Great Cities Institute/Illinois-Indiana Sea Grant College Program
Urban Water Resources Conference Proceedings

Improved Decision-Making for Water Resources:
The Key to Sustainable Development for Metropolitan Regions

September 16-17, 1999
University of Illinois at Chicago
Chicago, Illinois

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Introduction: Quandaries in Water Resources Decision-Making

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Water resources planning and management usually involves multiple stakeholders and attempts to achieve multiple objectives. This makes water resources planning a complicated, conflictual, and often ambiguous endeavor. Water resources planning and management, for example, often addresses water supply development, consumption, discharge, and irrigation by municipal, industrial and agricultural users. Planners attempt to balance water use and infrastructure needs among these diverse sectors so that most of the users' consumptive objectives can be met at least cost and with minimal public investment. Typically, where there is plenty of water available, future population and employment growth are estimated for a service area and the resulting water demand is projected by sector and location. Water supply production, distribution, storage and treatment infrastructure is then sized to meet this projected demand with a margin of safety for drought or other disruptive events. Municipal and private water utilities then charge users for the finished water at rates sufficient to retire the bonds issued to pay for this needed infrastructure and to recover their annualized operational and maintenance expenses, plus provide a revenue stream to the municipality or utility.

But where there is insufficient water available to meet projected demand, as is the case in arid regions (and even in the Chicago metropolitan area because of legal constraints on the use of Lake Michigan water), then water resources planning become more complicated and more controversial. One option is to make larger infrastructure investments to either import water over longer distances or to use water resources with lower ambient quality, both choices raising the costs of water transport and/or treatment and, thus, the price of water. Alternatively, users or sectors can bid against or compete with each other for rights to use the limited water, increasing their transaction costs and the price of water. These user conflicts can be resolved and water prices stabilized by increasing the amount of available water, by requiring existing and projected water use to be reduced to meet existing supplies, or by having the available supply rationally reallocated among users through public regulations or by private markets.

All of these management options raise thorny -- perhaps even "wicked"-- policy problems. Expanding available water supplies often simply bumps water disputes up a level from local controversies to regional ones, to conflicts between users within a service area or watershed to conflicts between service areas or watersheds. The decisional entity responsible for managing or resolving the controversies also gets bumped up a level or two, from a local water district to a state or federal agency (especially if interbasin or interstate water transfers or diversions are required). If water resource use is considered a zero-sum game in places where there are water shortages, then interbasin water transfer decisions may be recast as regional economic development decisions, exacerbating regional competition and conflict. Long-range diversions also often require substantial subsidies to make water affordable to users, raising additional policy conflicts between those who pay for the subsidies but receive no direct benefit from the increased water supplies. Who gets how much of the water subsidies and who has to ultimately pay for them generate some hard, and usually unpopular for some users, decisions from the management entity.

These allocational decisions are compounded by the institutional and legal context of water resources use. Water resources, especially ground water resources, are often considered as common or pooled resources and the unmanaged use of these types of resources often leads to a "tragedy of the commons." Individual users obtain all the benefits from withdrawing water from the resource, but bear only a portion of the costs of resource overuse (most of which are shifted to other users). State water laws usually support these patterns of water use and overuse. In the eastern U.S., all riparian users have a right to reasonable and beneficial use of surface water resources, for example, while in the west, users are allocated water use rights by their states on a "first-in-time, first-in-right" basis. The institutional framework under which legal rights to water are allocated to users is important in determining how the resource ought best to be managed. Moreover, different types of federal, state, regional, and local agencies have overlapping authority over water resource use and protection, complicating the management and planning process. Unfortunately, little is known about optimal institutional structures for managing our water resources, and this issue remains a research priority (NRC, 2001).

Water conservation and even water reuse are also obvious ways to increase water supplies in those areas that face limited water resources. There is a lot of experience with the conservation of high quality water supply resources but much less experience within the U.S. with the reclamation and reuse of contaminated water (NRC 1998). As a general premise, water conservation almost always makes economic sense in most communities, even in those with plenty of available water, if only to minimize future infrastructure expenditures by artificially increasing existing water treatment, storage and distribution facility capacity through water demand reduction. Making existing capacity go further will usually result in a favorable cost-benefit ratio, especially if most of these water conservation costs are borne by water users and not by the supplier. Despite some occasional grumbling about the functional efficacy of low-flush toilets, federal laws mandating the use of water conserving fixtures have already shifted many of these costs.

It is the process of rationally allocating water between users or sectors that is often most politically problematic for water resources planners. Deciding who should get limited water or who should be subsidized to reduce their water prices (through block pricing for industrial users, for example) implies that some users are deemed more important than others and that public water allocation decisions should be made to reflect these policies. These are obviously politically unpopular decisions for those users who are not preferential consumers under water resources plans. Hydroeconomic models can help planners and policy analysts justify these difficult allocational decisions, or at least to rationalize them in economic terms in terms of their costs and benefits. Systems-based decision-support models can also help water resources managers and planners better identify the critical stakeholders in the water allocation process and what their goals and concerns are so that potential policy tradeoffs can be better assessed.

Private market mechanisms for water allocation finesse some of these political issues by having Adam Smith's "invisible hand" automatically move water from low-value uses (like agriculture) to high-value uses (like industrial production) simply because high-value users can outbid low-value ones for access to the resource. But there may be countervailing public policies, such as food security, which can distort these market forces. Moreover, unbridled water markets are notoriously deficient in addressing environmental issues (many of which -- such as protecting aquatic biodiversity -- are difficult to price), third party or public impacts (that are often ignored in bilateral water transactions between sellers and buyers), and equity issues (such as poorer users being priced out of the market for an essential good).

Traditional water resources planning and management tends to focus on municipal, industrial and agricultural water use, but sound resource management also implies the adoption of policies for non-use. *In situ* water bodies and aquifers remain essential for maintaining wildlife habitats, protecting water quality, providing recreational and navigational functions, offering flood protection through stormwater storage, and supporting natural environmental processes. These natural capital aspects of water resources are critical for maintaining the ecological and hydrological integrity of a region, and ought to be recognized in the resource planning and management process. To some extent, maintaining these natural functions can substitute for installing expensive engineering facilities, resulting in economic savings. Maintaining stream baseflows at a level sufficient to meet environmental, navigational, recreational, and ecological functions and withdrawing ground water at a rate below an aquifer's sustainable yield are sensible strategies, but policies to preserve water resources are often neglected in water resources management plans that instead focus on how water users can meet their existing and projected demand most efficiently and economically.

The six major papers and their commentaries contained in this publication, "Improved Decision-Making for Water Resources: The Key to Sustainable Development for Metropolitan Regions," explore these water resources management problems and decisional quandaries in greater detail. The key theme of all six papers is how water planners and managers can make better decisions about using our water resources more sustainably, especially as these decisions relate to metropolitan growth and its associated water impacts. Professor A. Dan Tarlock and Henry Henderson examine the legal and institutional aspects of this relationship on both municipal and basin-wide scales. Professor William James explores some innovative urban infrastructure strategies to better manage water demand, while James M. Patchett and Gerould Wilhelm examine the non-use and natural capital aspects of water resources. Finally, Professors Robert Costanza and Alex Anas survey the utility of models and economic instruments in fashioning sustainable water resource allocation decisions.

Professor Tarlock notes that the traditional relationship between water supply and land use planning is that infrastructure follows the market: while land planners attempt to mitigate market-driven future growth, water utilities (with a legal "duty to serve") struggle to expand water supplies to meet the new demand generated by such growth. Tarlock observes that this traditional relationship (or, rather, lack of a relationship) is being challenged by legal developments in the Western states, where growing communities are attempting to match their water supplies to their desired growth rates through integrated land use and infrastructure planning. The process of better integrating growth management and water supply development in Illinois should follow three stages, Tarlock argues: first, by recognizing water as a limited resource, next by recognizing that land use and water supply should be better linked, and finally, by enacting "new laws to allow communities to subordinate land development to water supply and watershed protection strategies" This strategy would enable communities to restrict water service in those areas that a community does not wish to see developed, thus subordinating a water utility's "duty to serve" to municipal land use planning objectives.

According to Tarlock, initial steps in enhancing the sustainability of Illinois water policy would be to first rediscover the Chicago region's landscape (to understand the region's inherent natural growth constraints), then to incorporate water resources elements (including water availability and watershed protection) in community plans, and, finally, to reexamine the Lake Michigan allocation and its water markets in order to determine how best to integrate water supply planning and growth management in the Chicago metro region. In commenting on Tarlock's proposals, Professor James Wescoat draws insights from the experiences of the arid West. Wescoat notes that Western states are reluctant to use scientific evaluation and allocation approaches, instead using one body of law (e.g, environmental) against another (e.g., water) to adjust allocational decisions politically. Moreover, integrated planning in the West often involves large-scale water diversion projects and the use of relatively unregulated urban water supplies to support the desired growth and development of primate cities (such as Denver). The next water battles in the West, Wescoat opines, may be between water-rich cities and their growing suburbs. The potential links between landscape and law are interesting, Wescoat concludes, but the landscape research necessary to form such a synthesis is both emerging and daunting.

Henry Henderson's paper focuses on the convoluted governance structure of the Chicago metro region's major water resource, Lake Michigan. Decisions about using this water resource are constrained by U.S. Supreme Court decisions limiting the diversion of water from the Lake and from legal (under the 1986 federal Water Resources Act) and policy (by the Council of Great Lakes Governors) constraints within the Great Lakes Charter that give any Great Lakes state a veto over a diversion decision by another state under the Charter's "prior notice and consultation" provisions. In response to criticism that such veto authority can be exercised arbitrarily (thereby violating international trade agreements), the Council recently adopted its Charter Annex, where the Great Lakes states and provinces agreed to begin developing acceptable and defensible decision-making standards for diversions. The International Joint Commission has also entered the diversion fray, by preparing a report that assumes all Great Lakes water serves important ecological functions and that the burden should be on a prospective diverter to show that the diversion would not impair such functions as a condition of approving a diversion.

