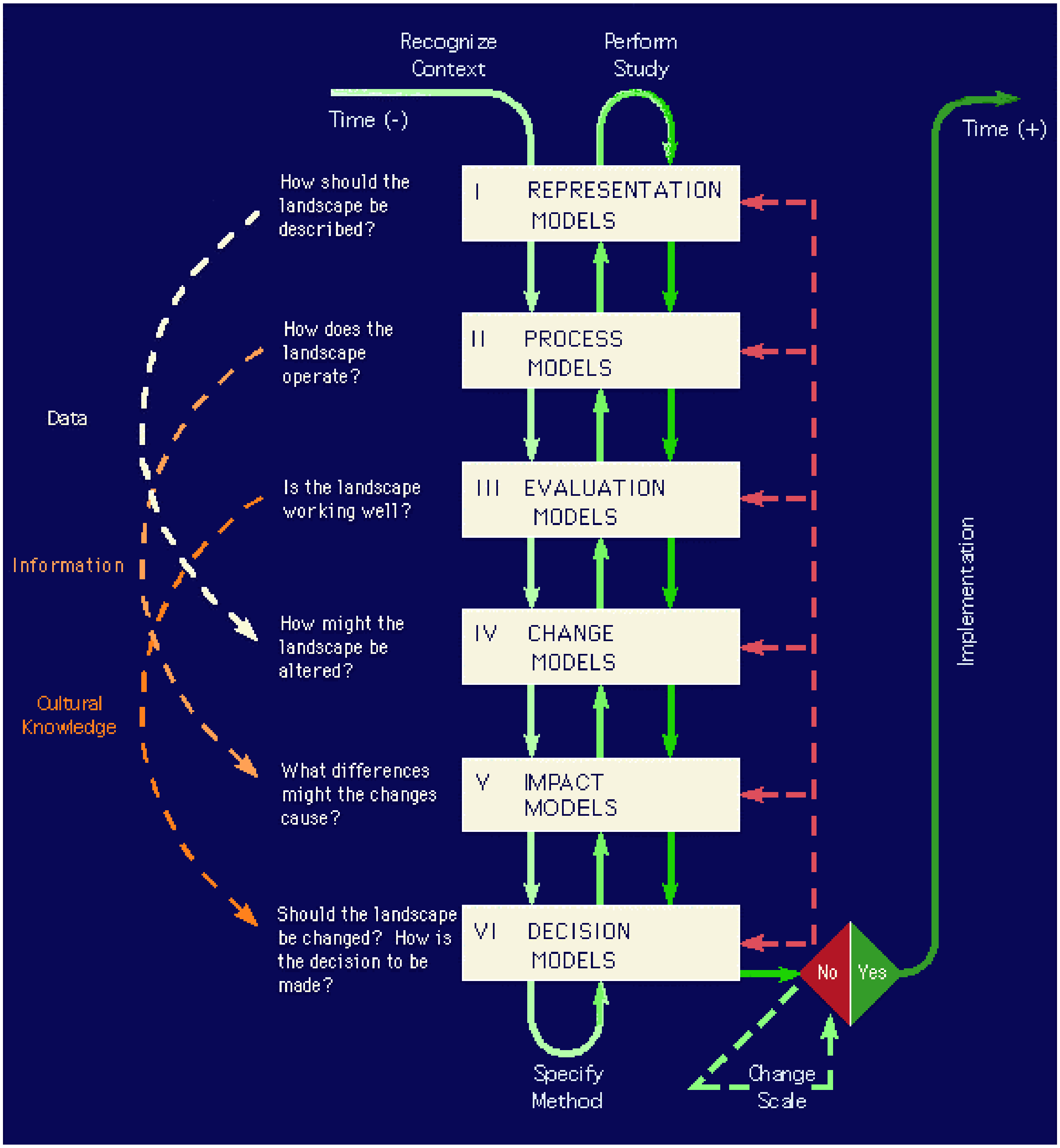


Figure 3-2. Steinitz's framework for landscape planning (source: *http://www.gsd.harvard.edu/brc/maps/fig_5.html).*

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Application of the Steinitz Framework in the Snyderville Basin, Utah

The Snyderville Basin, Utah, is located east of the highly developed Great Salt Lake Valley. The population in the area is approximately 10,000, who depend on agriculture and recreation as major economic activities. With world class ski resorts, such as Park City and Deer Valley, one of the most valued attributes of the county is its open landscape. Population growth in the Salt Lake Valley is expected to expand to the Snyderville area, threatening the environmental quality of the county.

In order to understand the extent of the problem, a GIS representation of the area was established. It included digital representation of terrain elevations, land cover, and land ownership. The GIS data, in addition to other non-GIS information, made a basis for evaluation of the current state of the ecosystem. Potential changes in the environment were simulated using current growth and development trends, and their impacts on the natural resources were estimated. The GIS provided tools for integrating geographic and descriptive information, and for presenting changes and their impacts in visual outputs, such as maps.

Five alternative futures were considered for the basin, in order to minimize infrastructure developments and their impact on the environment. All of the futures require public management of growth and development in the area.

Source: *http://www.gsd.harvard.edu/brc/framework/snyderville_basin.html*

4 GIS-Based Environmental Visioning

4.1 Introduction

4.1.1 Definition of a GIS

A GIS is a computerized, integrated system used to compile store, manipulate, and output mapped spatial data associated with a particular geographic area or region. The incorporation of geographic information into a GIS supports a wide range of analyses and promotes the use of these data to better understand the characteristics of the region under a wide range of management and/or development scenarios.

Although a GIS can be used to create maps, it is important to recognize that a GIS in itself is not just a map-making system, nor does it always attempt to provide an exact replication of all mapped data. A GIS contains analytical tools that also allow the user to identify the spatial relationships between map features. It utilizes the computerized representation of these features to provide the input data to a wide range of process, impact, and evaluation models. It also serves as the receptor for the output of these models and analytical tools to display impacts and results of development/management scenarios in both a graphical and tabular fashion.

4.1.2 History of a GIS

Engineers, landscape architects, and planners have long utilized some of the fundamental techniques such as manually created overlays, embodied within a GIS, long before the advent of computerized capabilities and data management systems. The advent of computers has increased the ease, complexity, and speed of completing such analyses.

Much in the evolution of GIS can be traced to the early to mid 1960s. For example, Howard Fisher at Harvard University invented two early GIS tools, SYMAP and SYMVU, which combined early data storage techniques in association with chloropleth plotting (SYMAP) and vector plotting techniques (SYMVU). These systems were used to display individual and combined characteristics stored in a digital database to better understand the interaction and consequences of various terrestrial parameters.

Significant increase in the use of GIS techniques began in the early 1970s, improving upon the capabilities inherent in SYMAP/SYMVU. The PIOS system in San Diego (which became the forerunner of ESRI's ARC/INFO technology), Maryland's 'MAC1' system, efforts by Dr. Roger Tomlinson in Canada, and the application of the Aerial Design and Planning Tool (ADAPT) System statewide in Kentucky and Ohio are examples of some of these pioneering efforts.

In the United States, major environmental programs were often drivers for the development and implementation of a GIS. For example, the Clean Water Act Amendments required the completion of basin-wide planning efforts under Section 303(e), area wide waste water management and planning under Section 208, and local facilities' plans under Section 201. The GIS capabilities, developed and applied in response to these needs, incorporated spatial database elements and integrated analytical models for rainfall runoff modeling, sewer design and costing, and water quality impact analysis.

In addition, GIS graphical display capabilities were used to show the impact of alternative development and management scenarios. Similarly, the programs and regulations developed in response to Section 502 of the Surface Mining Control Act required the development of land use plans associated with surface mining activities. This act also provided funding for regional and statewide planning efforts that was used to develop GIS capabilities to support the needs of sound environmental development and management of our nation's coal resources.

Although the application of GIS for environmental problems and issues has spanned at least 30 years, it was not until the 1980s, with the advent and broad utilization of microcomputer capabilities, that GIS technology and applications have accelerated. The rapid and expanded use of GIS is stimulated by a wide range of issues supported, both by the public and private sector due to:

- Reductions in the cost of hardware and software
- Efficiency in the development of the spatial database component (generally the most expensive element) in the application of GIS technology)

Several processes within CBEP and environmental visioning are very important from the perspective that they can, will, and do benefit from GIS applications.

4.1.3 Organization of This Chapter

The advent of environmental visioning, CBEP, watershed analysis, risk management and analysis, and related activities, have made comprehensive and efficient use of

GIS in the efforts to reduce the synergistic impacts of pollutants, and adopt pollutant management strategies. To illustrate the use of GIS in supporting these efforts, this chapter:

- Provides an overview of the various GIS components
- Identifies some of the benefits/pitfalls of GIS applications
- Summarizes existing approaches to GIS-based environmental visioning and highlights such approaches in several example case studies.

4.2 Components of a GIS

The three components of a GIS from a systems perspective are: (1) data, (2) hardware and, (3) software.

4.2.1 GIS Data

GIS data are stored in two complementary forms: geographic and descriptive. Geographic data include the geometry of physical features, such as sizes and shapes, and include such elements as political boundaries, soil boundary, roads, rivers, and buildings. Descriptive data are typically stored in tabular forms and contain information about physical features and their relationships. For example, when representing a lake, the boundaries of the lake are stored with geographic reference, such as latitude and longitude. Descriptive data about the lake, such as name, water quality, list of recreational activities, and standards and regulatory policies are stored in tabular forms. Descriptive data are usually coded so that they can be linked to the corresponding physical features. Therefore, a mouse click on a lake brings to the screen tabular information on the physical characteristics of the lake.

Common suppliers of data are local, state, and federal government agencies and private suppliers. The typical data sources are global positioning system (GPS) data and remote-sensing data, which are discussed in further detail in the following subsections.

4.2.1.1 Global Positioning System (GPS) Data

The Global Positioning System (GPS) provides the means to determine the latitude and the longitude of any position on the earth using a GPS receiver. The GPS is a set of satellites that transmit radio signals to GPS receivers for locating the position of the receiver. (Diggelen, 1994). The GPS technology is increasingly used for obtaining geographically referenced data in many applications, including GIS.

A GPS signal is a code modulated in a carrier radio wave. Each satellite transmits the signal in two frequencies so that errors introduced in the signal as it passes through the ionosphere are corrected. In order to determine the latitude, longitude, altitude, and time, a receiver should get signals from at least four satellites. The more signals received and processed the better the accuracy.

GPS receivers have a wide range of accuracy. The U.S. Air Force, which controls the GPS satellites, deliberately introduces noise, known as Selective Availability (SA), to GPS signals so that a single receiver (field) for civilian use has a positional accuracy of 100 meters. Using a second GPS receiver (reference), located at a position with known geographic coordinates, can significantly reduce SA. The reference GPS receiver uses the knowledge of its position to correct not only SA, but also other errors related to the atmosphere, clock, and orbit of the satellites. This correction method called differential GPS (DGPS) results in sub-meter accuracy. DGPS can be made in real-time through radio communication between the reference and field receivers. Alternatively, corrections can be made after data collection through a process known as post-processing. The prices of GPS receivers and their functional capabilities change with the intended use. For example, a recreational GPS costs a few hundred dollars, a GPS/GIS may cost several thousand dollars, and a Survey/GPS can cost up to $50,000. The following categories are common uses and characteristics of GPS receivers:

- Recreation—Portable, stand-alone, few channels, no data logging, 100-meter accuracy
- Navigation—Differential, 1-meter accuracy, specialized navigation features
- GIS—Portable, differential, 1-meter accuracy, data logging capability, software interface
- Survey/Geodesy—Portable, differential, dual frequency, centimeter accuracy, data logging capability
- Military applications require receivers with high accuracy

GPS/GIS receivers are generally portable weighing one kilogram (hand-held units) or 3 kilograms (backpack units). Some receivers store only coordinates of positions, while others can also record attributes in 3-level hierarchical structures.

4.2.1.2 Remote Sensing Data

Remote sensing is a method of gathering information about an object without physical contact (Campbell, 1987). The information is obtained by recording the electromagnetic radiation reflected or emitted by the object. Some remote sensors, such as radiometers, produce data points while others scan a surface (e.g., earth) and produce images. The latter group is referred to as imaging sensors. Satellite images and aerial photographs are examples of commonly used data from imaging sensors.

The most commonly used remote sensing data comes from satellite systems, airborne systems, and ground-based systems. Each system has advantages and shortcomings in the following areas:

- Spatial resolution
  Spatial resolution is defined as the smallest object that can be identified in an image. Generally, it depends on the sensor altitude and field of view (FOV). Satellite data has low resolutions varying from five meters to kilometers, although efforts are directed towards achieving higher resolutions. Airborne systems offer higher resolution since aircraft altitude is lower. Spatial resolutions in the order of centimeters can be obtained with airborne sensors.