The key to developing appropriate institutional management structures for the Great Lakes, Henderson argues, is to appreciate the hydrological and ecological interconnections within the basin and to manage the Great Lakes as a single, unified ecosystem. But this unified perspective is complicated by the fact that Great Lakes water possesses economic value and can also be considered a commodity in international trade. This makes the water resource also subject to national and international trade law, with potential water use conflicts resolved by the World Trade Organization's trade panels instead of through cooperative governance structures. Therefore, Henderson concludes, environmentally sound and commercially valid standards for managing the Great Lakes must be developed in order to treat the region's water as a valuable environmental good and to manage uncontrolled diversions in order to better protect this economic resource.

Commenting on Henderson's proposal, Daniel Injerd observes that few would oppose promoting the more sustainable use of Great Lakes water, but that implementing an effective and feasible governance structure will require that much closer attention be paid to developing credible, science-based water use decisions. Responsibly managing the Great Lakes basin, for instance, requires that decision-makers accurately know how much water is being withdrawn from the watershed or added to it, something that has not been technically feasible to date given the large margins of error in measurement. The very size and complexity of the Great Lakes also hinders its management as a single, integrated ecosystem, as does the willingness of local governments to integrate water resources planning into their land use decisions instead of simply seeking engineering solutions to their water supply problems. Despite these technical and institutional constraints, Injerd notes that there are recent initiatives by a number of regional and international agencies to cooperatively develop a more comprehensive management structure for the region.

Professor William James examines the sustainability of water resources infrastructure investments, broadly defining "sustainability" to "require that no non-renewable energy be consumed, nor should any water or energy be imported from remote areas, and also no by-products such as chemical contaminants should be exported or accumulated locally." In attempting to design more "sustainable" infrastructure, James develops an innovative proposal to radically change how our capital facilities for water supply, stormwater management, and wastewater collection and disposal are designed, repaired, monitored, and managed. James' engineering visions incorporate using distributed intelligence, real-time control, GIS, and the greater use of integrated modeling and management in order to create "smart" urban sewers, distributed storage systems, and infrastructure design and layouts that allow waste streams to be segregated more efficiently within an integrated and centrally-managed drinking water, stormwater, runoff, and wastewater infrastructure system. James also proposes using robotics for autonomous infrastructure inspection and repair, refocusing infrastructure planning to address population growth and waste generation, and creating new types of private-sector and public-private institutional arrangements to more efficiently address urban development objectives and to ensure better infrastructure performance and quality control.

Michael Sanders, in assessing Professor James' proposals, also recognizes the need for sophisticated intelligence and state-of-the-art modeling in designing integrated infrastructure systems, but sees the desired integration blunted by existing institutional arrangements and infrastructure failures, especially in developing areas. Moreover, Sanders notes that most of the innovative technologies James proposes are already in existence but have been rejected on economic terms. Many can be implemented through privatization, but others (such as managed population control) remain too controversial. Differing also with James' definition of "sustainability" to limit energy use and water imports, Sanders concludes that the key to creating integrated water resources management is stakeholder participation – "not just the integration of competing government agencies, jurisdictions, and regulations…the integration of the planning, design, construction and operation, and…the integration of computer models. What we must integrate are the strategies and policies that are proposed to resolve the stakeholders' issues and concerns."

James Patchett and Geould Wilhelm examine the ecology and culture of water in the upper Midwest and how these relate to urban infrastructure. "Understanding the human relationship to the interaction of water with the geology, soils, topography, flora and fauna unique to a place is the first step by which a culture can learn to live sustainably," they argue. Reviewing the historic integration of the region's hydrology and its natural systems, Patchett and Wilhelm note that urban development (and even agriculture) changes the relationship between these two subjects: sustainable design should attempt to retain water where it falls, treating water as a resource rather than as a waste product. Patchett and Wilhem argue that a new paradigm of sustainable design is needed to incorporate the understanding of natural hydrology into the development process and to better integrate urban, suburban and rural developments into the unique natural systems of their sites. In reviewing this premise, James Galloway, Jr. notes that a philosophical goal of this paradigm is to capture all of the water that falls to earth on the micro-urban scale, an objective that may be impossible to extend to the regional and national scales. Erosion, sedimentation and flooding are all natural hydrological processes. As Galloway points out "A system in which all water is captured by the ground is not the normal natural system."

The use of models to better understand complex relationships and thereby choose among alternative water resources decisions is a subtheme in almost all of the conference papers. Tarlock and Henderson both note in passing that modeling can help planners manage water resources better and develop the institutional strategies that are needed to address the forecasted impacts of using or consuming such resources, while James looks to sophisticated models and distributed intelligence as a means to design and to modify infrastructure characteristics in real time to meet changing use demands. Professor Alex Anas also notes, below, that models could help optimize metropolitan water resources policies, by calculating the social costs of different water quality or quantity standards.

In contrast to these tangential discussions of modeling, Professor Robert Costanza examines modeling as the major topic of his paper. Using case studies of natural ecosystems and urban watersheds, Costanza assesses how integrated dynamic models can help decision-makers better understand and manage complex decisions affecting ecological and economic systems. Rather than focusing on the simulations and outputs of the dynamic models as decision-making inputs, Costanza instead focuses on the modeling process itself as a vehicle to engage stakeholders in building consensus on the scoping, modeling and testing decisions.

The computerized dynamic models discussed by Costanza differ from traditional statistical or empirical models because they simulate natural processes and ecosystem dynamics, allowing non-linear relationships, disequalibrium conditions, and time and space lags to be addressed. Models can be misused, notes Costanza, to legitimize rather than inform policy decisions and to cloak normative decisions with an aura of scientific objectivity. Recognizing that large-scale integrated models are inherently "subjective," Costanza points out that they can be used to build consensus not only across academic disciplines but also between wide ranges of parties interested in or affected by water resources policy decisions. Graphical programming languages make the dynamic models more transparent to users, allowing the structure of the model (and its initial conditions, parameter values and functional relationships) to be clearly spelled out.

Costanza's dynamic modeling also uses a three stage process: first, the development (involving experts and stakeholders) of a generalizable and low-resolution scoping and consensus building model, next the creation of a research model that replicates the dynamics of the particular system of interest (including calibration and testing by experts), and, finally, the development of a management model (based on the earlier two models) that predicts system behavior under various management alternatives. Adaptive feedback and monitoring are used to check and improve the models, achieve better understanding, and to test policy options. Case studies of dynamic ecological and landscape assessment models suggest that the three stage modeling process provided a detailed set of management policies that reflected the input and judgments of the stakeholders, and provided a vehicle for building stakeholder consensus regarding complex ecological and economic decisions. Professor Elena Irwin notes some challenges posed by Costanza's approach, including how economic and ecological models are interlinked, the level of spatial and temporal detail devoted to economic modeling of land use change, and how to account for and value non-market ecosystem benefits under the economic components of the dynamic model.

Professor Alex Anas discusses the economics of preserving ecologically valuable land within the context of competing private property ownership rights. Market-based options are preferable to regulatory ones, since preserving land is ultimately an economic activity involving investment decisions and taking these private property rights requires landowner compensation. Anas notes that buying land to preserve it is therefore the most defensible strategy, but that it is often difficult to determine how it should be bought and who should pay for it (to avoid free rider problems), how much land to buy (to meet environmental objectives while minimizing land assembly problems), and how much to pay for it (to reflect its ecological functions and environmental utility). Recent trends affecting land acquisition include urban growth boundaries, and alternatives to fee simple land ownership, such as zoning and development taxes (when coupled with appropriate redistributive taxation). Hydroeconomic modeling can also help decision-makers better account for the spatial shifts in land values and user benefits from public infrastructure investments. Moreover, the marginal cost pricing of water becomes important in protecting scarce metropolitan water resources, Anas notes, while limiting land development is usually not deemed to be a critical factor in preserving water resources quality and quantity.

Professor John Landis's comments on Professor Anas's land acquisition proposals identifies five criteria for identifying potential acquisition sites: these include their ecological importance, the threats posed to them, and the extent that they already are protected by land use and environmental regulation. The ability to preserve these important lands in sufficient amount, size and shape should also affect acquisition decisions, as well as the land portfolio (i.e., the ability to acquire complementary and substitutable sites) of the entity acquiring the land. Landis also notes that land cover mapping and spatial modeling and analysis can help identify the most sensitive and threatened lands, but that more scientific research is needed in determining the minimum required preservation area, shapes and sizes (especially for wildlife habitats). Different levels of government and non-profit entities must also work together in implementing a sensitive lands acquisition program, and potential sites must be ranked and prioritized through careful study and mapping by government and university researchers. Finally, notes Landis, water resources planning may be more difficult than habitat planning in terms of land and resource acquisition, since water models are more process and flow-driven than the data-driven (through species and vegetation inventories) habitat models, and often exhibit greater temporal variability.

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Growth Management and Water Resources Planning
A Possible New Relationship

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Abstract

Historically, there was little linkage between land use planning and water allocation regimes. Water and public utility law assumed that cities had a duty to find the supplies necessary to accommodate unlimited market demand. In an era of rapid population growth and increasingly limited supplies, more and jurisdictions are beginning to integrate land use and water allocation law. The integration of land use planning and water resources law must proceed through three stages. The first is the recognition that water is a limited resource. The second is that recognition that water supply and land use planning should be linked beyond the traditional way of simply planning endless supply projects to meet anticipated growth. The third step is enactment of new laws to allow communities to subordinate land development to water supply and watershed protection policies. Northern Illinois has yet to reach the first of the three stages. Several western states are in transition from the second to the third stage and can provide some useful models for northern Illinois as more jurisdictions realize that they must live with available ground and non-Lake Michigan surface supplies as the Lake is fully allocated under federal and international law.

Key Words
Water law, land use law

I. Introduction: The Reevaluation of the "Duty" to Provide Sufficient Water to Meet Market Demand

The relationship between land-use planning and water supply in the northern Illinois metropolitan area is non-existent, but perhaps this situation is on the verge of change. The relationship is non-existent because local officials, planners and developers assume that the relationship is the simple, historic one that is reflected in public utility law and practice: urban growth is market driven and when and where it occurs, "host" communities have a duty to secure the necessary water supplies to accommodate the market. The power of the assumption that urban growth is fate can be seen in a recent case from the Southeast reviewing a FERC decision to approve the long contested pipeline from Lake Gaston North Carolina to Virginia Beach, Virginia.[1] North Carolina contested FERC's determination of project need. Her arguments included Virginia Beach's concession that water use declined in the area between 1990- 1994, the use of a projected growth in excess of Virginia Beach's actual per capita use, and the exclusion of alternative sources of supply such as aquifers and reservoir modifications, from safe-yield growth projections. North Carolina specifically challenged the need for a drought margin because safe yield was calculated on a worst-case scenario and emergency wells and demand management would see the city through s short-term drought. All were rejected. The Court concluded that it was reasonable for FERC to assume "per capita use rates in Virginia Beach and the other municipalities would likely increase as those areas become more urbanized," and the drought augments were rejected assistant with `sound water supply planning,' given that: (1) especially severe droughts might occur, (2) water sharing within the five-city region was not guaranteed, (3) water restrictions create public health and safety risks; and (4) future water demand might exceed projections." The Court's decision is probably correct as a standard arbitrary and capricious review of an expert administrative agency. However, the rhetoric of the opinion illustrates a view that water suppliers have a duty to acquire sufficient supplies to accommodate high end growth projections under worst case drought scenarios and that those who challenge this orthodoxy have a high, if not impossible, burden of persuasion.

This deeply embedded assumption in United States land and water use planning is slowly being questioned in western United States. Rapid growth is straining the region's limited water supplies, especially as environmental demands intensify and concern about the continued rapid conversion of prime agricultural land increases.[2] Some western states and communities are beginning to subordinate the duty to supply water to growth management. For the first time, the function of water law is to not remove the limitations on urban growth inherent in limited and variable supplies, but it is to allow communities to base growth strategies on the carrying capacity of their natural resources base.

The basic argument of this paper is that growing communities have the discretion to match water supply to desired growth rates. Water and land use regulation have long been considered two separate property and regulatory regimes but they should be integrated through local planning processes. State water law currently encourages urban growth and gives limited recognition to the local values attached to water. It also does not encourage watershed-based planning and regulation. Local communities have little opportunity to subordinate water to growth management policies where they exist. The first step to reversing the disincentives to integrate land and water policy is to recognize that local values have a legitimate place in water allocation law, even if the weight that should be given to this voice can not presently be precisely defined and that neither the law of water rights nor the public utility law duty to serve prevent this coordination among growing cities. Ultimately, water resources planning can become an exercise in watershed protection and landscape definition.

The integration of land use planning and water resources law must proceed through three stages. The first is the recognition that water is a limited resource. The second is that recognition that water supply and land use planning should be linked beyond the traditional way of simply planning endless supply projects to meet anticipated growth. The third step is enactment of new laws to allow communities to subordinate land development to water supply and watershed protection policies. Northern Illinois has yet to reach the first of the three stages. Several western states are in transition from the second to the third stage and can provide some useful models for northern Illinois to study.

II. The Recognition of the Potential Limits Water Resources Impose on Urban Growth

A. Lake Michigan Water: The Paradox of Institutional Scarcity

Water is not perceived as a limiting resource in Northern Illinois for two primary reasons. First, Illinois is in the humid one-half of the United States and is blessed with abundant and regular rainfall. Droughts are generally short-lived and infrequent and water resources are not scarce. Second, and perhaps more important, northern Illinois is located next to the world's largest supply of fresh water, the Great Lakes. However, if one removes the availability of Great Lakes water, northern's Illinois' water resources become less abundant. The nub of the region's problem is that Lake Michigan diversions are unlikely to support the region's future growth for institutional reasons.

The first step toward the recognition that water is a limiting resource is an understanding of the limited availability of Lake Michigan water. This source of water is institutionally rather than naturally scarce. The Great Lakes have never been formally allocated among the basin states by interstate compact, Supreme Court degree or congressional legislation or between Canada and the United States by treaty. However, the body of Great Lakes law which has evolved since the Boundary Waters Treaty of 1909 effectively precludes Illinois from diverting more water than it now does.[3] In fact, Illinois may be over-diverting and will be forced to curtail its use of Lake Michigan water.

Illinois' right to divert Lake Michigan water derives directly from a Supreme Court decree which is the end product of federal, other littoral state and Canadian challenges to the reversal of the flow of the Chicago River and the construction of the Chicago Ship and Sanitary Canal in 1900. In brief, Illinois is limited to 3,200 cubic feet per second over a forty-year accounting period.[4] The state's allocation is administered by the Office of Water Resources of the Illinois Department of Natural Resources. The allocations have created a limited municipal water market in northern Illinois as lake front communities market water to inland municipalities. This market may intensify as allocations are readjusted and capped. Illinois has exceeded its diversion in past years. The Supreme Court has authorized both in kind and monetary restitution as penalties for state that exceed their interstate allocation, but Illinois has voluntarily agreed to limit future diversions to maintain the 3,200 c.f.s. cap over the forty-year averaging period. The cap is the most immediate limitation on the state, but more generally the "law of the lake" is evolving toward an ecosystem management approach. Under this view, most Great Lakes states and the federal and provincial governments of Canada view the lakes as fully "allocated" or "used." In short, the status quo, including natural fluctuating in water level, is the desirable hydrologic baseline and all modifications, including di minimis ones, are presumptively illegal because they might impair the Great Lakes ecosystem.

B. Surface and Ground Water Resources

Northern Illinois has alternative ground and surface resources. These are naturally, but not institutionally, limited to some extent. The Fox and Kankakee Rivers are sources of water supply but their ambient water quality is poor. Pumping from the deep Cambrian-Ordovician aquifer is slightly in excess of safe yield. Shallow ground water is available, but as Martin Jaffe of the University of Illinois at Chicago has observed, the "Silurian dolomite aquifer is susceptible to contamination where its overlying glacial materials are composed of highly permeable outwash sand and gravels."[5] The problem is acerbated by the lack of clear water-use entitlements in the state. Illinois' statutory and common law water allocation regime is still tort-based and thus is effectively a rule of capture. It is more concerned with redressing post hoc injuries rather than facilitating water resources planning.[6] Thus, it encourages unrestricted use by public or private users and creates no legal incentives to limit withdrawals.

III. The Growing Integration of Water Resources Availability and Growth Management in the West

The barriers to the integration of water- and land-use planning are substantial, and remain in place throughout the West. State control over water is the principal barrier because it enabled the states to hand out rights to remove water from areas of origin and to cooperate with the federal government to built the necessary water supply facilities so that water availability would not limit the manifest destiny of endless urban growth. There are, however, scattered signs that state control over water allocation and use is eroding. Urban suppliers ad local communities are becoming more involved in water issues, and some this localism is being reflected in legislation and judicial decisions. This section describes the changing legal and political landscape that gives more weight to local interests in water allocation and use decisions.

A. State Preemption

The traditional assumption of water allocation is that control should not be shared between different levels of state government, but this assumption is challenged by environmental interests and advocates of greater watershed control over the resource. The statewide interest in water rests of the entrenched policy that water should be put to its highest economic use. However, the traditional equation of value with demand neglects other components of the resources' value. The core principle is that water has place and community values, which are submerged by state recognition and administration. Water law scholars have argued that water has extra-market or community values. In their study of water conflicts in northern New Mexico, F. Lee Brown and Helen Ingram concluded that "water has an emotional and symbolic meaning for the West that transcends its commodity value."[7] Local control is a way, although not an exclusive one, by which these in place values can be recognized. Once these values are recognized as legitimate, the case for preemption diminishes. Professor Daniel Rodriguez has written, "[w]here the issue is ecosystem management, the case for field preemption is not strong. . . . That ecosystem issues raise matters of statewide concern need not mean that same issues are not simultaneously matters of local concern."[8] For example, pollution regulation is much less centralized compared to surface pollution and local communities are taking an active role in regulating land use to protect drinking water sources from contamination.[9]

Western water cases are starting to reevaluate the traditional preference for exclusive state control. California has long refused to enact statewide regulate ground water extraction regulation. The state's conscious refusal to regulate has opened the door to counties, which want to control the export of ground water. Potential exporters challenged these ordinances as outside the scope of local authority, but a California intermediate court of appeals refused to find field preemption and upheld the power of counties to prohibit the export of groundwater because the state had not effectively occupied the field of ground water regulation.[10] A Colorado court reached a similar conclusion construing the ambiguous delegation of land use authority to local governments. Colorado long sanctioned the export of water from the western to the eastern slope of the Rocky Mountains, but it has begun to grant west slope counties more say in the diversions as these counties have gained population and developed major tourist economies. Legislation allows counties to designate activities, such as transbasin diversion, a matter of state interest and to develop permitting procedures for these activities.[11] A west slope county did so and denied a permit for a transbasin diversion because the diversion structure would impair a wetland. The water right holder argued that state water law preempted the local regulation, but the state court of appeals held that an entitlement to divert water "should not be understood to carry with it absolute rights to build any diversion project."[12]