- Spectral channels
  Remote sensors use filters that are sensitive to narrow bands of the radiation spectrum. The breakdown of the total radiation into small bands is important for studying different types of objects. Some bands are useful for studying water, others provide information about air, vegetation, soils, rocks, etc. For example, combinations of some bands, known as vegetation indices, provide valuable information about vegetation health, plant stress, and potential yield of a crop. Sensors that measure radiation in a number of fine bands are useful for a wide range of studies.

- Radiometric quality
  The quality of radiometric data gathered by a sensor is affected by several factors. Radiometric resolution is the detail in radiometric values (digital numbers) and depends on the sensor type. For example, a 7-bit system has a range of 128 values (shades) for each pixel (unit of image), while an 8-bit system provides 256 values for the same pixel.

  Another factor that affects the radiometric quality is the atmosphere. Atmospheric material (e.g., gases, clouds, and water vapor) between a satellite sensor and the surface of the earth can affect the quality of the satellite image by attenuating radiation or reflecting and emitting into the sensor.

- Ground coverage
  Ground coverage is the geographic area that an image covers. For example, a satellite image may cover a large area of 100 kilometers by 60 kilometers, while a typical image from an airborne system would cover an area of 3 kilometers by 2 kilometers. A large number of images may be processed if an airborne system is used for studies covering large areas.

- Flexibility
  Flexibility in timing and location of data acquisition is important for many projects. For example, with airborne systems, you can decide where, when and how often to collect data, and at what altitudes (with limitations). Satellite systems do not offer such flexibility.

4.2.2 GIS Hardware

Computer hardware used to support GIS is a highly variable part of the overall system. A fully functional GIS must contain hardware to support data input, output, storage, retrieval, display, and analysis.

GIS data and databases are sometimes so huge that it takes minutes just to display, and hours to make an analysis. Users should customize their hardware environment to best meet their own individual needs.

A typical GIS unit is composed of a computer workstation, printer, plotter, and digitizing table. The workstation is desirably equipped with a high-speed processor, large storage capacity, and a high-resolution color monitor. Getting high-speed processors and high-resolution monitors can improve the efficiency of the presentations. However, high-end products cost more than low-end products and a balance between cost and performance should be considered. In addition, simplified fast GIS products are far more effective with local organizations.

4.2.3 GIS Software

Software is a combination of computer programs, routines, and symbolic languages that control and operate computer hardware, or manipulate data. There are two classes of software in a GIS environment. The first is the operating system software, which is designed to allow communication between the computer and the user. The operating system controls the flow of data, the application of other

How to Detect Environmental Changes Using Remote Sensing

- Define scope of change detection
  - Study area
  - Frequency of change (e.g., seasonal, year)
  - Change indicators (classes of vegetation, soil, etc.)
- Process and classify multiple-date digital images of the area with similar
  - Spatial resolution
  - Spectral channels
  - Radiometric quality
  - Atmospheric conditions
  - Phenological considerations
- Perform GIS-based analysis
  - Change detection
  - Statistical analysis

More information is available on the Internet site:

http://www.geog.nottingham.ac.uk/~dee/ceo/chdetect/rssec.html

How to Map Industrial and Urban Air Pollution Using Remote Sensing

Air pollutants released by industrial and urban sites may be mapped by using the Light Detection and Range (LIDAR) finding technology. LIDAR is an instrument that measures the reflection and scattering of infrared pulses aimed at an object (e.g., clouds, gases).

Fluxes of SO_2, NO_2, and Hg released into the atmosphere by industrial plants can be measured using the differential absorption LIDAR (DIAL). The concentrations of these gases can be shown both vertically and horizontally, to identify the most vulnerable areas.

For more information, visit the Internet site:
http://atompc2.fysik.lth.se/AFDOCS/progrep/html/30.htm

programs, the organization and management of files, and the display of information.

The second class of software is the GIS software, which includes programs and tools that provide an interface between users and their geographic data. These tools include those used for entering, manipulating, analyzing, and displaying GIS data. As a user submits a request by clicking on a mouse, or entering a command on a keyboard, GIS software interprets the request and executes a set of commands to produce the results. The unique method of storing and manipulating data differentiates GIS from other drafting or cartographic software.

4.2.3.1 GIS Database Software

A GIS must allow the operator to: (1) incorporate (import) data from outside sources, (2) easily update and alter data, and (3) ask data-related questions of (or query) the database. The database management system (DBMS) software, that is a part of a typical GIS, provides these capabilities. In order to store and manipulate data, DBMS uses a data model, such as the hierarchical, network, and relational data models. The hierarchical data model consists of an ordered set of trees, organizing the data into child-parent structures. The network model is based on two sets of data, a set of records and a set of links. Network databases are complex, and can be regarded as an extended form of the hierarchical databases, since they use multiple child-parent relationship structures.

The relational model, which is the most widely used data model, is based on the mathematics of set theory. The basic model consists of three parts: data structures, known as tables or relations, rules for data integrity, and data manipulation operators. A relational DBMS (RDBMS) allows for easy data entry and manipulation, provides fast query and display, and maintains data integrity and security. All GIS packages use some type of database for storing and maintaining data.

4.2.4 Models

A model is an abstraction of reality designed to achieve a specific goal. Models can be classified into conceptual models and mathematical/computer models. “There are some very generic, conceptual models that will help kindle the visioning process. One such model is rooted in conservation biology. It depicts the importance of conserving those landscape patches that are relatively intact and environmentally significant (e.g., refugia). Another conceptual model of great importance is rooted in landscape ecology. It depicts landscapes as being comprised of various pathways for the movement of energy and materials (e.g., source areas, channels, and sinks). Therefore, in order to conserve our valued, ecologically significant patches, we must protect other patches and corridors that serve as their source, channel, and sink areas. Landscape design and environmental visioning can proceed using these models as initial assumptions.” (Sumner, 1998).

Mathematical models use equations and formulas for estimating results. They are useful in simulating various scenarios and events and in predicting current and future impacts. A GIS provides tools for developing models or creating interface for existing models. For example, existing hydrologic, hydraulic and water quality models can enhance a GIS by increasing its capacity to simulate flooding, to estimate stream bank erosion, and to predict pollutant loading.

The broad categorization of models is presented to dispel the notion that models are necessarily complex “things” that are implemented in computer software. This categorization of models into conceptual and mathematical is not the only one. For example, Steinitz (1993) classified models into six groups, according to their use in landscape planning. McAllister et al., (1996) provide a conceptual framework for synoptic assessment of the Prairie Pothole Region (PPR) as a rapid assessment technique for cases in which time, resources, and information are limited. Another conceptual framework adopted by public agencies across the Northwest for watershed management and native fish recovery has been published by the Pacific Rivers Council (1996).

How to Create Process Models

The "process models" used in evaluating the ecological effects of "alternative futures" often are associational. Many visioning projects start with a classification and characterization of land cover within a study area (e.g., forest, agriculture, high-density urban, low density urban).

Environmental attributes then are assigned to each class. The level of effort afforded to characterization can range from using the best professional judgement (BPJ) to empirically derived data. When following the simple BPJ or rule-based approach, for example, land cover can be simply associated with higher versus lower wildlife function. Likewise, some classes can be associated with high and low water quality. Each alternative future represents a relative change (acreage) in the various patches of land cover, with corresponding (shift) effect on a given assessment endpoint (wildlife, water quality) – and from there we get into the "evaluation" and "change" models"(Sumner, 1998).

4.2.5 Outputs

Output data from GIS can be presented in several forms including maps, graphs, tables and animated displays. Maps are usually paper-based medium on which images are drawn. Examples of GIS maps include topographic maps, road maps, and land cover/land use maps. Graphs are charts used to compare data elements or show temporal or spatial trends. GIS provides methods for summarizing data into graphs. Tables are the basis of a database, and illustrate information in columns and rows. They can be used for creating graphs. GIS products outputs can also be displayed in an animated manner. For example, a set of digital maps or graphs can be "set in motion" to display temporal changes.

4.3 Benefits/Pitfalls of GIS Applications

This section will highlight some of the benefits and pitfalls with a GIS application, particularly as they relate to the environmental visioning process. This list is not meant to be all-inclusive but does identify the key elements of GIS application that need to be considered by all users. Users must be aware of the full range of benefits and opportunities that can be realized through the application of this technology, to reap the maximum benefits.

4.3.1 Benefits

The important benefit of a GIS application to environmental visioning is its inherent ability to support the incorporation and analysis of all spatial data essential to the complete integrated environmental decision-making process. The integration of data, models and perspectives for representation of a desired community is inherent in the environmental visioning and CBEP approach.

A GIS provides the uniformity of data usage and the flexibility to test and evaluate multiple scenarios that will preclude these arguments from interfering with the decision-making process. Use of a common database takes out the differences in presentation, evaluation, and decision making, based on using different forms and types of data.

A GIS provides the opportunity to conduct sensitivity analyses appropriate for the level of accuracy of the input data. This allows the engineers, planners, elected officials, and the public in general to focus on the impacts and analysis of alternatives, as opposed to arguments over the accuracy of the data being utilized in the analysis. Visual outputs, available through use of GIS technology, can be used to present maps, overlays, and three-dimensional depictions of alternative environmental and ecosystem management scenarios.

Clearly, one of the decided benefits and advantages of the GIS technology is to enhance the communication of information, outputs, and decision-making materials to a wide range of decision-makers. Application of a GIS can significantly reduce time and monetary constraints, and the complexities associated with traditional, analytical, and evaluation methodologies.

After the planning process and decision-making efforts have been moved onto the implementation phase, the GIS can continue to support the process by tracking the success and/or failures associated with alternative strategies. A GIS permits the tracking of plan performance and the testing of new approaches, based on new parameters, new information, and/or new conditions within or outside the study area. Supporting the implementation process enhances the environmental visioning and CBEP process and ensures a continually evolving ecosystem and environmental management approach.

Thus, it is essential, when developing and applying a GIS, that the capabilities for ongoing application and utilization are incorporated within the decision-making group/organization. Such an ongoing staff/personnel commitment will be required to take full advantage of the efforts initiated in the initial visioning efforts.

4.3.2 Pitfalls

Application of GIS technology has not been without its stumbles, falls, and, unfortunately, some significant collapses. The current stand-alone and various loose or tight coupling approaches for integrating GIS with environmental modeling are essentially technology driven without ad-

Delineate Effective Riparian Buffers Using GIS-based Models

GIS can be used to delineate an effective riparian buffer for protecting stream water quality from agricultural chemicals and sediment loading. A riparian buffer is a vegetated patch along a stream or lakeshore. It has the following advantages:

Protects stream/lake water quality by reducing direct sediment and chemical loading

Maintains stream bank integrity by reducing precipitation runoff and erosion

Enhances biodiversity and aquatic life

Buffer widths can either be assigned (e.g., 50-200 meters) or determined from Riparian Buffer Delineation Equations (RBDE). Effective solutions can be obtained by using RBDE in a GIS environment.

More information can be obtained on the Internet at: *(http:www.grida.no/prog/global/cgair/awpack/water.htm)*

equately addressing the conceptual problems involved in the integration (Sui, 1999).

Instead of being dictated by GIS technology, it is imperative to evaluate the necessity for a GIS based on the size of the study area as well as the nature of the solutions that are required. For example, a small community of 5000 people may be interested in implementing GIS software to integrate their geographic and local information, as well as to serve as a platform for spatial visualization and analysis for better community services, within a limited budget and time frame. GIS application, for such a project, can be out of reach due to constrained resources such as data, software, time and staff expertise, unless help from external agents such as federal and/or state governments, academic and/or local institutions for hardware and human resources is obtained.

The first issue faced for setting up a GIS is the substantial time and cost required to compile the necessary data and analyze the system's data. Improper applications of GIS will result in costly time-consuming efforts of implementing the GIS and training the personnel to operate it. High initial costs will be incurred in purchasing the necessary hardware, software, and for constant maintenance, leading to difficulty in complying with the stringent time and budget constraints.

GIS applications are disadvantageous when one fails to

1. Understand the requirements for the vision in mind.

2. Define the tools (such as the extent of spatial visualization, the need of external models) that would be required in order to attain the vision. For instance, if people fail to look carefully at the data and explore the cartographic alternatives, they can easily overlook interesting spatial trends or regional groupings (Monmonier, 1996).

3. Select the right technology that would integrate the required tools for better decision making. With powerful computers and "user friendly" mapping software, unintentional cartographic self deception can be inevitable (Monmonier, 1996).