B. Duty to Serve and to Plan

The recognition that growth management is a legitimate local government function has modified the traditional duty to serve principle. Public utility law has proceeded on the assumption that water suppliers, public and private, have a duty to serve all customers within their service area who can pay reasonable service charges. The common carrier and public utility duty was premised on the idea that the public interest required courts to police monopoly under production.[13] The duty remains an important limitation on utility service, especially as gas and electric service are deregulated. However, the primary beneficiaries of the doctrine should be captive consumers[14] not new entrants into a community.[15]

The duty to serve is ultimately based on principles of fairness and estoppel and thus does not limit the integration of land and water use planning. Courts protected those who had entered into a service relationship with a common carrier or were within the service area of a public utility but were denied service when carrier or the utility was able or should have been able[16] to provide it. [17] A variety of excuses for the refusal of service were also recognized.[18] This required the utility to anticipate immediate future growth,[19] but the duty never extended to remote areas. Utilities were only required to extend service when it was fiscally reasonable to do so.[20] The estoppel basis of the duty to serve is illustrated by a 1996 opinion of the New York Public Service Commission on competition in the generation of electricity.[21] Several industry groups raised the issue of whether the duty to serve would survive deregulation, and the Commission recommended that transmission and distribution companies must remain providers of last resort, but it qualified this duty. "In order to protect all customers, transmission and distribution companies will need to remain obligated to serve all customers, at least in the short run."

Communities that wish to define growth and non-growth areas have articulated a public interest in limiting utility service to confined areas. Courts initially suggested that this conflicted with the duty to serve.[22] This ignores the fact a new public interest has been articulated by a local government. A city should not be required to undermine its own growth management policy simply because it is also a water supplier, and more recent courts have so held.[23] Non-municipal suppliers should be subordinate to this policy so long as the policy does not impair their constitutionality guaranteed fair rate of return. Consistent with this analysis, the Nevada Supreme Court has held that a county may deny a subdivision permit because it inconsistent with a county water-use plan[24] To preserve the hydrologic balance in the southern part of Washoe County (Reno), the County's plan prohibited five acre or fewer subdivisions "until a new water source is available." The developer argued that the county's action impaired his state water rights, but the court held that the power to define rational growth "includes the ability of county government to determine water availability for itself."[25] The Washington Supreme Court has held that actual application to beneficial use rather than capacity of a private municipal water system is the measure of the water right.[26] This opinion is significant because it questions the soundness of the "growing communities doctrine" which allows cities to amass substantial water supplies in advance of actual demand.

C. New Legislation That Subordinate the Duty to Service to Land Use Planning Objectives

Recent legislation in Idaho and California imposes increased water planning duties on cities, lessens the duty to serve, and opens to the door to alternative growth scenarios. This legislation assumes that the duty to serve is not absolute. Idaho strikes the balance more in favor of rural areas and thus potentially limits rural-urban water transfers to growing areas. The statute gives the Director of the Department of Water Resources to deny a transfer from agriculture to municipal use because the city does not need it. As the previous discussion of Colorado's attempts to subject municipal water planning to the anti-speculation doctrine, local governments have almost but not quite unlimited discretion to make population growth projections. Idaho recently limited municipal discretion to provide some basis to address the water resources impacts of land conversion around Boise.[27] Idaho now authorizes the Department of Water Resources to determine the planning horizon for municipal retention of water rights. Planning horizon is defined as "the length of time that the department determines is reasonable for a municipal provider to hold water rights to meet reasonably anticipated future needs."[28] Such needs are calculated by population and other planning data but "shall not include uses of water within areas overlapped by conflicting comprehensive land use plans."[29] This standard is used to evaluate transfers. The Director must decide that the municipal change of use application is necessary to serve reasonable anticipated future need and will not significantly affect the agricultural base of the area.[30] This provides a basis for the state to use a local agricultural preservation plan as a basis to deny an agricultural to M&I transfer.

California has linked water supply and land use planning objectives in a way that gives local governments some ability, if they take advantage of it, to control the use of local water resources. The Bay Area growth has spilled into Central Valley, one of the world's most productive agricultural districts. The case, problematic as it is, for farm production preservation[31] is stronger here than in many other parts of the West along with the Central Snake River Plain in Idaho. In 1995, California enacted legislation, primarily in response to the rapid and dispersed urban growth and conversion of prime agricultural land in the San Joaquin Valley. The Valley is growing faster than the state average and may triple its population to 12.24 million in 2040.[32] One half of the projected farmland conversion is classified prime farmland by the Natural Resources Conservation Service (formerly the Soil Conservation Service).[33] The legislation requires cities to have a firm water supply plan in place before large, new developments are approved. This legislation reflects the end of the Reclamation era because cities can no longer assume that either the state or the federal government will build and finance the necessary supply augmentation project. Unlike Arizona, the statute does not impose a de facto duty on city to acquire sufficient water rights, but it limits the power of cities to approve new growth and defer the issue of actually providing an adequate water supply until a later date.

This duty reinforces municipal duties under CEQA to consider the adverse environmental impacts of water-dependent growth. This duty includes the assessment the impacts of rural to urban water transfers in the area of origin. An intermediate appellate court has interpreted the California Environmental Quality Act to reinforce the duty to match growth to availability of water supplies. The court held that a county cannot defer the consideration of water supply issues in a phased commercial-residential project when a permanent supply is not available unless a subsequent EIS is prepared for the specific residential phase.[34] The second opinion in Inyo County's challenge to Los Angeles' EIR assessing expanded groundwater extraction stated that "it is doubtful whether an EIR can fulfill CEQA's demands without proposing so obvious a solution" as "water conservation goals within Los Angeles' service area."[35]

The Inyo-Los Angeles litigation was finally settled in 1997 [36] and the settlement indicates that the EIS process is more effective at protecting areas of origin than in stimulating "downstream" demand management. Under the settlement,[37] which was stimulated by the Superior Court of Inyo's invalidation of a groundwater export ban, Los Angeles and Inyo counties formed a standing committee and technical group to monitor the vegetation and groundwater conditions around Los Angeles' well fields. All existing fields are designated management areas, and the vegetation within each area has been classified and mapped. The goal of settlement is to manage pumping so that withdrawals will not exceed total recharge over a 20-year period and to avoid the adverse environmental impacts of vegetation changes in the five different classifications such as crop land, riparian and marshlands and meadows. "Significant" is not defined, but the Settlement provides a process and set of factors.[38] Water balances for each field will be established by the first day of each month, and these balances plus other hydrologic data will be the basis for the County to prepare a yearly operations and pumping program.

IV. Implications for Illinois

Illinois does not immediately face that rapid resource and resource stress problems that the rapidly growing western states face. The state is not, however, immune from one of the central messages of environmentalism that society must learn to live with in natural limits. In fact, urban water suppliers have tried to remove any natural hydrologic limitations to urban growth. The environmental and social costs of this policy are becoming clearer, and states have begun to react to the mounting evidence that failure to coordinate urban growth with water demand can high social and environment costs. States have not repudiated the idea that water should never be a barrier to growth, but states are slowing rethinking this assumption. The Legislation which requires more coordination between water suppliers and urban planners and increased willingness of courts to find that local water initiative are not preempted by state law are creating more opportunities for local control over water allocation and give local governments a new growth management tool. At the present time, Illinois remains firmly committed to the idea that infrastructure must follow the market and it is futile to think otherwise. Thus, its land use and transportation policies are textbook studies in unsustainability. The prospects for change in this attitude appear to be minimal, but the following suggestions would be a first toward to a more sustainable future and one that is consistent with the sustainability of the Great Lakes ecosystem:

1. The rediscovery of the northern Illinois landscape. The dominant vision of northern Illinois is an endless plane that ends at Lake Michigan. The flatness and monotonous urban sprawl makes it easy to ignore the region's watersheds and other natural features, but the first step toward the integration of land and water resources planning is the rediscovery of the landscape so that one can appreciate the possible limitations imposed by the landscape.
2. Community plans should include a water resources component, which describes available sources of water and the impact of alternative supplies on future growth and available demand management options to reduce water use. The plan should also delineate watershed components and protection strategies. Illinois has a distinguished tradition of water resources research, which can serve as the basis for the water resource components of plans.

3. The existing water markets and Lake Michigan allocation regime in metropolitan need to be carefully delineated and evaluated to determine if existing pricing policies and allocation formulas hinder or encourage the integration of water supply planning and growth management.

Endnotes

1. North Carolina v. FERC, 112 F.3d 1175 (D.C. Cir. 1997).

2. More generally, the reevaluation of the relationship between water supply and urban growth reflects the influence of the concept of sustainable development. In the future, the accommodation of economic and environmental and community interests will take place within the framework of sustainable water use and management. Sustainable development incorporates both the idea of use to satisfy human needs and environmental protection and restoration. As the Report of the Western Water Policy Review Advisory Commission concluded, "available supplies must be sustainably managed to ensure that adequate resources are available for future generations. "Western Water Policy Review Advisory Commission, WATER IN THE WEST: CHALLENGE FOR THE NEXT CENTURY 3-1 (1998). Sustainable development is currently more of a process than a standard, although it is evolving toward the articulation of legal principles that will allow regulators to distinguish between sustainable and unsustainable uses. J.B. Ruhl, *The Seven Degrees of Relevance: Why Should Real- World Environmental Attorneys Care About Sustainable Development Policy?*, 8 Duke Envir. L. & Policy Forum 273 (1998). Sustainable water management has four primary elements: (1) the accurate pricing of water resources so that most users will pay the true or unsubsidized cost of providing the water, Sandra Postel, LAST OASIS: FACING WATER SCARCITY 165- 182 (1997), (2) increased efficiency in using and storing water, (3) the incorporation of equity claims for historically marginal groups such as Native Americans, WATER IN THE WEST, *supra* at 3-2., and (4) the establishment of "hydrologic baselines for individual basins" against which consumptive uses can be measured.