Another major pitfall in developing a GIS relates to the development of the database. The cost to develop a GIS database rapidly accelerates with the application of the GIS, thus exceeding the requirements of the problem(s) at hand. Often this means capturing "potential" data, larger than needed, resulting in the development of an extensive GIS database, leading to tremendous expenditures that may not be required. The "potential" data may not be consistent with the modeling and analytical tools to be employed. Such an approach used is called a 'data-driven, or bottom-up approach.

For example, in early GIS applications associated with non-point source analysis, some GIS efforts stressed incorporation of soils series survey data from the U.S. Natural Resources Conservation Service, because soil series maps were deemed to be "the best data available." As soon as the data were encoded, after laborious and time-consuming efforts, applications of erosion modeling based on the Universal Soil Loss Equation immediately aggregated the detailed information from the soils series into data organized by soils association.

The 'bottom-up' approach caused large expenditure of money to incorporate data into a format that was not used in the analysis. Considerable money could have been saved if soils' associations had been incorporated; recognizing this level of detail was most appropriate to support the analysis tools and the questions to be answered.

A more appropriate approach to selection and development of a GIS database is a 'top-down' approach, based on the following scenario:

1) Define the problem that needs to be solved and addressed.

2) Identify and select the tools (i.e., models, analytical capabilities) that will be used to generate the alternative management scenarios for environmental visioning. The choice of development tools strongly influences the user interface (Moser et al., 1999).

3) Define the levels and types of data necessary to support these tools and address the problem.

4) Incorporate these data into the GIS, and integrate the GIS with the models.

This top-down approach, as opposed to the data-driven bottom-up approach, is the most cost-effective and meaningful way to establish a GIS to meet the needs of each specific visioning application. However, this does lead to a chicken and egg problem, where it is necessary to understand the details to select a "right" GIS tool, but the detail requirements can be rapidly developed with a GIS.

This problem can be defused by developing a pre-implementation plan such as to

(i) Hold discussions with people who have been in similar situations, and learn from their experience.

(ii) Hire GIS and planning experts who can draw upon their experiences to recommend ways to build the GIS or to select better GIS visioning tool.

(iii) Conduct a pilot plan study to carry out a cost analysis to evaluate the time required to build the system, cost of operating the system over an extended period, time savings using the system and non-quantifiable benefits of GIS.

GIS capabilities greatly enhance the amount of information, data, and analytical capabilities available to the decision-making group(s). In doing so, there is always the possibility that the capabilities of the GIS can create a sense of 'information overload' on the decision makers. The use of a GIS must be tailored and targeted to the needs of each decision-making group, so that the appropriate information is presented in an understandable and meaningful way.

Similarly, the technical complexity of using a GIS can sometimes intimidate and confuse some of the stakeholders and, thus, delay the decision-making process. Fortunately, the application and acceptance of computer tools has greatly increased in the last decade, and the historical fear of computers or misunderstanding of their application has diminished.

The construction of a database, the application of modeling tools, and the acquisition of hardware and software to support these efforts can be an expensive process. Improper planning of a GIS application can result in expensive investments, with little or no tangible outputs to contribute to the environmental visioning and decision-making process.

In the worst circumstances, the misapplication of a GIS can frustrate and/or preclude the successful completion of the process itself. The demands and capabilities of the latest technology can hide the inadequacies and complexities of the simulation models. Hence, it is necessary to hold a series of negotiations involving trade-offs between clarity and capabilities of the interface, features of the simulation model, and the time and effort required to develop a good interface between the developers and client/users (Moser et al., 1999).

One of the key detriments to the effective use of GIS technology is lack of adequately trained in-house human resources. This issue has to be addressed early, and proper measures, such as employee training, hiring experts, and outsourcing, must be undertaken.

The final and important aspect of GIS application is budgetary control. Unfortunately, the 'bells and whistles of new technology,' the temptation to incorporate more data and information, and the ability to generate a wide range of outputs can yield significant overruns in the proposed budget. Thus, it is imperative that the top-down approach to GIS development be employed and that only the required data, models, and display tools be selected to meet the specific problems and issues being addressed by the visioning process.

4.4 Existing Approaches to GIS-Based Environmental Visioning

4.4.1 Quantitative

Quantitative analysis involves numerical measurement to analyze a phenomenon. It is the most common approach for studying directly observable processes. Some of the issues addressed during an environmental visioning process require some degree of measurement, what their current state is, and what it should be. For example, the boundary of a watershed basin marked in a GIS layer involves a quantitative analysis. The process requires the terrain elevations of the area, so that the high points are linked together to form the boundary of the watershed. Quantitative approaches use clearly defined methodology and provide objective scientific results that are generally acceptable.

Most physical processes discussed during environmental visioning require quantitative analysis. For example, hydrologic studies involving estimation of runoff from precipitation or simulation of groundwater flow; vegetation mapping used for assessing forest stand; and land cover analysis used for estimating agricultural production all use quantitative analyses. Performance standards (e.g., ratio of impervious to pervious surfaces) used in zoning and land management are also quantitative. However, some social and cultural processes cannot be analyzed with quantitative approaches.

4.4.2 Qualitative

Qualitative approaches are used for processes that do not require numerical measurements. Observations on some natural phenomena can be recorded in word categories that describe the processes involved or state the condition of a system. For example, in order to evaluate the visual preference of a community, a set of photographs representing different scenes of an area may be used (Steinitz et al., 1996). A response from visual observation of the photographs can be categorized from worst to best. Although qualitative analysis is subjective, some processes that are important for decision making require it. Qualitative data should be tackled with caution when designing a study or when interpreting the results of the study.

4.4.3 Advanced vs. Basic

A very basic environmental visioning approach can start with a description of the preferred state, requiring a pen and paper, as tools, but no more. An artist's rendition of the preferred state, either using paint on a canvas or by digitally manipulating photographs, can also fall into the basic category.

GIS technology can also be used in the basic approach. Visual technology that manipulates digital images (images captured by video camera or other scanning device) can also be used to produce alternative scenarios. This approach was effectively used in the Mill Creek Project in Moab, Utah (Natural Resources Conservation Service, 1995). For example, current GIS maps may be edited to depict desired environmental conditions, such as location of new riparian zones. Basic environmental visioning approaches do not engage in advanced modeling or significant analytical computations.

Advanced environmental visioning involves studying the key variables that affect environmental processes and often requires analytical modeling. For example, the interaction between physical, biological, and cultural processes may be modeled to depict how predictable changes affect the whole landscape. Such comprehensive analyses lead to realistic visions by providing the likely alternative futures.

The advances in computer software, hardware and graphic presentation have made it possible to use GIS to readdress the environmental issues and provide a better means to better understand and manage the growth, environmental quality, and economic vitality of the communities. Smith (1999) introduced a new suite of software with a core GIS program designed to involve people in the decision-making process, evaluate different scenarios and policy decisions, and present the result in a fully interactive 3-D environment. Examples of GIS-based advanced environmental visioning are discussed in the next section.

4.5 Case Studies

This section presents the summary of three case studies that used GIS for environmental planning. The studies depict the likely landscape futures for their communities by using advanced, GIS-based environmental visioning. The first study actively involved community members in determining the alternative futures, whereas the other two studies were primarily conducted with the help of area planners and designers.

4.5.1 West Muddy Creek, Benton County, Oregon

Note: This review summarizes the document "Possible Futures for the Muddy Creek Watershed, Benton County, Oregon" by Hulse (ed.) et al., (1997). Reference to the document is listed at the end of the chapter and in the bibliography in Appendix A. Further information can be obtained at: http://ise.uoregon.edu/Muddy/Muddy_abstract.html

Introduction

Oregon's Willamette River Basin encompasses an area of approximately 12,000 square miles in thirteen counties. The basin provides rich and diverse landscapes including high mountains, wilderness areas, productive agricultural lowlands, and large urban centers. Forests cover 75% of the basin's area. The population in the Willamette River Basin is expected to double early in the 21st century. Growth and development for accommodating the anticipated demographic change pose threats to the health and preservation of the current ecosystem.

To learn about the possible futures of the Willamette River Basin, a representative area that would reflect impacts from growth and development was studied. The West Muddy Creek Watershed has high-quality natural resources and is located in an area that has potential for growth and development. The watershed is large enough to capture important hydrologic processes and is representative of the Willamette River Basin in terms of biodiversity and land use practices.

Recognizing the importance of local stakeholders' participation in defining the important issues that affect both development and conservation of the environment, community involvement was pivotal in depicting plausible alternative futures. A series of public meetings were held, followed by intensive discussions in small groups. The leading community concerns were related to watershed health and included maintaining rural character, reducing land use regulations, and improving summer stream flow and fish habitat. Two indicators of watershed health, terrestrial biodiversity and water quality, were studied to assess the current state and possible futures of the ecosystem.

Ecosystem Health and Indicators

Biodiversity, defined as richness of life processes, is important for the health and stability of ecosystems. Generally, there is a complex interdependence among species, such that a change in some species or their habitat affects other species to a varying degree. Hence, a study on biodiversity in the West Muddy Creek Watershed would provide information useful in tracking environmental health of the Willamette River Basin. The study took two approaches to assessing biodiversity: one focused on the well being of a few species (single species approach), and the other addressed a variety of species (multi-species approach). Human beings benefit from biodiversity in a number of ways. For example, supply of vital resources, such as food and water, depends on the quality of biodiversity. Yet, human actions, which cause loss of wildlife habitat, are the biggest threat to biodiversity (National Research Council, 1992).

The study on the water quality of the watershed identified sources of non-point source (NPS) pollution, including sediment and nutrient transport processes, such as the total phosphorous, nitrate, and suspended solids in runoff waters. The land use practices and hydrologic processes were modeled to assess pollution contributions from subbasins. Information on dissolved oxygen, fecal coliform, stream temperature, and water flow modifications were obtained from the Oregon Department of Environmental Quality. A GIS hydrologic model used these data, in addition to climatic and land cover data, to simulate possible changes and predict impacts. The model was calibrated with field data from the Muddy Creek and its tributaries.

Conservation and Development

Residential development, agriculture, and forestry will account for most of the anticipated changes in the West Muddy Creek Watershed ecosystem. Through an environmental visioning process, stakeholders and researchers identified a range of possible futures for the watershed. The future alternatives were based on the degree of development and conservation adopted during the period between 1990 and 2025. The number and distribution of new residents, timber harvesting, and agricultural management in the watershed will define the patterns of landscape. For example, low-density residential areas may require less development in infrastructure, while high-density areas would require improved water supply, sewer system, and transportation infrastructures.

Anticipated changes in the agricultural landscape come from the introduction of new crops, such as hybrid poplar, and the degree of replacement of old crops. These changes will vary with the various development plans.

Forest management policies also vary with ownership (e.g., private, public), and size (e.g., small, large industrial), at least for privately owned areas. Changes in forested lands are based on the different management guidelines on harvest cycles, harvest cuts (location, type, size, distribution), treatment of riparian zones, and replanting procedures.

In order to define the structure for the study process, the past landscape trajectories (how Muddy Creek had evolved during the past 150 years) were studied in detail. A study

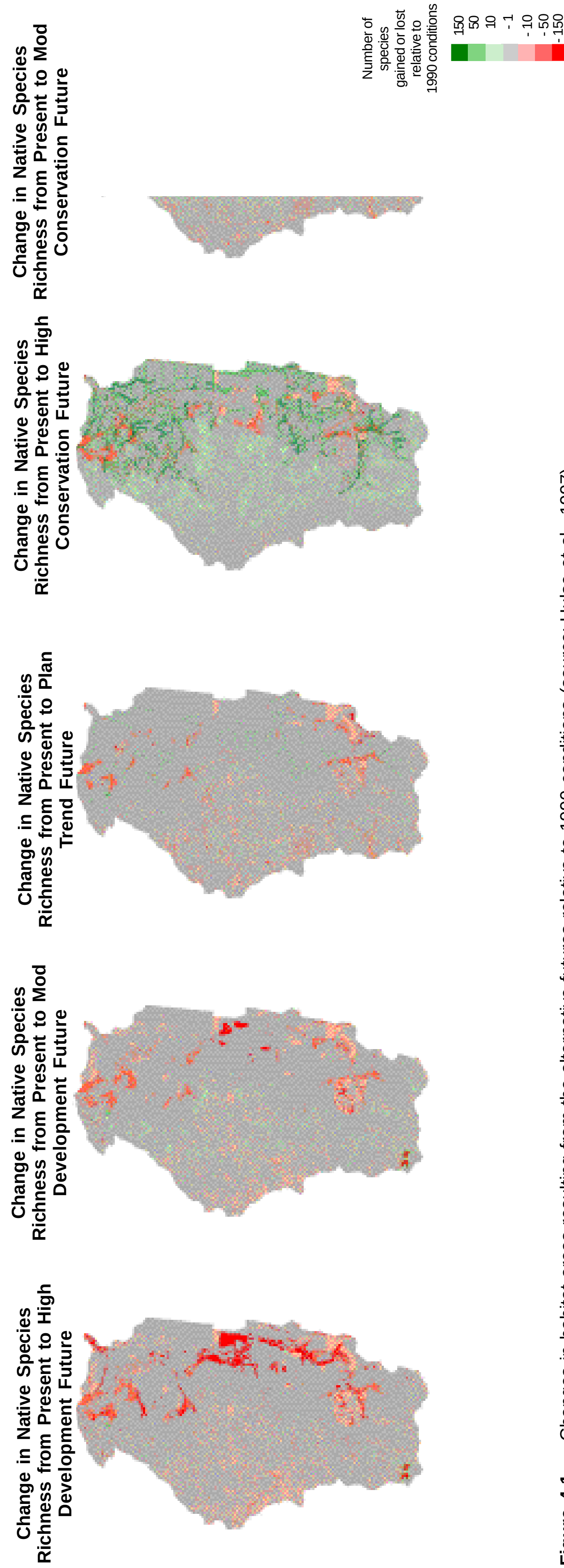

Figure 4-1. Changes in habitat areas resulting from the alternative futures relative to 1990 conditions (source: Hulse et al., 1997).

GIS used for Identifying & Evaluating Alternative Futures for Muddy Creek, Oregon

A research project on the possible futures for Muddy Creek, Oregon, was carried out in areas west of the Willamette River. The goals of the study included describing land use impacts on the ecology and quality of life, and identifying alternative futures for the area. Water quality and biodiversity were considered indicators of ecosystem health. Scenarios of possible future changes including the current development plans, moderate and high development, and moderate and high conservation, as well as their impact on the two indicators were studied.

The landscape changes were evaluated using GIS-based simulations. The biodiversity model estimated the change in potential habitat areas for 234 species of amphibians, reptiles, birds and mammals, while the water quality model simulated pollutant loads under the five development scenarios. The results illustrated on GIS simulated perspectives indicated a high ecological risk if moderate or high development occurs. On the other hand, the ecological response indicates a lower risk if moderate or high conservation alternatives are adopted.

of the trajectories helped the researchers to characterize how the area had changed, and to examine how the change agents interacted to result in diverse landscapes over time.

Alternative Futures for Muddy Creek
Five alternative futures for the Muddy Creek Watershed were considered: high and medium conservation, high and medium development, and Plan Trend, which is projection of the current development plans. Each alternative future is based on a set of scenarios representing possible changes in demography, urban development, agriculture, and forestry.

The Plan Trend Alternative Future is based on projection of current land use and zoning trends. This alternative assumes accommodation of new residents in existing rural residential zones. No major changes are expected in current agricultural lands, however, small pasture areas will be taken over by hybrid poplar. Public forests will follow current guidelines, including 300-foot buffers for riparian zones. Rotation schedules will be 80 years for public forest and 50 years for private forests of all ages.

The High Development Future assumes that the population would double by the year 2025. High development strategies will be employed in order to accommodate such a large number of people and to generate revenues. While no significant change is anticipated in the agricultural landscape, the High Development Future recognizes a change in forest management. For example, all public and private forests will be managed under a 40-year rotation cycle, compared to the 80-year cycle in the Plan Trend. Smaller riparian buffers (40 feet) will be used.

The High Conservation Future is based on an extensive conservation effort and a small population growth that is accommodated within the existing rural residential areas. A 100-foot buffer zone along streams, and additional 100 feet of cover crops or secondary forest products are introduced. Moreover, a 200-foot wide hedgerow/windbreak will be established along all paved roads. Wetlands are connected by hedgerows, which also line the edges of all grass seed fields. Under this future, public forests are carefully managed to simulate pre-settlement conditions, and old growth patches in private forests are purchased.

The Moderate Development and Moderate Conservation Futures are middle grounds between High Development and Plan Trend, and High Conservation and Plan Trend, respectively. Hence, the impact on agricultural and forest areas will be intermediate between the corresponding futures.

Comparison of the Alternative Futures
Maps representing the response of the ecosystem to the alternative futures relative to the status in 1990 were created using the biodiversity model. Figures 4-1 and 4-2 illustrate the results. The Moderate and High Conservation Futures are the only options that maintain the conditions of 1990. The other futures, including the Plan Trend, result in a higher risk to biodiversity and environmental health. Similarly, the water quality will deteriorate if Plan Trend or any of the Development Futures are employed. The two Conservation Futures slightly improve water quality (Figures 4-3, and 4-4). Therefore, a Future Alternative between Plan Trend and Moderate Conservation seems to provide a good balance between conservation and development.

4.5.2 Monroe County, Pennsylvania

Note: This review summarizes the document "Alternative Futures for Monroe County, Pennsylvania" by Steinitz (ed.) et al., (1997). Reference to the document is listed at the end of the chapter and in the bibliography in Appendix A. Further information can be obtained at: http://www.gsd.harvard.edu/depts/larchdep/research/monroe

Introduction
Monroe County has traditionally enjoyed good water quality, diverse landscape scenery, and year-round recreational opportunities. The County's local economy also benefits

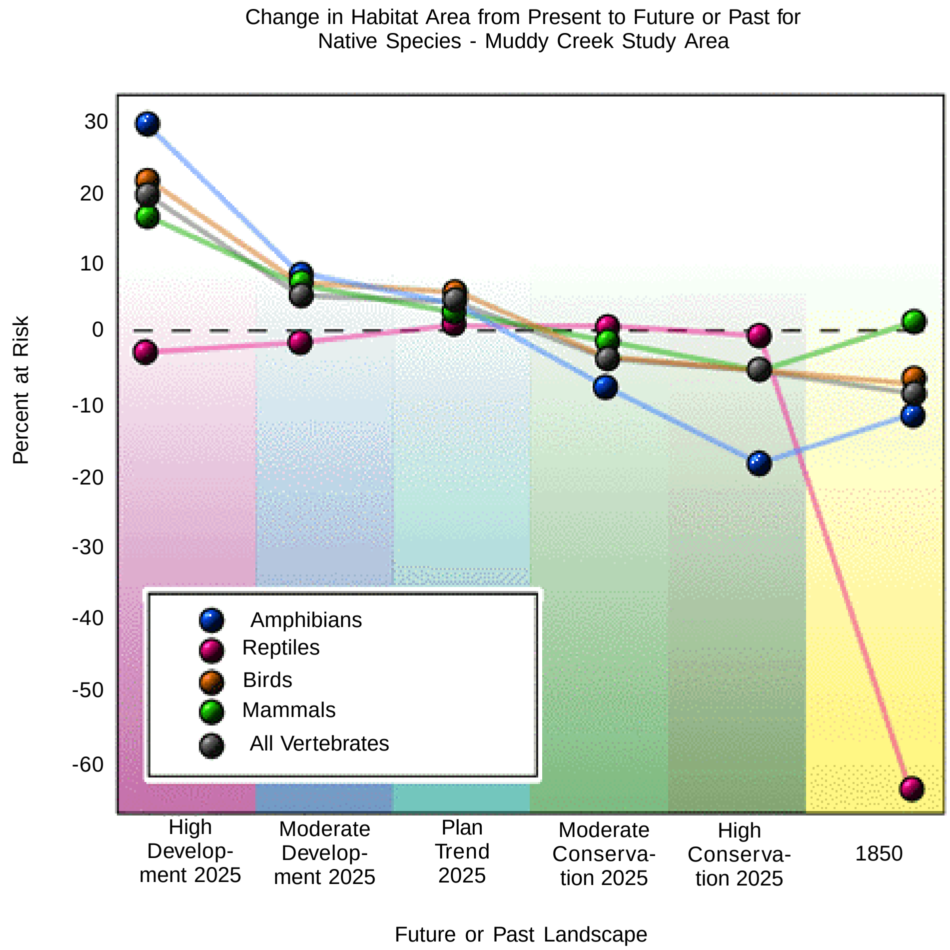

Figure 4-2. Changes in species richness resulting from the alternative futures relative to 1990 conditions (source: Hulse et al., 1997).

from the quality of natural resources. For example, recreational activities such as fishing, boating, and swimming are all too common in the streams and lakes. Continuation of these benefits depends on preservation of the ecosystem. Today, Monroe County is one of the fastest growing areas in Pennsylvania. The current growth trend indicates that the County's population will nearly double by the year 2020. Urban development associated with this demographic change is expected to affect Monroe County's ecosystem and quality of life.

In light of these concerns, a study on the possible futures of the County was conducted using the "Steinitz Framework" (Section 3.5). In order to evaluate the current state of the County and compare it to the alternative futures, a number of processes, grouped into six major categories, were selected for evaluation. These were:

- Geology (surface water quality, ground water recharge area, and agricultural soils)
- Biology (biodiversity, bear habitat, and special natural areas)
- Visual landscape (scenic landscape elements and view quality)
- Demography (projected population change)
- Economy (land value, cost of public actions, and employment)
- Politics (private role, township role, county role).

Ecosystem Health and Indicators

The county's drinking water comes from underground wells and is rated as high quality. However, the groundwater is vulnerable to contamination from some development areas that lack proper sewage system. Surface waters are also of high quality supporting a variety of recreational activities. Current regulations require a vegetation buffer along streams, preserving stream bank integrity and reducing soil erosion and pollutant loading. The risk of overuse and new developments associated with population growth threatens the ecosystem. The county also has large areas of highly productive agricultural soils. These soils are expected to be the first victims of urban development.

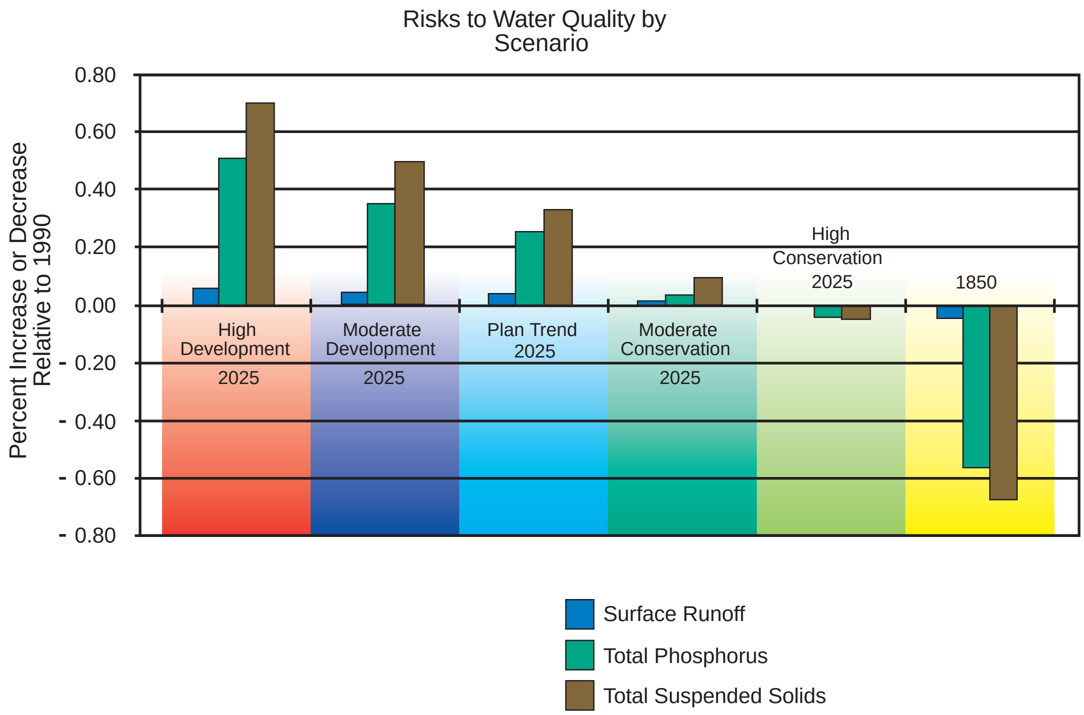

Figure 4-3. Impacts on water quality resulting from the alternative futures relative to 1990 conditions (source: Hulse et al., 1997).

Monroe County has a high biodiversity in a valuable landscape that has been a center for studies for a long time. EPA has recognized the risk to biodiversity and has conducted research on preservation methods. Interpreted satellite images of the county provided information on the vegetation types, which was used for estimating the number of species that potentially use them for habitat. Therefore, biodiversity density maps of the area were generated. In addition to species richness and biodiversity, several endangered plants and animals are also found in the county. For example, the world's only mesic pine barren is found on the Pocono Plateau. Another example is the black bear, which is the symbol of choice for Monroe County. The wetlands and low shrub areas that provide habitat for the black bear are currently regulated. However, most corridors that link these wetland patches are threatened by urban development.