3. See A. Dan Tarlock, *Inter and Intra Useage of Great Lakes Waters: An Overview*, 18 Case Western Reserve J. Int. L.67 (1985) and *Global Climate Change and Great Lakes Diversions*, in LAKE MICHIGAN DIVERSIONS AT CHICAGO AND URBAN DROUGHT: PAST, PRESENT AND FUTURE REGIONAL IMPACTS AND RESPONSES TO GLOBAL CLIMATE CHANGE (Stanley Chagnon ed. NOAA Contract No. 50WCNR306047, November, 1994).

4. Wisconsin v. Illinois, 388 U.S. 426 (1967), modified 449 U.S. 48 (1980). See Martin Jaffe, Background Paper on Regional Water Supply Issues prepared for Northern Illinois Planning Commission Regional Water Supply Task Force, April, 1999.

5. Martin Jaffe, "Background Paper on Regional Water Supply Issues", report prepared for the Northeastern

Illinois Planning Commission Water Supply Task Force, April, 1999.

6. The most recent summary of Illinois water law is Planning and Management Consultants, Ltd., ASSESSMENT OF WATER QUANTITY IN ILLINOIS (July 1996). The report surveys the long history of state task forces which have examined the inadequacy of existing law to respect to increased competition. For example, the Water Use Act of 1983, 525 ILCS 45/4(g), adopts the reasonable use for ground water withdrawals. Bridgman v. Sanitary District of Decatur, 517 N.E.2d 309 (Ill.App. 4th Dist. 1987).But, as ASSESSMENT OF WATER QUANTITY IN ILLINOIS at A- 25 notes, the Act "confers only limited authority to regulate groundwater withdrawals. The effect is disputes between competing users will continue to be resolved through the courts using reasonable use principles outlined over 150 years ago . . . "

7. F. Lee Brown and Helen Ingram, WATER AND POVERTY IN THE SOUTHWEST 187 (1987).

8.. Daniel B. Rodriguez, *The Role of Legal Innovation in Ecosystem Management: Perspectives from American Local Government Law*, 24 Ecology L. Q. 745, 767 (1997).

9. George Homsy, *Liquid Gold*, 63 Planning, No. 5, p. 10, May, 1997.

10. Baldwin v. County of Tehema, 31 Cal.App.4th 166, 36 Cal.Rptr.2d 886 (3d Dist. 1994), *review denied*. Illinois has experienced conflicts between municipalities who seek to locate well fields in rural areas and rural residents who wish to control access to the resource. See ASSESSMENT OF ILLINOIS WATER QUALITY LAW at 44 - 45.

11. Colo. Rev. Stat. § 24-65.1-501,

12. City of Colorado Springs v. Board of Commissioners of Eagle County, 895 P.2d 1105)Colo.Ct.app. 1994), cert. denied, 1995 Colo. Lexis 443 (Colo. 1995), cert. denied, 116 S. Ct. 564 (1995).

13. Cf. the dissenting opinion of Justice Cardozo in Interstate Commerce Commission v. Oregon Washington Railroad and Navigation Co., 288 U.S. 14 (1932).

14. See James Rossi, *The Common Law "Duty to Serve" and the Protection of Customers in an Age of Competitive Retail Public Utility Restructuring* (forthcoming).

15. This assumes that new entrants to a community do not have an absolute right to enter, and thus communities have the discretion to decide the rate and spatial distribution of new entrants. A municipal timing scheme was upheld against a right to travel argument in Construction Industry Ass'n v. City of Peteluma, 522 F.2d 897 (9th Cir. 1975), cert. denied, 112 S.Ct. 934 (1976), but cities may be subject to equal protection, Beck v. Town of Raymond, 394 A.2d 847 (N.H. 1978), and statutory, e.g. Cal.Gov.Code § 65302.8, duties not to discriminate against new comers. See Robert C. Ellickson, *Suburban Growth Controls: An Economic and Legal Analysis*, 86 Yale L. J. 385, 455- 457 (1977).

16. Illinois Central Railroad Co. v. River & Rail Coal & Coke Co., 150 Ky. 489, 150 S.W. 641 (1912)(common carrier has a duty to carry amount of freight commensurate with expectations generated by carrier.)

17. The duty was not recognized for common carriers when no contractual relationship existed with a carrier, Little Rock & Fort Smith Railway Co., 61 Ark. 560 (1896), where the goods where offered to a carrier outside its defined service area, Bullard v. American Express Co., 107 Mich. 695, 65 N.W. 551 (1895), or where a strike prevented the transportation of the goods. Gage v. Arkansas Central Railroad Co., 160 Ark. 402, 254 S.W. 665 (1923).

18. e.g. Bond v. Starkey, 180 Ky. 50, 201 S.W. 461 (1918)(telephone company may deny service to physician who used "profane" language.); Nelson v. Boalt, 180 F. 779 (E.D. Pa. 1910)((hotel could refuse service to prize fighter who participated 100 illegal "hotly contested battles.")

19. People of State of New York ex rel. Woodhaven Gas Light Co. v. Public Service, 209 U.S. 244 (1925).

20. Levitt v. Public Utilities Commission, 114 Conn. 628, 159 A. 878 (1932); Interstate Commerce Commission v. Oregon Washington Railroad and Navigation Co., 288 U.S. 14 (1932).

21. Re Competitive Opportunities Regarding Electric Service, Case 94-E-0952, 168 PUR4th 515 (1996).

22. The leading case is Robinson v. City of Boulder, 547 P.2d 228 (Colo. 1976).

23. Dateline Builders, Inc. v. City of Santa Rosa, 194 Cal.Rptr. 258 (Cal.App. 1983).

24. Serpa v. County of Washoe, 111 Nev. 1081, 901 P.2d 690 (1995).

25. 901 P.2d at 692.

26. State, Department of Ecology v. Theodoratus, 135 Wash.2d 582, 957 P.2d 1241 (1998). The court left open the issue of whether the holding applies to municipal water suppliers. The growing communities doctrine was strongly endorsed in the dissenting opinion. Id. at 1257- 1258 (Sanders, J. dissenting).

27. Riebsame, *Western Land Use Trends and Policy*, *supra* Note ___ at 94- 95 reports that officials are concerned about the maintenance of canal distribution systems as canals are rerouted and ground water recharge.

28. Idaho Code §42-202B(5).

29. Idaho Code §42-202B(6).

30. Idaho Code §42-202B(5).

31. In 1981 the United States Department of Agriculture published the NATIONAL AGRICULTURAL LANDS STUDY which identified a farmland "crisis." However, agricultural economists have discounted any food or fiber threat from farmland loss, but Riebsame, *Western Land Use Trends and Policy*, *supra* Note ____ at 75- 76 argues that farmland conversion can be an important local issue because of the combination of crop losses, local economic and cultural disruption and the loss of open space and valuable wildlife habitat and other potential ecosystem loses.

32. Riebsame, *Western Land Use Trends and Policies*, *supra* Note ___ at 108.

33. *Ibid*.

34. Stanilaus Heritage Project v. County of Stanilaus, 48 Cal.App.4th 182, 55 Cal.App.2d 625, 635 (5th Dist. 1996), *reh'g denied*, 49 Cal.App.4th 727 (1996), *review denied*, ___Cal.4th ___ (1996). See also Serpa v. County of Washoe, 901 P.2d 690 (Nev. 1995).

35. County of Inyo v. City of Los Angeles, 71 Cal.App.3d 185, 139 Cal.Rptr. 396 (1977)

36. County of Inyo v. City of Los Angeles, C004068, ___ Cal.App.3d____ (3rd Dist. 1997) (unpublished order discharging preemptory writ of mandate issued August 6, 1993).

37. City of Los Angeles v. County of Inyo, Case No. 12908, Superior Court of the State of California, County of Inyo

38. The factors include the size, location and use of the affected area, the permanency of the change and a comparison of the change in the affected area with the conditions of other areas impacted by groundwater pumping. Id. at 19.

West by Midwest: Comments on
"Growth Management and Water Resources Planning" by A. Dan Tarlock

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It is a pleasure, honor, and challenge to comment on this paper by Professor Tarlock and to stand in for Gilbert White as discussant. Much of what I have learned as a water resource geographer in Chicago and Colorado has been guided by these two professors. Geographers have a particular interest in the contexts of water management, how those contexts shape alternative solutions, and how solutions diffuse from one geographic context to another, in this case the western and Midwestern regions of North America.

Professor Tarlock's paper focuses on gaps between water allocation and growth management policies and on some promising policy developments in the western U.S. His perspective comes as a pleasant surprise, as we are more accustomed to thinking of the American West as a source of water problems than solutions, and to thinking of Dan Tarlock as a leading advocate for reform of western water policy! [1]

Out West, we think of northeastern Illinois as a source of innovations -- as the place where the public trust doctrine was rediscovered in the late 19th century,[2] where interstate and international water quality policies developed,[3] where the earliest metropolitan floodplain maps were produced;[4] and where people like Jack Sheaffer pioneered innovative and integrative approaches to land application of municipal wastewater, floodplain management, and wetlands restoration.[5] So it comes as a pleasant surprise to learn that we may have something to contribute in return.