The visual landscape of Monroe County has a high aesthetic value. The scenic landscape of lakes, streams, wetlands, and agricultural lands attracts many visitors and tourists each year. It also attracts new residents, whose arrival threatens the very ecosystem that brought them to Monroe County. While improvements in the current infrastructure may add value to the visual landscape, any endeavor to increase its capacity (e.g., enlarging roads) or to establish new developments poses a threat to the ecosystem.

Monroe County has seen a sharp demographic change during the past few decades. The county's population doubled in the last twenty years. Current forecasts show that the population will also double during the next two decades. Most of the new residents are expected to relocate from metropolitan New York and New Jersey. The challenge in Monroe County is how to accommodate such population increase while preserving its high quality ecosystem and unique identity.

The natural landscape has economic value related to tourism and recreational activities. However, future investments and policies, in addition to efforts in natural conservation and infrastructure development, will affect land values. The land values are based on accessibility, such as vicinity to interstate highways or state and county roads, services, such as water supply and sewage system, and access to scenic views and water bodies. Much of the recent developments are on areas with high land values.

Townships provide government services for most of the residents in Pennsylvania. For example, planning, zoning, and wastewater management activities are in the jurisdiction of townships. Township programs affect areas beyond their boundaries, burdening the county to coordinate among township plans, policies and decisions that affect the natural resources.

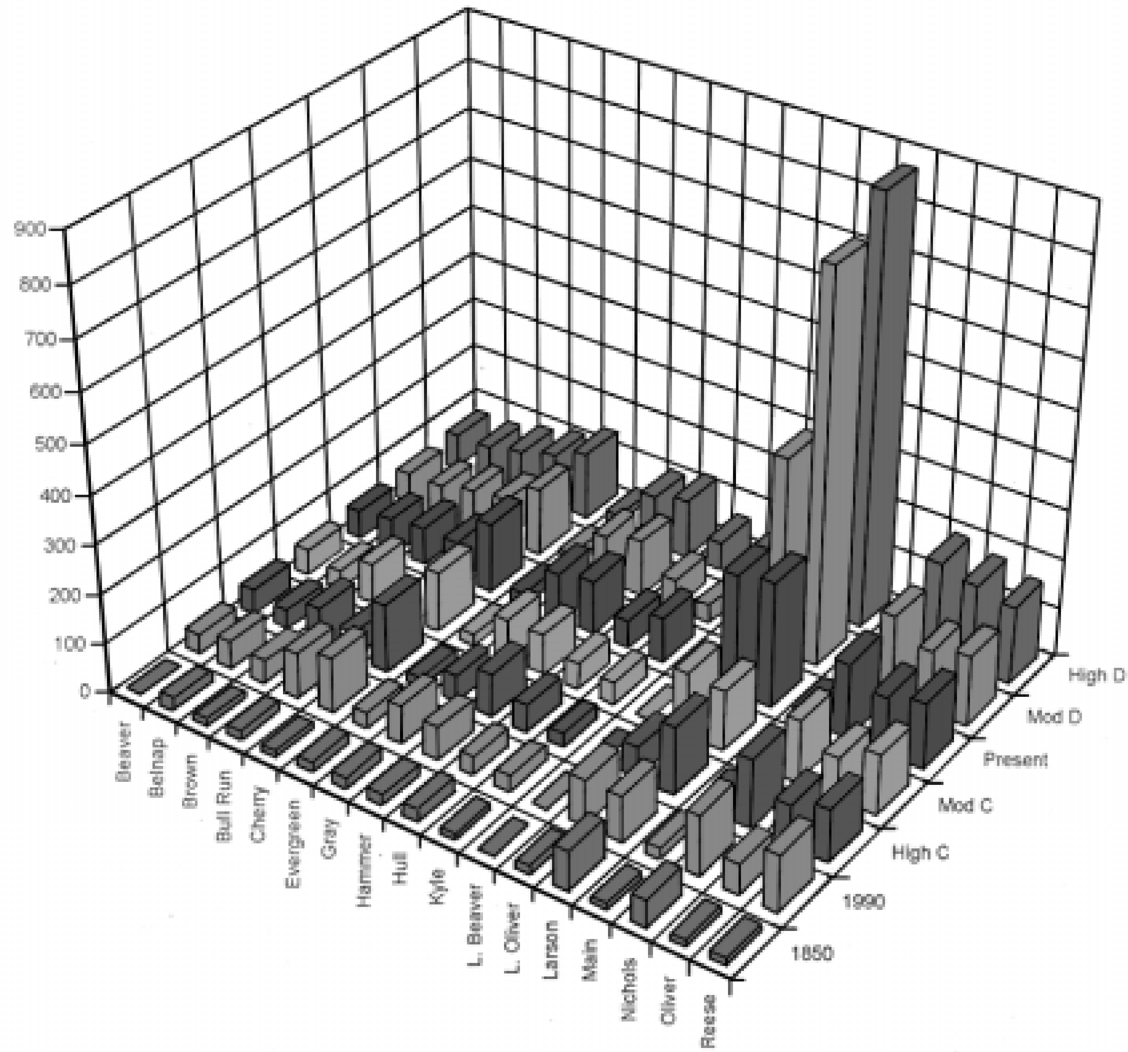

Figure 4-4. Erosion and total suspended solids (metric tons/hectare), by sub-basins, resulting from the alternative futures compared to 1990 and 1850 conditions (source: Hulse et al., 1997).

Urban Development and Conservation

The interaction between policies and actions of the County and Townships towards conservation and development will shape the future patterns of urban development and will shape the landscape. The major projects that make the basis for future alternatives are related to conservation, recreation, sewage, railroad, zoning, development guidelines, Pocono raceway, and billboards.

Two levels of conservation were considered. The first assumes that future developments will not affect all public lands owned by the U.S. or the Common Wealth, or regulated by government. These include lakes, streams, and wetlands. The second conservation plan is based on preservation of ecologically essential lands. These include areas of importance to the geologic landscape (surface water, groundwater, wetlands, and agriculturally productive soils), biologic landscape (biodiversity and bear habitat), and visual landscape (water bodies, agricultural lands, and other scenic areas). Currently, most of these areas are privately owned. Hence, acquisition of conservation rights through purchase or other means is necessary.

Recreation (e.g., tourism, resort hotels) is a leading industry in Monroe County's economy. Some of the measures the county may take in order to keep this industry healthy include preservation of the landscape and development of additional public and commercial recreation services.

The Tunkhannock Township has the Pocono raceway, which provides a unique recreational service to the Mid-Atlantic States. Expansion of the raceway and development of recreational services (e.g., hotel, indoor sports coliseum) are desired for accommodating more people. On the other hand, conservation of the ecologically rich Long Pond is a priority. A number of alternative designs were considered for expanding the raceway and for developing additional recreational services. A design plan that would have least impact on the ecology, while providing major access to the raceway and its recreational facilities, was proposed.

Railroad services are important for Monroe County in order to improve business with the metropolitan areas of New York and New Jersey. In addition, most of the new residents are expected to keep their jobs in these metropolitan areas. The desired rail service includes high-speed commuting and slower freight and tourism services. A new alignment, capable of supporting state of the art high-speed trains, was proposed. This alignment would use several existing right-of-ways, in addition to acquiring right-of-way for some sections. Construction of railroad stations was also proposed on flat areas where commercial development around the station would be feasible. The services accompanying the proposed railroad station include parking lots, and commercial and retail. Also proposed near the railroad station is a recreational area. Other actions that will affect the future alternatives include improving road conditions and reorganizing road signs.

Most of the soils in Monroe County do not support septic discharges. Despite this fact, residential septic tanks are commonly used in most of the County's townships. Only the four Boroughs have sewer treatment systems. Any new development should include a sewer service. One option is to increase the capacity of the existing sewer treatment facilities, and to link sewer lines from newly developed areas to these facilities. A less expensive alternative is to use greenhouses and constructed wetlands for processing waste. Though environmentally sound, these methods are less efficient and have limited capacity. In any case, groundwater quality will be affected if waste is not properly treated.

Monroe County has zoning codes that reflect population density and type of activity. There are three categories of residential codes: high density (one residential per unit acre or less), medium density (one residential per one to two acres), and low density (one residential on more than two acres). Another two classes are commercial and industrial zones. Two additional zones were proposed to provide a greater zoning flexibility: very low density residential (one residential per 20 acres) and mixed residential-commercial.

Alternative Futures for Monroe County

The future of Monroe County is determined by the set of choices made from the above-mentioned alternative change. Six possible alternatives are presented in this study. The first alternative, the Plan Trend, is a projection of the Monroe County Comprehensive Plan. The assumptions in the alternative were that only the public lands that are currently owned or regulated will be conserved. Infrastructure developments will include wastewater management, while current railroad alignments will be used.

Another alternative, the Build-out, assumes that the market will determine development and conservation actions. This alternative will yield results similar to the other suburban developments in the region (e.g., Connecticut, New Jersey). Low-density population is considered, with no major infrastructure developments, such as sewer management, roads, or railroad services.

Four other alternative futures were proposed, namely, Township, Southern, Spine, and Park. These were generated by simulating landscape changes that could result in a more favorable conservation based on the County's physical landscape characteristics.

The Township Alternative proposes high-density urban development in existing subdivisions, and mixed residential-commercial development near town centers. Thus it provides conservation for open spaces and maintains traditional Township political structures. New railway alignment and alternative sewer technology make part of the infrastructure development.

Based on two distinct characters of the county, the Southern Alternative envisions conservation for the north and its wilderness, and development for the south. This ensures that both areas maintain their unique landscape. In order to extend conservation efforts in the north, development rights may be transferred to southern areas. Improvements in roads and adoption of alternative sewer systems are proposed. However, development in the south will fol-

GIS Used for Studying Possible Futures in Monroe County, Pennsylvania

Monroe County, Pennsylvania, faced problems rooted in population growth and suburban land development. A GIS was used to put together data gathered from various sources in order to assess the current state of the landscape. The data included interpreted satellite images, infrastructure plans, and field notes. GIS maps illustrating the current condition of the ecosystem were produced. These base maps were used for simulating the possible development changes, and comparing impacts from the changes. Six possible futures for the County were based on several scenarios of land development practices and their impacts on the landscape. The results were illustrated in number of GIS maps and other governmental images. Further information is available at:

http://www.gsd.harvard.edu/depts/larchdep/research/monroe low strict guideline for protecting agriculturally productive soils and other valuable landscape.

To accommodate the anticipated population growth, while minimizing impacts on the landscape, the Spine Alternative proposes that, urban development be planned between Mount Pocono and Stroudsburg. This alternative will also promote tourism. Fast access to employment centers in metropolitan areas of New York, Philadelphia, and New Jersey will be made possible by high-speed commuter-trains. This requires new railway alignment and development of several railroad stations. The plan includes sewer treatment in high-density areas and improvements in roads.

Finally, the Park Alternative proposes that all undeveloped lands be conserved. This alternative recognizes the negative impact of urban development on the environment, and envisions preservation of the county's high quality landscape by concentrating new developments in and around existing centers, perhaps at high densities. A new railroad and sewer system will include infrastructure services.

Comparison of Alternative Futures

Maps representing each of the alternative futures were compared to a map illustrating the current state of the ecosystem. The evaluation focused on the relative changes in natural resources (geologic, biologic, and visual landscapes), as well as changes in the demography, economy and politics of the county. The results are summarized in Figure 4-5. The proposed four alternative futures provide better results than the projection of current plans.

4.5.3 Camp Pendleton, California

Note: This review summarizes the document "Biodiversity and Landscape Planning: Alternative Futures for the Region of Camp Pendleton, California" by the Steinitz (ed.) et al., (1996). Reference to the document is listed at the end of the chapter and in the bibliography in Appendix A. Further information can be obtained at: http://www.gsd.harvard.edu/brc/brc.html

Introduction

Camp Pendleton is located in one of the country's most desirable areas that is experiencing growth and development. Its unique location provides scenic landscapes and wilderness, and a fast access to the metropolitan centers of Los Angeles and San Diego (Figure 4-6). The region surrounding Camp Pendleton is one of the most biologically diverse ecosystems in the country, ranging from coastal lagoons and estuaries, to oak woodlands and coniferous mountains, to hot and dry deserts. The region provides habitat for more than 200 species listed as endangered, threatened, or rare.

The study was conducted to investigate how population growth and subsequent developments would change the landscape ecosystem in the region of Camp Pendleton. To capture the physical processes, such as the hydrologic regimes, the five drainage basins surrounding Camp Pendleton were included in the study. These are the San Juan, San Mateo, San Onofre, San Luis Rey, and Santa Margarita watersheds. A number of processes that reflect the health of the ecosystem were studied. These include physical processes, such as soils, fires, and hydrology; visual preference; and biodiversity, which was assessed by three models based on landscape patterns, single species and species richness approaches. Analytical models representing the above processes and a GIS were used for simulating changes for the alternative futures.

Ecosystem Health and Indicators

The current land uses and management practices were studied to identify potential development areas and to evaluate the current and future protection efforts. The most protected areas in the region are the biological reserves, which are managed to maintain natural conditions. National forests, BLM lands, and State, County and local parks also provide habitat for many species, enriching the ecosystem, but they are not managed to conserve biodiversity. Other lands, including agricultural areas, military zones, Indian reservations, private holdings, and urban areas have potential for development.

There are several classes of soils in the region, varying in appearance, texture, productivity, and management requirements. Generally speaking, coastal plains have well drained sandy-clay-loam soils that are highly fertile, and suitable for agricultural crop production. Foothills are covered with moderately drained soils that support citrus, avocados, and other irrigated crops. Mountain soils, on the other hand, are generally excessively drained and are unsuitable for crops. Urban development is expected to take over some of the rich agricultural soils. Hydrologic processes have direct relationship with biodiversity and environmental quality. A hydrologic regime also responds to changes in land cover. For example, developments in an area generally increase the impervious surface resulting in low infiltration and high runoffs. This results in flooding if stream channel capacities are exceeded. Future developments in the Camp Pendleton region are expected to increase the volume and velocity of runoffs, possibly resulting in major floods. Physical damages caused by floods and loss of water to the ocean are among the disadvantages of developments.

The major vegetation types in the area include herbaceous, hardwood and conifer trees, and shrubs, including chaparral, desert, coastal sage, and great basin shrubs. Varied vegetation is important for biodiversity, and survival of endangered species. Vegetation growth and health is affected by a set of processes, including hydrology, soils, and land management.

Survival of native plants in the area is also affected by the fire regime. While fire poses threat to life and property of residents, periodic fires are needed to enhance native plant communities. However, the fire regime responds to hydrologic conditions and land management practices. For example, there is high potential for fire during dry and hot weather.

	Existing	Plan Trend	Build-Out	Township	Southern	Spine	Park
Geologic Landscape							
Surface Water	+	-	- -	0	0	0	+ +
Water Recharge	-	-	- -	-	0	-	+
Agricultural Soils	+	-	- -	+	+	+	+
Biological Landscape							
Biodiversity	+ +	-	- -	0	+	0	+ +
Bear Habitat	+ +	- -	- -	0	+	-	+ +
Spec. Nat. Areas	+	- -	- -	+	+	+	+ +
VisualLandscape							
Scenic Elements	+ -	- -	- -	0	+	+	+ +
View Quality	+ -	- -	- -	+	+	+	+ +
Demographics							
Pop. Capacity	+	- -	-	-	-	-	-
Economics							
Cost Public Action	$20m	$20m	$20m	$1733m	$1854m	$1996m	$2072m
Annual Cost of 20yr. Bond @4%	---	$1m	$1m	$104m	$120m	$106m	$135m
Overall	+	+	+	-	-	-	- -
Politics							
Private Roles	+ +	+	+	+	-	-	- -
Township Roles	+ +	- -	- -	+	-	-	- -
County Roles	0	-	-	0	+	+ +	+ +

Legend

Most Positive	+ +
Positive	+
Neutral	0
Negative	-
Most Negative	- -

Figure 4-5. Impact on natural and cultural systems resulting from the alternative futures (source: Steinitz (ed.) et al., 1994).

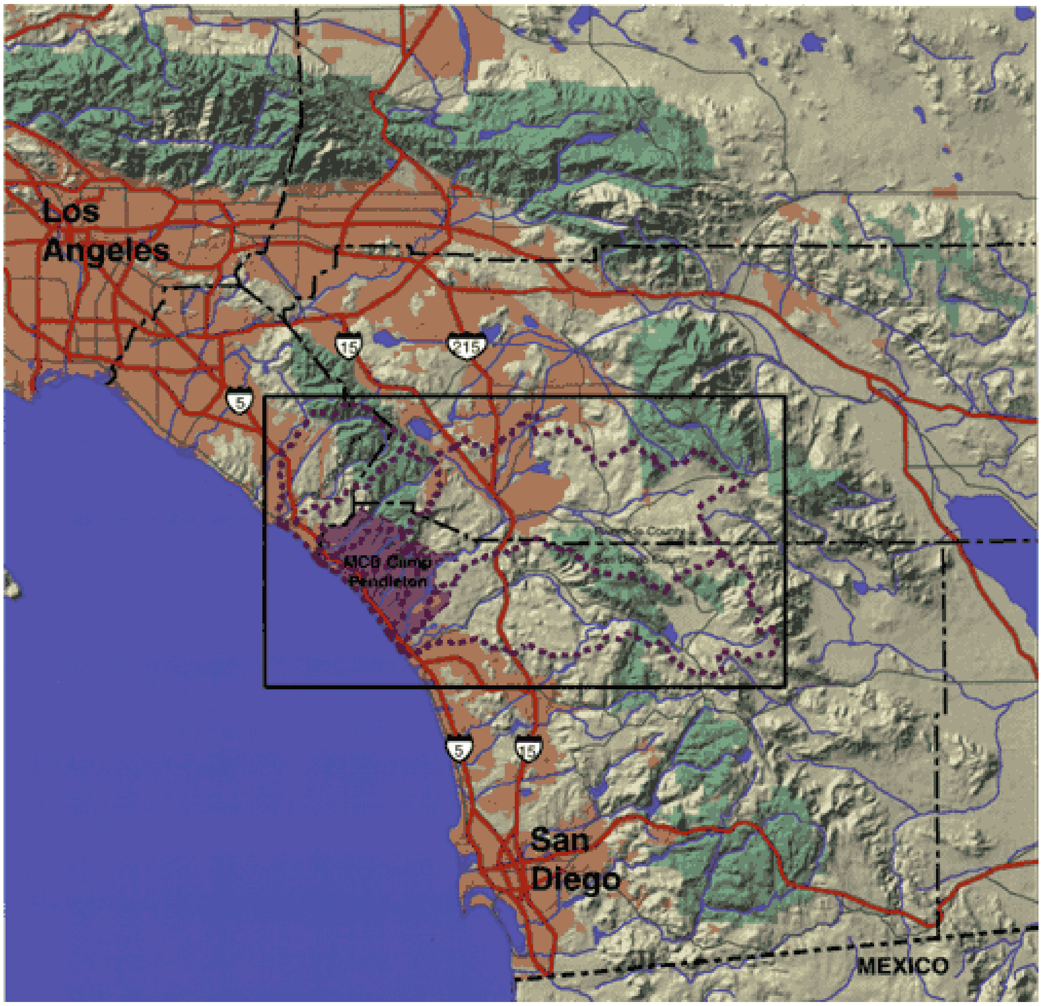

Figure 4-6. Map of the study area (source: Steinitz (ed.) et al., 1996).

GIS Used for Envisioning the Future for the Camp Pendleton Region

Located between San Diego and Los Angeles, Camp Pendleton is surrounded by the largest undeveloped area in southern California. A number of species, listed as endangered or of concern, use this area as habitat. Current growth trends indicate that land developments will alter the landscape ecosystem. Steinitz et al., (1996) conducted research to investigate the possible futures for this area and their impact on biodiversity.

The tools used in the study included GIS aided with analytical models for simulation of the processes involving hydrology, soils, fire, visual preference, and biodiversity. The Steinitz Framework was used to study six alternative projected developments and their impacts on biodiversity, landscape ecology, agricultural soils, fire risk, hydrologic regime, and visual preference. The considered alternative developments included the current local and regional plans, two futures with low-density growth, one of which introduces conservation strategies in the year 2010, large-lot ownership with conservation of biodiversity, multi-center development, and a single new city. The results were summarized in a table rating the impacts from these alternatives into five categories, from the worst to the best (Figure 4-7).

Alternative Futures of Camp Pendleton, California
The Plans Build-Out Future is a projection of the regional land use plans, which are coordinated at county and regional levels. This future alternative assumes no changes in current urban infrastructures and considers continued protection for biological reserves, national forests, BLM lands, and state and county parks. Urban development will take over all developable and unprotected lands. High development is anticipated on slopes between 0% and 5%, while orchard may take over some of the slopes higher than 25%, on which developments are restricted.

The Spread Alternative is a continuation of the current development patterns in Southern California. It is based on medium density single-family-residence in the valleys and extensive rural residence throughout the landscape. No major changes are anticipated in conservation lands or transportation infrastructure development. Developments are assumed to continue without regard to environmental programs such as biodiversity, erosion control, flooding, and water quality. Another alternative, Spread with Conservation, assumes that by the year 2010, conservation projects will start to save the then fragmented ecological patches and critical vegetation.

The Private Conservation Alternative Future is based on private ownership of environmentally sensitive areas, and a low-density residential development in ecologically important areas. Developments in these areas will be conservation oriented, while the current development plans will be followed on other developable lands.

The Multi-Center Future Alternative envisions accommodation of population growth by developing small number of centers with a high residential density, and commercial services. Lands that are critical for habitat continuity are purchased for conservation. Also protected are fertile agricultural soils, wetlands and riparian vegetation, coastal estuaries and scrubs, and scenic landscapes.

Finally, the New City Alternative Future proposes development of an urban center in the Temecula Valley. New residences in this area will be encouraged to protect environmentally sensitive areas. Urban communities in coastal areas will be satellites for the New City. In this alternative, currently protected areas and other environmentally important locations will be protected, and sound environmental programs will be adopted.

Comparison of the Alternative Futures
Impacts from the Alternative Futures were compared as indicated by such process as soils, hydrology, fire, biodiversity, and visual preference. For example, the Multi-center and Private Conservation Futures result in the least amount of loss in agricultural soils, while the Plan Build-out has the biggest impact by loosing half of these fertile soils. Similar comparisons based on the other processes were made ranking the Alternative Futures from worst to best for each process. The results are illustrated in Figure 4-7.

Related Studies
San Diego Association of Governments (SANDAG) has successfully created GIS databases with biological information, such as vegetation and the location of certain plants, soils, and vernal pools, covering the Southwestern, Northwestern and Eastern portion of the San Diego region (SANDAG, Info, 1998). The information is used by the decision makers to assess and rank land based on biological factors. GIS is successfully used for conducting gap analysis (i.e., examining land use management layers along with biological information) to connect and develop separate areas for healthier habitats for wildlife, as well as estimating land value information necessary to create the habitat preserves (Miller, 1994).

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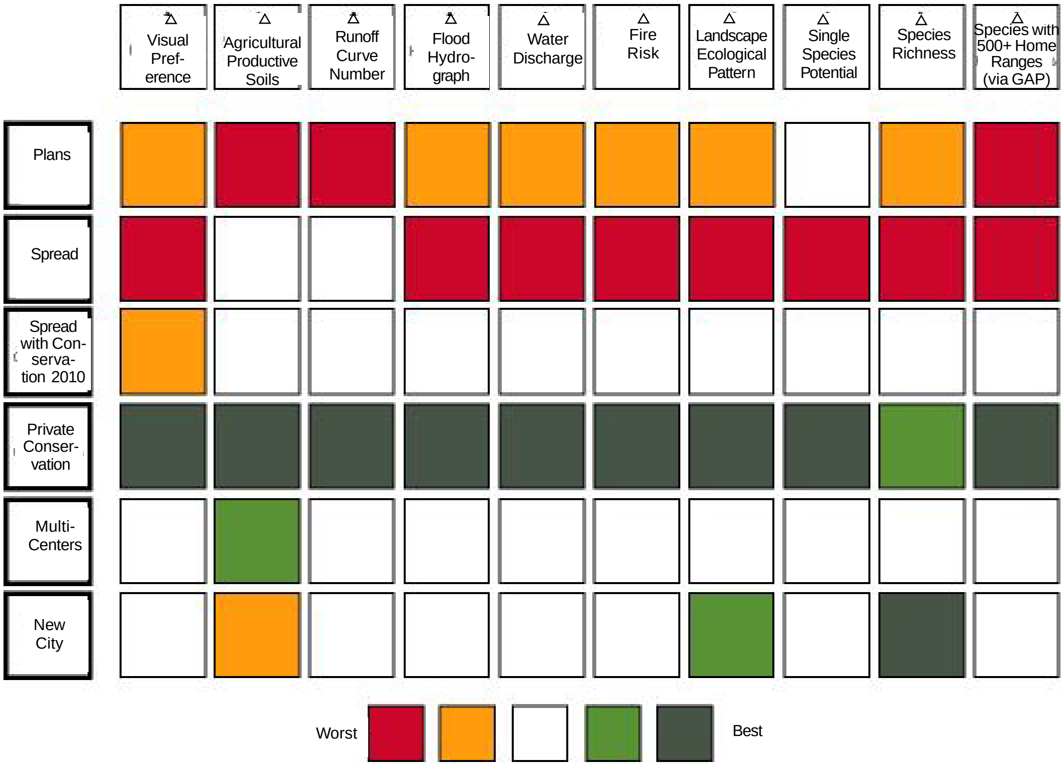

Figure 4-7. Comparative impacts of the alternative futures (source: Steinitz (ed.) et al. 1996).