Dan Tarlock's paper argues that the potential contributions lie in changing relationships among three generally separate bodies of law (water law, land use law, and public utilities law). It offers a three-stage model for integrating these fields, the first of which is recognizing growth management problems and associated land use policies, followed by modifying and subordinating the "duty to serve" principle to land use planning and growth management. The three implications for Illinois are rediscovering regional landscape characteristics, expanding community planning to encompass water management, and evaluating Lake Michigan water markets and allocations.

Among the many aspects of this paper that I would enjoy discussing, it seems most promising to focus on these three implications and work back to examples of where law, policy, and governance in the West and Midwest do--or do not yet--seem to support them. In each case, there is the seed of an important idea that leads to a common question, "What do we need to learn about policy precedents and innovations for these seeds to germinate?" Let's start with the final implication, which is to:

1. Evaluate Water Markets and Allocations

This implication is generally well-supported by recent water policy research in the Western U.S.[6] The question of whether water markets and allocation rules, "hinder or encourage the integration of water supply planning and growth management," has received less attention but is very important.[7] Dan Tarlock's diagnosis of the deleterious land use effects of the "great and growing cities doctrine" in water law and the "duty to serve" principle in public utility law is persuasive. His characterization of the Lake Michigan allocation as "institutional scarcity" bears comparison with California's pressing need to cut back to its 4.4 million acre-feet compact share of the Colorado River. But it also raises some basic questions:

- What is the scientific basis for the present allocation?
- What are the likely environmental, economic, and landscape consequences of increasing or decreasing withdrawals?

A lesson from the Western U.S. is the extraordinary reluctance to scientifically evaluate vested allocations, or to use the results of evaluations that are done. Allocations tend to be treated as assumptions rather than as variables. In this context, a common political strategy has been to use one body of law to adjust another--environmental law to reshape water law, water law to reshape land use law, and so on. The results of these efforts are messy, but their prevalence raises the question of whether integration is possible, or desirable, in a society that chooses to focus on sensitive policy issues indirectly rather than in direct scientific ways?

2. Expand Communities Planning to Encompass Water Resources

This is increasingly seen as a way out of the problems of institutional fragmentation where water laws lag behind growth management initiatives. Dan Tarlock's paper discusses important precedents in Colorado and Nevada that lend support to these alternatives. It examines separations among water law, land use law, and public utilities law that have consequences for urban growth, especially through the massive water allocations obtained by large cities.

But is it the whole story? What types of integrated planning have resolved problems of growth; what types have fueled growth; and what types have shifted it from one location to another? To answer these questions, we need legal historians, historical geographers, and planning historians to dig deeper into the aims, accomplishments, and limitations of land and water planning.

It might be found, for example, that certain types of local planning supported the massive water allocations for Chicago, Denver, and Los Angeles (where the story has been especially well told). These allocations facilitated growth in undesirable but not entirely unplanned or uncoordinated ways.[8] Large-scale water development required the formation of special purpose water districts to finance and integrate water management across regions with disparate community plans.[9] Denver's argument for the "great and growing cities" doctrine was that it was necessary for rational growth management, as it was defined and understood in the mid-20th century.[10] This doctrine was arguably the greatest legal fiction imposed upon the prior appropriation doctrine and its tenet that you can only own what you can beneficially use without waste, which for all of its failings is the closest approximation of John Locke's natural theory of property ever attempted in the United States.[11]

Public works historians in Chicago have shown that two additional factors (other than land development) drove large urban water allocations -- fire and disease.[12] Because contagion and conflagration in poor urban neighborhoods readily spread to wealthy areas, cities organized to provide water at relatively equal pressure and quality, and limited cost, to all. Those historical decisions, and the high level of social equity they achieved, may be undone if pressures to privatize, market, and conserve water resources combine with the politics of more spatially extensive class-stratified patterns of metropolitan land use.[13]

Predicting policy trends and outcomes is difficult, however, because while public utility law governs some aspects of urban water, urban water supply is not highly regulated (e.g., by a public utilities commission). As a result, western water law has lagged behind electricity on issues of efficiency, pricing, and equity. In an era of deregulation, it may seem absurd to study the advantages and disadvantages of state regulatory commissions, but it should not be ruled out as an alternative over the longer-term.

A second set of questions concerns the relationships between "community planning" and larger "urban," "metropolitan," and "regional" scales of water management. Out West, there are growing tensions between "primate cities," like Denver, and their increasingly wealthy and powerful suburban communities. These tensions escalated after US EPA's veto of the Two Forks Dam proposal which Denver and suburbs had collectively promoted at a cost of $40 million. Denver went its own way with an existing portfolio of water rights, infrastructure, and new conservation programs while the suburbs began to fend, factiously, for themselves.

Suburban and associated recreational growth may drive the next generation of water conflicts. It is a high-stakes game in Douglas County, the fastest growing county in Colorado with the lowest poverty level (1.9%), which is developing expensive homes in areas of limited groundwater supplies on the gamble that it can cut or force a deal with the water-rich but reluctant Denver Water Department to sell water beyond its service area. Does that sound familiar in northeastern Illinois?

Dan Tarlock's paper describes the first stage of reform as "recognition." But what is recognition? And when does it make a difference? The cities of Aurora and Colorado Springs do not recognize the claims of distant water-rich counties. They regard those counties as "selfish" for "sitting on" resources they do not use rather than releasing them to people and places that need them.[14] Although their proposed long-distance water transfers involve prosperous communities, there are poor suburbs and unincorporated areas without safe drinking water, sanitation, and flood protection in metropolitan Denver and Chicago. And there are homeless families, migrant workers, and transients who lack even the public baths that existed a century ago.[15]

Some of these poor areas and groups depend upon water utilities while others are displaced by them. Localities that do battle against urban utilities have to have a substantial "war chest" for legal costs and be supported by judgments in the state and federal courts to establish their local authority to coordinate land use and water management.[16]

Institutional historians could help us determine which water districts have fueled unplanned growth and environmental degradation and which have soundly guided water management in turbulent policy environments. They could help us discern the variable roles of state, federal, and international organizations. "Integration" would need to take different forms in these different local and larger institutional contexts.

3. Rediscover the Northern Illinois Landscape

Issues of geographic context are central in Dan Tarlock's argument that, "Ultimately, water resources planning can become an exercise in watershed protection and landscape definition" (p. 5). Professor White's copy of the paper and mine independently highlighted this key sentence.

What does it mean? The paper contrasts "watersheds and other natural features" with "flatness and monotonous urban sprawl," and it calls for an appreciation of "possible limitations imposed by the landscape" (p. 22). These points resonate with current watershed initiatives and place-based community movements in the West and elsewhere.[17]

A historical-geographic perspective on the past century of watershed movements reveals a rich legacy, but it cautions against purely local approaches.[18] Watershed movements do have a record of integrating land and water management for local benefit. In the 1890s, headwaters protection had the joint aims of protecting municipal water supply, sustainable forestry, and small-scale irrigation. Watershed policies linked land use management with flood protection in the 1910s, soil erosion control in the 1930s, crop yields in the 1960s, and non-point source pollution in the 1980s.

Each of these earlier watershed movements waxed and waned with internal weaknesses and larger-scale pressures. They have not been well coordinated with river basin planning. New relationships between watershed approaches and river and lake basin management must be envisioned if the landscape is to be effectively rediscovered regional as well as local scales.

Beyond watersheds and basins, what does a landscape approach entail? As Dan Tarlock's paper argues, it might involve subordinating water and utility laws to land use planning objectives, as examples of rural landscape protection in Idaho and California illustrate. Beyond that, five lines of landscape research might help elaborate and advance this conclusion: [19]

- **Landscape history**, which reconstructs changing relations between environmental modification and human settlement.
- **Landscape experience,** which focuses on changing human perceptions, lifeways, struggles, and values.
- **Landscape ecology**, which examines ecosystem processes and effects in settled and disturbed environments.
- **Landscape and law**, which strives to understand how laws shape landscape patterns and experience.
- **Landscape architecture and planning**, which consciously strives reconstruct human-environment relationships.

There are gaps among these five lines of inquiry, in part because they have emerged from different academic disciplines and professions. Synthesis is beginning to occur in the discipline of geography and profession of landscape architecture. The theoretical, scientific, and methodological challenges are exciting but daunting, as are the substantive debates. For example, a debate is now underway about whether Jens Jensen's ideas about nature and naturalism in Chicago park design and it's northern Illinois landscape context reflected racist and nationalistic ideologies. [20]

The potential links between landscape and law are very interesting.[21] The paper discusses three pertinent bodies of law. To these we might add several more, based on land use and water management innovations in Illinois and the West, to more fully constitute a landscape approach (e.g., floodplain regulation, drainage law, and water quality/wastewater law). And then there are bodies of law and policy not yet effectively connected with water and growth management in the U.S. that may arise in tomorrow's discussion of lessons from the Middle East and other regions. [22]

To advance these lines of research, creatively opened up in Dan Tarlock's paper on "Growth Management and Water Resources Planning," a bold program of collaborative inquiry will be required among legal scholars, water managers, environmental scientists, and landscape planners.

Endnotes

1. E.g., Tarlock chaired the writing team for the Western Water Policy Review Advisory Commission, Water in the West: Challenge for the Next Century, Denver, 1998.

2. Illinois Central Railroad Co. v. Illinois, 146 U.S. 387, 1892.

3. Illinois v. Milwaukee, 406 U.S. 91, 1972; International Joint Commission, Protection of the Waters of the Great Lakes, Interim Report to the Governments of Canada and the U.S., Washington, D.C., August 1999.

4. Jamie W. Moore and Dorothy P. Moore, The Army Corps of Engineers and the Evolution of Federal Floodplain Management Policy. Special publications no. 20. Boulder: Institute of Behavioral Sciences, 1989.