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5 Creating a GIS to Support Environmental Visioning

5.1 Introduction

5.1.1 Importance of a GIS in Environmental Visioning

To illustrate the significance of a GIS in environmental visioning, consider the following scenario. The town planners of a developing area are faced with the problem of an increase in the traffic flow due to the population growth and suburban land development. Their goal is to build highways in order to improve the transit accessibility over the next 15 years, within the geographic boundary of concern.

A GIS provides tools to put together the data gathered from various sources (such as population density, transportation routing, business areas) in order to compare and assess the existing route accessibility. A GIS is then used in analyzing, and visualizing the population trend and economic growth, travel behavior (tendency of the people in using the routes) over time as well as existing land use to correlate it with the demographic pattern. The GIS tools, with or without the aid of other analytical models, help in the study of the alternative futures for the area. The visualization of the generated GIS maps allows the user to emphasize, generalize, and omit certain features (routes) from the display, to meet the design objectives (improving the accessibility of highly congested areas). The results that are obtained from the GIS analysis can be printed on maps or other visual material. This would allow the town planners to make informed decisions on the implementation of an optimal number of highways at feasible locations.

Thus, understanding the interaction among several processes, natural or cultural, and the environmental impact from changes made in one or more of these processes is required for envisioning a path to a preferred future. An accurate representation of the natural and cultural entities is a prerequisite for understanding and evaluating the current conditions of an ecosystem. Chapter 4 discussed the functional capabilities of GIS components that could be used for environmental visioning and this chapter deals with how to select and use GIS tools for environmental visioning.

5.1.2 Organization of This Chapter

This chapter includes five sections that describe the elements of GIS used for environmental visioning. This section provides a brief introduction on the importance of GIS, and the organization of the chapter. Section 5.2 discusses the groundwork that is involved in selecting a GIS application. A description of the various types of GIS output is given in Section 5.3, and Section 5.4 provides guidance on how to adapt the selected GIS for environmental visioning. Section 5.5 delineates the steps to be conducted for evaluating and comparing possible future scenarios for the community.

5.2 Groundwork for a Successful GIS Application

5.2.1 GIS Tools

Currently, there are four different types of GIS tools in the market, categorized based on increasing cost and functionality (ESRI, 1996).

1. Consumer GIS represents the low cost products available at retail computer stores. These transform the information from databases, spreadsheets to color-filled maps.

2. Desktop mapping represents the next step in providing simple tools to explore digital maps.

3. Desktop GIS provides more functionality. It can create, edit, display, and manage spatial data, and can also analyze and model geographic relationships.

4. Professional GIS packages offer the most advanced spatial and preprocessing tools available.

The decision makers must choose the most appropriate GIS they require for their application. By following a series of logical steps (discussed in the following sections), the selection and successful application of a GIS in environmental visioning can be achieved.

5.2.2 Issues to Be Addressed

The first step involved in the selection and development of a GIS, is to explicitly define the following:

- Goal for the environmental visioning project and issues concerned with planning, land development, conservation of ecology, transportation, and environmental management.

- Needs and requirements for the particular project.

- The tools to be employed such as the hardware requirements against the computer capabilities available to the decision-making group, range of public and commercially software packages that could meet the needs.

- Extent of the data required.

5.2.3 Size of Study Area

The second step in the selection and development of a GIS is size of the study area. It is important to clearly identify all the areas that are included in and/or impacted by the decision-making process, so that the information can be collected, stored, and analyzed over the appropriate area. Larger areas contribute more data, leading to large data sets, thus requiring a more powerful GIS technology, which creates higher costs.

5.2.4 Range of Analyses to Be Completed

After delineating the tasks that are to be accomplished in a defined area of study, the third step is to consider the range of analyses that needs to be completed in the GIS-based project. In a multimedia environmental analysis, such as environmental visioning, information and modeling tools on air, water, land, and other environmental impacts, such as noise, may need to be incorporated into the analytical process. Some expensive GIS products provide built-in support for models, such as network routing, but may incur more costs.

5.2.5 Definition of Desired Data Resolution

The fourth step in the decision of a GIS application is to determine the degree of accuracy that is required for a good data representation.

For example, to study the nature of the water quality in a watershed, a hydrologic model can be generated using the information based on stream temperature, water flow modifications, dissolved oxygen, climatic and land cover data. If the study of the water quality is focussed on identifying specific sources of pollutants in the runoff waters, detailed information on sediment and nutrient transport processes such as total phosphorus, nitrate, and suspended solids, will be required. Thus, it is important to understand the nature and the complexity of the problems to be addressed, the tools to be used, and, therefore, the desired resolution and confidence in the data required in generating the appropriate outputs.

5.2.6 Available Data

The next important task, after doing a thoughtful analysis on what type of data is required, how the data will be used, and what analyses are to be performed at what resolution and scale, is the acquisition of GIS data. If information is already available in a digitized format, selection of a GIS should be based on the one that can accept this information in a short time, thus expediting the process of developing the database for specific applications. The feasibility of obtaining such information should be investigated (discussed in Section 5.4) soon after the decision is made to utilize a GIS.

5.2.7 Available Hardware

The selection of an appropriate GIS hardware depends on the scope of the environmental visioning project as well as on the available resources. The GIS hardware can be setup in a stand-alone or in a networked configuration. Stand-alone configuration uses one or more workstations operating independently. In a networked configuration, two or more workstations are linked together, or to a central computer called server, so that their data and software can be shared.

The typical requirements for a stand-alone GIS unit are listed below.

- Computer workstation
  - High-speed processor, large memory and disk space
  - High resolution color monitor
  - Keyboard
  - Mouse
  - CD-ROM
  - Tape drive
- Map input devices
- Digitizing table
- Scanner
- GPS receivers
  - Portability
  - Number of channels
  - Differential accuracy
  - Memory
  - Software (DOS/Windows)
  - Data dictionary levels
- Plotter
- Printer
- Screen copy devices

Additional hardware that is usually needed, depending on the scale of the environmental visioning project, includes computer servers, which provide high computational power, large storage space, and a file-sharing capacity in networked configurations.

5.2.8 Available Software

After deciding the hardware, the next step is choosing the GIS software. Several commercial GIS packages available in the market can be readily installed and operated. They provide a separate version for each operating platform (e.g., UNIX, Windows). However, there are some packages that operate only under a particular system. Section 4.2.3 gives further details on the types of software and database.

5.2.9 Available Support/Resources

Last is to consider the elements that aid in the successful performance of a GIS application. These include:

- Training: If the people involved are technically oriented, with prior GIS experience, this can enhance the capabilities and utilization of the technology. Those who do not have GIS experience should be trained to acquire a basic understanding of the GIS.

- Technical support: Some members of the environmental visioning team should be designated to work with consulting firms, local universities, government staff, or others who are going to support the GIS application.

- Good product documentation: This may enrich the contribution of the members to the development and implementation of the technology.

5.3 GIS Outputs

Having made the decision on the GIS application that is to be utilized for analysis, the next stage in the process of planning is to explore the ways to transfer the spatial GIS results from screen to print. Two types of output can be generated:

5.3.1 Basic Output

Base Maps

A base map, typically, has general information that covers the study area and illustrates major infrastructures (such as roads and buildings), and natural land covers (such as streams and water bodies). In a GIS environment, base maps are used as sources of geographic reference for other maps or layers of information. The USGS topographic maps are good sources of base maps.

Other Maps and Overlays

A GIS generally stores physical information in thematic layers or digital maps. The layers are geographically referenced so that overlaying information matches. Examples of thematic maps are hydrographic maps, vegetation maps, and land cover/land use maps. Information from more than one GIS layer may be printed on a single map sheet, resulting in mapped overlays. These maps are generally produced to display information of interest, by eliminating irrelevant material.

5.3.2 Advanced Outputs

Landscape Scenarios

A GIS provides tools for generating landscape scenarios by modeling and projecting existing information. For example, a number of scenarios may be generated to illustrate how the landscape will look, say in 10 years, based on different land development and conservation practices. These alternatives are important in the prediction and visualization of the environmental impacts. Some GIS packages provide additional tools for interactively querying environmental effects in an ecosystem.

Animation

Animation provides enhanced visual sensing for temporal changes or trends in some processes. For example, changes in a forestland over the past decades can be shown by animation. This provides a focus on the dynamic changes for the visual observer. Some GIS packages display 3-dimensional elements, such as the landscape of a canyon, which allows the viewer to “walk through” or “navigate” through space, looking at scenes from different angles.

5.4 Developing the GIS for Environmental Visioning

5.4.1 Road Map for Building a GIS

Typical environmental visioning projects, that involve balancing between development and conservation, go through several phases of increasing value and complexity. The first and most widely used phase is representation, which involves inventory of resources and production of maps based on known information requirements. The second phase is building an information management system for improving data access and manipulation. The third phase is advanced GIS, which provides additional modeling and simulation capabilities, acquired by incorporating analytical models into the GIS (Klimas, 1998).

Phase 1: Representation of the geographic area involves creation, georeferencing, and arranging the geographic data for the natural and cultural systems and infrastructures, within the area of concern. It is also termed base data, which is representation of features (as indicated below) in the GIS database.

- Hydrology
  - Rivers
  - Lakes
  - Water bodies
- Geology
  - Soil types
- Hydrogeology
  - Groundwater
  - Surface water
- Biology
  - Vegetation classes
  - Wetland species
  - Fish and important species
  - Wildlife
- Topography
  - Terrain elevations
- Land use
  - Agricultural
  - Industrial
  - Residential
- Infrastructures
  - Transportation
  - Energy and power grids
  - Buildings
  - Communication Systems
  - Navigable waterways
  - Sewer and water installation
- Demography
  - Census data

Some of the base data are processed to yield meaningful derived data. Examples of derived data include slope and aspect acquired from elevation data, stream buffers based on streams, and vegetation classes (e.g., forest, wetland, and riparian) from vegetation and other themes. Both base and derived data are usually manipulated to generate interpreted maps. For example, Elk habitat—an interpreted data set—can be mapped using vegetation maps as well as slope and aspect data.

Phase 2: An information management system The GIS data structure can be improved for better security and easy accessibility, by integrating the GIS database with the other databases. Using this database, the GIS can produce maps that provide valuable information related to the geographic data. Examples of such databases include records of air and water quality, pollution history, and regulatory policies. A hydrologic map can show not only the locations of streams, but also the water quality, sampling locations, and sources of contamination.

Phase 3: Enhanced modeling and analysis Most GIS packages can characterize the environmental setting and simulate the spatial changes, but they require external models for solving complex scientific and engineering problems. For instance, a study is conducted in an area to predict the fate of contaminants in groundwater. GIS software can create a three dimensional terrain representation, but hydraulic and hydrologic models have to be used to simulate complex groundwater flow and predict subsurface contaminant fate.

The enhanced GIS (a combination of the GIS and other analytical models) has the functional capabilities to:

- Simulate possible future changes
- Predict impact from a set of scenarios
- Evaluate resulting future conditions

The advantages of using a GIS include:

Shortened turn around time for creating 'what if' scenarios

Enhanced flexibility in type and format for presentation of data and information necessary to evaluate such scenarios

Provides a common information framework with which disparate stakeholder groups can achieve similar understanding of landscape status and trends

5.4.2 GIS operations

The previous section gave an outline on collecting, manipulating, analyzing, and presenting the GIS data. This section describes these operations in detail.

- Data input
  - Manual digitizing. Hardcopy map can be digitized manually by using a special digitizing tablet over a digitizing table that is configured to record tablet movement over the table. For example, moving the tablet over a stream on the paper map generates a series of points making a line representing the stream.
  - Scanning. Hardcopy maps can also be scanned to produce a raster image of the map. Scanning is more suited to raster GIS. However, special software is commercially available that can convert raster data into vector.
  - Keyboard entry. This method involves entering data through a computer keyboard. It is labor intensive and not practical for large data sets.

File Loading. Data obtained from GPS and other survey instruments, or generated by a cartographic software, can be loaded into GIS using interfaces provided in the GIS package.