5. John R. Sheaffer and Leonard Stevens, Future Water, New York, William Morrow & Co., 1983; and Rutherford Platt, ed., The Ecological City: Preserving and Restoring Urban Biodiversity, Amherst, University of Massachusetts, 1994.

6. E.g., National Research Council, Water Transfers in the West: Efficiency, Equity, and the Environment, Washington, National Academy Press, 1992; L. MacDonnell et al., Water Banks in the West, Boulder, Natural Resources Law Center.

7. William Riebsame with James L. Wescoat Jr. and Peter Morrisette, "Western Land Use Trends and Policy, Implications for Water Resources," Denver, CO, WWPRAC, 1997.

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Toward Sustainable Governance of the Waters of the Great Lakes Basin

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Abstract

This paper examines the ability of the current governance structure of the Great Lakes Basin to respond to growing international demand for fresh water and commercial pressure for diversion of water from the Basin. The paper finds that the current governance of the Great Lakes is characterized by fragmentation among multiple, competing regulatory regimes and jurisdictions. This "structure" contains gaps, redundancies and conflicts. Most immediately, it stands at odds with both international trade law and the Commerce Clause of the United States Constitution, which treat water as a commercial good, and prohibit protectionist measures that discriminate against the even-handed movement of commercial goods. Such a governance approach cannot sustain the Great Lakes ecosystem, which contains nearly 20% of the world's fresh water, against uncontrolled withdrawals. The paper argues that a new governance structure based on uniform standards to protect the Great Lakes as a single ecosystem, applicable to in-Basin and out-of-Basin uses, is necessary to protect the Basin under international trade laws and the United States Constitution. The paper concludes with an examination of the newly adopted Annex 2001 to the Great Lakes Charter as the beginning of such a sustainable governance regime.

Key Words

Great Lakes governance, water withdrawals, ecosystem management, watershed management, International Joint Commission, Commerce Clause, General Agreement on Tariffs and Trade, North American Free trade Agreement, Public Trust Doctrine, Great Lakes Charter, Annex 2001.

I. Introduction

The governments of Canada and the United States of America on February 10, 1999, officially requested the International Joint Commission ("IJC") to initiate an examination of present and potential future uses of Great Lakes waters, and to inform the governments about possible threats to the integrity of the Basin waters from unsustainable use (hereinafter "Reference").[1] The IJC completed a comprehensive study of the matter on February 22, 2000 (hereinafter "Final Report").[2]

The immediate cause for the Reference was a proposed export of water from Lake Superior, by a private company called the Nova Group, for sale in Asia. This proposed sale of water outside the Great Lakes Basin raised grave concerns that the sustainability of the water resources upon which Great Lakes communities rely are at risk from increased commercial exploitation of the water. The IJC, in recommending a strict moratorium on all new sales and removals of water from the Basin, concludes that the concern of Canada and the United States about this threat is warranted.

It is the argument of this paper that there is indeed a threat to the sustainability of the Great Lakes water system that calls for creation of a new governance structure to manage the Great Lakes Basin as a single, integrated ecological system within the global economy. The paper argues that the most immediate threat to the sustainability of the Basin comes from the fragmented governance structures and antiquated legal doctrines through which the states, provinces and national governments of Canada and the United States now manage the water of the Great Lakes.

The fragmented governance structure breaks the Basin into discrete, unrelated parts, and impedes efforts to address the Basin as the single, unified ecosystem that it in fact is. The states, provinces, and national governments cling to untenable laws and procedures that perpetuate the fragmentation of Great Lakes water, and ignore the commercial realities and institutions that will determine the fate of the Great Lakes water as a commodity. This situation bars the development of both appropriate standards and an integrated management structure necessary for the ecological and economic sustainability of the Basin.

The paper advances a modest proposal for a new governance structure for the Great Lakes Basin based on the following principles:

- The Great Lakes Basin is a single, unified ecosystem, which includes surface waters, tributary streams, wetlands, ground water, upland watersheds and precipitation.
- Current governance structures break the Basin into separate political and administrative jurisdictions at odds with the hydrological cycles of the Great Lakes water system and with the ecological unity of the Basin itself.
- This ecosystem has been transformed by multiple human interventions, the extent and nature of which have not been fully understood or addressed, and the transformation is in large part a product of the fragmentation of the current basin governance.
- Water is a commercial good, with unique environmental, social and economic features.
- The Great Lakes Basin is legally subject to commercial laws, and its water is vulnerable to commercially driven, uncontrolled and ecologically damaging transfer out of the Basin, unless its legal and governance structure is tailored to the requirements of controlling commercial laws.
- Commercial laws and treaties provide the context for management of water, and can protect it and enhance it as an ecological resource if properly applied, or can wreak havoc on the resource, community and ecosystem if improperly understood and applied.
- The controlling national and international commercial laws can be used to protect the water of the Great Lakes, and leverage resources to enhance the environment of the Great Lakes Basin.
- New governance structure is needed to achieve this.

In short, the argument of the paper is that growing commercial pressure on Great Lakes water is real, and presents an opportunity to develop a sustainable governance structure for the Great Lakes Basin, with environmentally sound and commercially valid standards for managing the water upon which the Basin depends. By treating the water as a unique commercial good subject to national and international trade law, the communities of the Basin can protect the water from uncontrolled transfers, and leverage investment to conserve and rehabilitate the environment of the Basin.

The paper will first consider briefly the growing global scarcity of fresh water and its ecological impacts, in order to situate the discussion of Great Lakes water within an international context. The paper will then set forth its argument regarding the challenge, need and opportunity to develop a sustainable governance structure for the Great Lakes to successfully manage the abundant water resources of the Basin in an age of growing scarcity.

2. Scarcity and Growing Demand for Water

A. *International Perspective: Approaching the Century of Water*

Scarcity of fresh water threatens the sustainability of communities in both the developed and the developing world. Currently, approximately 460 million people[3] in 29 countries live in conditions of severe shortage of fresh water.[4] The development scholars Rod Burgess, Marisa Carmona and Theo Kolstee, in a study of the growth of urban communities, have identified scarce water supply as a central challenge to sustainability:

> Even with the existing population size, consumption levels and inequalities, many megacities are already exhausting their environmental support capacity, with water consumption exceeding the replacement capacity of primary sources.[5]

It is projected that the number of people living in conditions of severe water shortage will grow by 2025 to include as much as two-thirds of the world population.[6]

An ecologically devastating dynamic is created by water shortage, excessive use and inattention to hydrological cycles. This dynamic encourages practices that further damage and deplete scarce water resources. It can be seen at work throughout the world, particularly in developing, rapidly urbanizing communities. As populations move from locations with scarce water resources, and settle in locations with apparently more abundant water sources, they remove trees and essential vegetation, fill wetlands, occupy floodplains and coastal areas. These settlement processes obliterate ecosystems critical for the maintenance of water quality and quantity. Increased populations draw down ground water and divert surface streams and lakes. The loss of tree cover, vegetation and other ecological features such as wetlands, combined with increase of impervious surfaces brought on with urbanization, compromises recharge of aquifers and surface waters, increasing water scarcity.[7] It also causes soil erosion, and sedimentation of drainage channels, increasing run-off, rate of storm water flow, and the cruel irony of devastating floods in the midst of water shortages.[8]

Excessive pumping of aquifers draws contaminants into the watershed, undercutting its ability to provide safe fresh water in the future. This can be seen in the salinization of previously fresh groundwater occurring in coastal communities, as the result of seawater seepage into the "cone of depression" created by over use of the ground water. Excessive pumping of ground water also lowers the water table, causing subsidence of the land. This damages buildings and infrastructure, including water and sewage pipes, further undercutting the availability of safe, fresh water. It also creates further risk of flooding and damage.[9]

These are stark demonstrations of what is meant by "unsustainable development." A spiral of damage and creation of new risks can be observed growing out of short-term, fragmented decision-making about management of scarce water resources. The failure to consider water as an integrated, ecological phenomenon, related to land-use, development, and practices that take place across political jurisdictions, results in unsustainable conditions, threatening to life and economy. With the projection of growth in populations, urbanization, and scarcity of fresh water, unsustainable practices in managing water threatens not only individuals, but also the stability of local communities and metropolitan regions within their separate jurisdictions. Water, like other environmental resources, does not respect of political boundaries; it can, however, exert dramatic pressures and create powerful tensions across such boundaries. Accordingly, it is critical for the sustainability of peace among nations to develop the appropriate standards, analytical tools and decision-making structures in order to properly manage the increasingly scarce, critical resource: fresh water.[10]

It is obvious that these conditions of fresh water scarcity, and the spiraling ecological and material devastation that ensues when the conditions are not successfully managed, threaten the lives and vitality of individuals and communities. They also threaten the relations between nations and peoples. Issues of water scarcity involve complex decisions about environmental science, infrastructure, economics, commerce and public health and safety. These issues are intertwined and highly charged. Proper decision structures – laws and governance – are necessary to assure that these intertwined aspects of water management are recognized, considered and balanced, and that sustainable conclusions are reached regarding water management.