- Data manipulation (conversion, validation, rectification)
  - Raster-to-Vector. This process converts raster data (e.g., scanned maps, interpreted satellite images) to vector format using either a single batch process, or a semiautomatic operation of line -following.
  - Vector-to-Raster. This process converts the geometric features of a database to a raster grid of cells or pixels, usually allowing the user to specify the resolution and number of rows and columns of the raster map.
  - Identification and correction of graphical errors. This process involves several commands or functions for identifying, displaying, and correcting overshoots, undershoots, open polygons, and similar errors manually.
  - Identification and correction of attribute errors. Attribute tabular data describing the graphical data are often not in the desired format or structure. Based on the required geographic model, the attributes tables are joined or split, or new relations between tables are created. In addition to tabular relationships, the attributes usually need cleaning and corrections.

- Geo-referencing. This process assigns known geographic coordinates (e.g., latitude and longitude) to the GIS data. Examples of geo-referencing uses include spatial analyses (e.g., distance measurements) and network modeling.

- Transform map projections. GIS maps are often transformed from one map projection (digitized map) to another in order to conform to data standards.

- Merge data and map joining. Digital maps separately digitized from different paper maps are merged to form a large mosaic map of an area of interest.

• Data analysis

  - Compute buffers. A buffer is a zone of a specified distance around a feature. For example, to determine the number of hospitals that are located within a distance of 2 miles around a particular residence, a buffer zone for the specified distance (2 miles), is created around the feature (the residence).

  - Analyze point, line, and polygon overlays. These help in describing the relationship between the features. For example, in a biodiversity model, one can determine what features (animals, human beings, plants etc.,) affect another feature (e.g., food) or what do the features have in common.

  - Perform proximity analysis. This analysis is used to determine which features are near others. For instance, identifying the location of the nearest fire station to a residential colony and computing the distance.

  - Query spatial and attribute data. Queries are questions sent to the GIS database that return requested information if available. For example, a query on the number of facilities that discharge contaminants into a water system returns count of facilities in that category and highlights the selected facilities on the computer display.

  - Model digital terrain elevations. Terrain elevations are modeled to produce surface maps with slopes and aspects for studying., For example, hydrologic processes such as precipitation runoff and snow melting.

  - Perform network analysis. This analysis is used to model flow (such as water, traffic) through a linear feature (e.g., road, stream).

  - Interface with external models. External models are sometimes needed to provide functionality that is not available in the GIS package. For example, hydrologic models may be interfaced with the GIS software to provide more analytical capabilities.

• Data output and presentation. One of the final GIS output operations is map making. However, for printing purposes, the maps are usually created, edited, and displayed several times. The following activities include the output operations:

  - Generate symbols and legends for maps. The process of associating certain graphic or label features with selected symbols, patterns, and colors may require creating reference look-up tables.

  - Display spatial/attribute data. Data display involves zooming (magnifying or reducing the scale of a map, or image displayed on the monitor), panning (changing the position at which the view is displayed, without modifying the scale), and refreshing display.

  - Generate reports. This process involves generating statistical summaries of spatial features as well as their attributes in the tabular data. Additional reporting capabilities, come at varying degrees with the relational database management system (RDBMS) used.

  - Print maps. This process is accomplished in two steps: create a digital map and plot (print) the map. The main features of a map are spatial data (polygons, lines, and points) representing physical features (e.g., roads, houses) supported by explanatory text (e.g., names), symbols (e.g., north, scale), and legends.

5.4.3 Resource Planning

The costs incurred in the development of a GIS, includes initial investment costs, and the maintenance cost.

• Purchasing cost constitutes a large portion of a GIS system.

  - Hardware: High-powered networked systems provide greater efficiency and high performance. They are sometimes too costly for small projects, and require highly skilled operators.

  - Software: Public domain GIS packages can be obtained either free of charge or with nominal fees.

  - Data acquisition (discussed in Section 5.4.4).

- Maintenance cost
    - User training
    - System management
    - Database maintenance
    - Data conversion
    - Hardware/software upgrades
    - Supplies
    - Internal staff

Today, the price of a GIS software and hardware package, vary from a few hundred dollars to thousands of dollars. How much should you pay? The value of any GIS component is not reflected by an affordable price but, more importantly, by its functional capabilities. Inappropriate selection and utilization of a GIS can lead to significant overruns and expenditures in the project. Cost-related issues of data acquisition, personnel requirements, and system management are addressed in the following sections.

5.4.4 Data Acquisition

The following three approaches are commonly used to obtain data (Ossenholler, 1997).

- Existing data

    This is the easiest and often the least expensive, data acquisition method. A number of GIS institutions provide data either free of charge or for a small fee. The following are a few available sources:

    - National sources, such as the U.S. Geological Survey, the National Weather Service, and the National Spatial Data Infrastructure *(www.fgdc.gov)*
    - State and regional agencies
    - Local planning commissions
    - Other organizations, such as educational institutions, and nonprofit organizations that make use of spatial databases for their operations and activities.
    - Data can also be purchased from commercial companies. Some software vendors provide data or links to data sources.

Also check the value of the existing data to your projects and examine the following.

- Extent: Do the data cover the area under investigation? How much information is available?
- Quality of data: Are the data geo-referenced? What is the scale and resolution of data?
- Availability and timeliness: How and when can you obtain the data?

In addition to these concerns, consider the following if purchasing data:

- Make sure the vendor knows what you expect
- Examine the data before purchasing
- Obtain licensing agreement and review for restrictions on data use
- Get metadata for evaluating the data

- Field collection

    Field acquisition is used if data is not available at the desired quality, coverage or price. Intensive field campaigns can be expensive and require human and financial resources. The following tips may useful for collecting data:

- Assemble base-line data. Examples of commonly used base-line maps include:
    - Topographic maps
    - Road maps
    - Soil surveys
    - Aerial photographs
    - Satellite images
    - Census data

    These base-line data provide understanding of the project area and help in designing a data collection strategy.

- Plan data collection strategy
    - Windshield surveys provide fast results and better understanding of the study area.
    - Field sampling may be considered since a thorough collection of data in large project areas is expensive. However, sampling should be repeatable, representative and unbiased.

- Contracting data acquisition

  A contractor may be paid to gather the required data if qualified staff members are not available and existing data is not adequate.

  - Make sure the contractor knows what is expected by arranging meetings between the contractor and data users
  - Examine the data before purchasing
  - Obtain contract agreements and review for restrictions on data use
  - Get metadata for evaluating the data

5.4.5 Personnel Requirement

The number of trained personnel and the required GIS experience depend on the complexity of the environmental visioning project. Three classes of skilled personnel are needed:

- GIS manager who runs overall management and maintenance of the GIS
- GIS analyst who is responsible for project level analysis and research
- GIS technician who assists in data acquisition, data input, and data output

The GIS technician should have basic computer knowledge, and should be trained for handling data input and output devices, such as digitizing tables, scanners, and plotters. The GIS manager and GIS analyst require advanced training and experience to do their tasks. Several GIS analysts may be needed for demanding projects, while a single GIS analyst may be able to perform all three categories for small projects.

5.4.6 System Integration

It is important to integrate the GIS into existing information architecture. Whether such integration can be seamlessly achieved depends on the heterogeneity of the hardware in place. Existence of multitude of computer platforms and their diverse operating systems can make the job of intersystem linkage quite difficult. Lack of well-linked architecture can raise significant barriers to efficient information transfer.

5.5 How to Create an Environmental Vision Using the GIS

At this stage, you must have a vision in mind, a trend plan, and have made the decision on the GIS application that you are going to implement to attain that vision. This section describes the steps that should be considered to achieve the desired results using the GIS application:

1. GIS database: The first step is to create a database containing both map data (depicting location of geographical objects) and attribute data (describing physical characteristics of each object). Physical characteristics (such as agricultural yield, soil types, annual precipitation) and/or nonphysical characteristics (such as, soil moisture conditions, water availability) are examples of attribute data.

2. Representation: In order to understand the extent of the problem, a GIS representation (2-D or 3-D visualization) of the study area is established, like an architect's blueprint representation of a building. It is important to be aware that sometimes the GIS may use a geographic boundary slightly different than that defined in the CBEP for varied reasons.

   For example, if a stream extends beyond the project boundary, activities upstream of the project boundary will have impact on both water quality and quantity. Consequently, some major upstream activities have to be included in the study. Alternatively, partnerships may be extended to the upstream communities in a watershed. (Refer to Chapter 2, Section 2.2 for partnerships and geographic boundaries.)

Steps for the application of a GIS in environmental visioning:

1. Database: Create a GIS database with the geographic and descriptive data of the study area.
2. Representation: Spatial representation of the data using GIS tools, by generating maps and pictures.
3. Processing: Simulate the current scenario using GIS tools with or without the aid of external models.
4. Evaluating: Based on certain tradeoffs, the feasibility of the current scenario is assessed.
5. Scenario building: The changes with the pertinent parameters in the current scenario are constructed, simulated and evaluated, in order to achieve the vision in mind.
6. Decision making: Comparison of the different scenarios and a visual representation of their impacts leads you to make informed decisions on the implementation of the best scenario.

3. Processing: Mapped data indicates where the objects are located. For example, an aerial photo may show that there is land development in certain sections of a county but cannot explain why there isn't in other areas. Using the tools provided by the GIS, a relational link between the tabular data, describing the physical and nonphysical characteristics of the pertinent parameters of the project, can be created. GIS analysis can show the connection between land use, population growth, and economic effects.

   If the project requires the functions of external models, then GIS can be interfaced with those models to provide a better analysis. For instance, during a spill management study, in order to trace the pollutant in a water body, a hydraulic model is used to determine the temporal change of pollutant concentrations in the water body. The solution obtained from the hydraulic model can then be used in GIS to do a spatial and temporal study on the patterns of the pollutant travel in the water body. Refer section 4.2.5 for a broad categorization of the models.

4. Evaluation: Sometimes a change in the assumptions made in a process model results in a forecast different than expected. It is important to test the model's assumptions through sensitivity analysis and determine how much the solution depends on the assumptions used by the model. The evaluation step is to establish certain measures of judgement, to rate the effect of the changes in the scenario from the least to most desirable. For example, if you are faced with the question of setting a speed limit along roads to decrease the traffic fatalities occurring, it would be necessary to compare and assess the traffic trend with varying posted speeds to come up with a viable solution.

5. Scenario building: This step should lead you to answers, to questions of the type "What would happen if…." You can create a hypothetical situation, and different model designs can be constructed, processed and evaluated by following steps 2, 3, 4. The GIS provides tools for depicting different perspectives on how the landscape will/should look in the future. Digital images or photographs of the area may be manipulated to reflect changes and illustrate a future environmental vision.

6. Decision making: The final step is to make the decision. The problem has been assessed and you have come up with either different solutions to solve the problem, or created situations to achieve your vision. A comparative analysis on the alternative future scenarios based on current regional plans as well as other possible options, predicted changes, and their visual impacts allows you to make informed decisions on what changes, should or should not be made to achieve your vision.

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Appendix B: Glossary of Terms

Attribute	an item of text, a numeric value or an image that is a characteristic of a spatial entity
Biodiversity	the number and variety of different species
Buffer	user-specified distance around a point, line or area
Data model	a view of data for representing the real world
Digitizing	conversion of existing maps from paper or film into digital form
Ecosystem	a physical environment and its community of plants and animals
Georeferencing, geocoding	assigning geographic coordinates to physical structures
Global Positioning Systems	a system that receives radio signals from satellites and identifies the location of the signal receiver
Habitat	an environment that supports plant and animal species
Indicators	specific measures of progress or condition
Operating System	computer programs which control the operation of the computer itself
Peripheral	a hardware component connected to a computer to perform special functions
Raster	a data structure composed of a grid of cells
Relational Database	a database which arranges data in the form of tables
Resolution	the size of the smallest object which can be represented
Scanning	conversion of data from analog (paper or film) into digital raster form
Vector	a data structure composed of points and lines
Watershed	an area where rain and other water drain into a common location such as a river or lake

Appendix C: List of Abbreviations

BPJ	Best Professional Judgement
CBEP	Community-Based Environmental Protection
COTS	Common off the Shelf
DBMS	Database Management System
DGPS	Differential Global Positioning System
EPA	Environmental Protection Agency
FOV	Field of View
GIS	Geographic Information System
GPS	Global Positioning System
LIDAR	Light Detection and Range
NRCS	Natural Resources Conservation Service
NPS	Non-point Source
OEPA	Ohio Environmental Protection Agency
OSEC	Office of Sustainable Ecosystems and Communities
PCSD	President's Council on Sustainable Development
RBDE	Riparian Buffer Delineation Equations
RDMS	Relational Database Management System
SA	Selective Availability
USGS	United States Geologic Survey

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