B. *Water Scarcity and the Great Lakes*

(1) *Growing Demands on Great Lakes Water*

From the perspective of the Great Lakes Basin, which is the largest surface body of fresh water in the world,[11] the problem of water scarcity can seem a relatively distant matter for concern, affecting the sustainability of other communities, not those with access to the Great Lakes. As expressed in *The Great Lakes: An Environmental Atlas and Resource Book*:

"The magnitude of the Great Lakes water system is difficult to appreciate, even for those who live within the basin. The lakes contain about 23,000 km(3) (5,500 cu. mi.) of water, covering a total area of 244,000 km(2) (94,000 sq. mi.) The Great Lakes are the largest system of fresh, surface water on earth, containing roughly 18 percent of the world supply. Only the polar ice caps contain more fresh water."[12]

However, the abundant Great Lakes water system is itself at risk, and subject to growing demands for fresh water resources, from both outside of the Basin and within the Basin itself.[13]
The Nova Group's proposal to export water from the Basin for use in Asia is a harbinger of future demands for out-of-basin transfers. With the growing scarcity of fresh water and subsequent increased commercial value, future proposals to exploit the Great Lakes water as commercially valuable good will inevitably occur.[14] The Nova Group incident demonstrates the potential for international marketing of Great Lakes water. A more immediate potential market for Great Lakes water also exists in the water scarce regions of North America, including dry western states and drought stricken eastern states.[15]

Within the Great Lakes watershed itself, population and economic growth will exert pressure for increased water access and usage. While the extent of increased usage is unclear, the IJC Final Report claims that there is general agreement that water withdrawals will continue to increase in the future.[16]

Water use projections are subject to considerable uncertainty, due in part to environmental variables such as global warming and change in precipitation.[17] Further uncertainty regarding the impact of changes in the human population and economy of the Great Lakes communities derives from the uncoordinated, often haphazard nature of the changes.

For instance, restructuring of energy markets and utilities is underway within some of the Great Lakes jurisdictions. The effects of this are already beginning to affect plans for the construction of new generation facilities, as well as the maintenance and possible closure of aging facilities. Generation facilities, whether hydroelectric, natural gas, coal or nuclear, demand significant fresh water for their operation. The number, size, location, type and service area of energy generation facilities will have significant impact on fresh water usage within the Basin. However, the restructuring of the energy markets has been undertaken on a state-by-state basis, without serious consideration of these water impacts, either within the individual state, or as to the potential impacts for the Great Lakes Basin as a whole.

Similarly, the growth of metropolitan areas within the Great Lakes bring changes in land-use, development patterns, spatial configurations, vegetation, drainage and water storage capacity. These changes will affect the usage of fresh water and the recharge of Basin resources in highly uncertain ways. Again, this is in large part due to the fragmented, uncoordinated and often haphazard nature of growth and land-use decisions across the Basin communities. It is certain that these future economic and population developments will affect the quality and quantity of the Basin's fresh water resources; only the extent and nature of the impacts are uncertain.[18] The uncertain impacts on water quality and quantity within the Basin fits within the general context of increased fresh water scarcity within the world. The law of unintended affects is fully in place within the Basin, and the "go slow" approach to new water usage recommended by the IJC is prudent under these circumstances.

(2) Legally Mandated Scarcity: The Case of the Chicago Diversion

A vivid example of fresh water "scarcity" and the unintended affects of human water usage, is the transformation of Basin geography and ecology brought about by the reversal of the Chicago River in 1900. Litigation was filed against Illinois by other Great Lakes states because of the transfer of water out of the Lakes resulting from the reversal of the Chicago River. In the course of the litigation, the U.S. Supreme Court set a limit on the amount of water Illinois communities can draw from the Basin.[19] In essence, Illinois communities now operate under a legally mandated "scarcity" of fresh water, while living on the edge of the largest surface body of fresh water in the world.

Until 1900, the Chicago River was a tributary of Lake Michigan. It was also an open sewer, and carried industrial and human wastes into the Lake, poisoning the City of Chicago's fresh water source and spreading fatal diseases.[20] Through construction of a canal known as the Ship & Sanitary Canal, the Chicago River was reversed away from Lake Michigan and connected into the Mississippi River watershed. This breached the natural "continental divide" between the St. Lawrence Seaway and Mississippi River watersheds, and rendered the Great Lakes Basin a tributary to both the Mississippi and the Gulf of Mexico, and the St Lawrence and Atlantic Ocean. In addition to helping manage Chicago's waste in a manner less lethal to Chicagoans, the project opened a new, expansive water connection for commerce from the Atlantic coast into the heart of the North American Continent.[21]

Other Great Lakes states came to view the reversal of the Chicago River as an inappropriate diversion of Basin resources, and brought suit to limit the loss of the water to the Mississippi watershed. As the result of this litigation, the U.S. Supreme Court set limits on the amount of water that can be diverted through what is now known as the "Chicago Diversion." [22] All commercial, industrial, navigational and domestic uses, plus waste and storm water management, that runs through the sewer and treatment systems in the greater Chicago region, is subject to the diversion limits set by the Supreme Court.

The U.S. Army Corps of Engineers measures and monitors the volume of water diverted through the Chicago Diversion. The Corps' measurements indicating a cumulative overdraft for 1993 and 1994 led the other Great Lake states to threaten suit against Illinois to enforce the Supreme Court limitations on Lake water withdrawals. A Memorandum of Understanding was negotiated among the eight Great Lake states, and signed by the Governors in July of 1996, averting new litigation. In the settlement, Illinois agreed to mitigate the overdraft of water from the Basin, by replacing the amounts of water overdrawn.

Thus, Illinois must limit water withdrawals from the Basin and devise ways to "repay" amounts of water withdrawn in the past under previous population and economic demand. The Northeastern Illinois Planning Commission projects growth within the greater Chicago region of approximately 1.78 million people and 1.43 million jobs by 2020.[23] This will complicate the efforts to meet the water use restrictions ordered by the Supreme Court, and "repayment" of overdrafts agreed to with the other Great Lakes states. It is clear that the limits on Illinois' Lake withdrawals restrict the availability of water to meet current usage demands, and to sustain development and economic growth in the region.

(3) Learning to Live With Scarcity and Demand

Though located within a uniquely abundant watershed, Illinois and the greater Chicago region face the challenge of managing growth of population and demand for water in a context of water scarcity. Like many communities, past decisions, developments and investments have contributed to water shortage.

In Chicago's case, the reversal of the River, while providing intended economic and health benefits, had the unintended consequences of transferring a precious resource out of the region, creating multiple conflicts with neighboring communities and bringing a legal mandate limiting access to a critical resource. Other decisions made in Chicago compounded the unintended problems following the reversal of the River. These decisions included the filling of wetlands and destruction of other ecological features that serve to capture, purify and recharge water resources within the region.[24] Similarly, the investment in infrastructure to consolidate storm water with human sewage and industrial effluent into a single "waste," direct it into a single treatment system, and remove it from the region, added to the loss of water rather than helped recharge the watershed.

These decisions were made in pursuit of specific goals, but with limited information, assumptions and considerations, tailored to limited problems and outcomes. Important data and potential consequences were not taken into account by the decision -makers and institutions. The loss of precious water resources to the Basin were not considered in the course of building the Ship & Sanitary Canal, or building a regional combined sewer system. Similarly, elsewhere in the basin, the negative potential for creating of a pathway for damaging alien species to enter the Great Lakes and transform their ecology, was not part of the decision process for constructing the Welland Canal between Lake Ontario and Lake Erie.

The negative unintended outcomes of decisions regarding complicated ecological and economic systems derive in large part from the abstract, rational, well-intentioned institutional structures that seek to narrow the decision-making process and focus it on limited conditions and goals.[25] Most decision-making structures regarding water resources are limited in focus, jurisdiction and purpose. Continuing unintended consequences of limited decisions are unavoidable under these decision-making conditions. The serious increase in water scarcity makes this an increasingly serious challenge to the sustainability of communities and the environment on which they depend. As Burgess, et al. have written:

> The environment operates as an integrated system, and human modifications, even if they are local in nature, may precipitate a chain reaction of multifarious effects that are regional, national or even international in scale…[E]nvironmental sustainability cannot be achieved by discrete and poorly integrated policies that confine themselves to the household, neighborhood, municipal or city-wide levels.[26]

What is required is a decision-management structure that recognizes a broad range of data and issues as relevant to specific projects and problems, including environmental, spatial and economic phenomena, and integrates these into its decision-making. For sustainable water management decisions, this will require significant scientific examination and modeling of water cycles, to determine appropriate scale of analysis for understanding the impacts of projects, infrastructure and land-uses.

It will also require the development of an integrated approach to ecology and economics. Water is a unique ecological phenomenon. It is also an economic resource. The growing scarcity and consequent demand for fresh water increases the importance of understanding it as both an ecological phenomenon and an economic resource. It is essential for sustainable management of fresh water to integrate its ecological and economic aspects.

Economic reality is fundamentally concerned with the valuation and exchange of scarce resources. From the Great Lakes perspective, economic reality will exert greater and greater pressure on the Basin's water. To manage this pressure, an institutional structure is needed to shepherd the Basin's water resource, and integrate its unique "value" into a sustainable economic system, that is global, national and local. Absent this, the Basin's water is at extreme risk.

IV. A Modest Proposal for Sustainable Governance of the Great Lakes Water

Protection against uncontrolled, commercially driven, transfers of water out of the Great Lakes Basin can be provided by the creation of a governance structure that manages the Great Lakes as a single, integrated ecosystem. Elements of this approach already exist, but a coherent, legally valid governance structure to administer and enforce ecosystem management of all uses of Great Lakes water does not exist. The following sets forth the elements for an integrated, ecosystem based governance of the Basin that can protect the water from uncontrolled transfers, and enhance the ecology and economy of the Great Lakes.

A. The Great Lakes Basin is a Single, Unified Ecosystem.

An ecosystem approach is based on the inter-relation of physical and biological phenomena, attentive to the interaction, reliance and mutual impacts of various living things and their environments. For instance, an ecosystem approach to Lake Michigan would be aware that coastal wetlands support vegetation that removes certain contaminants from storm water prior to it entering the Lake. The vegetation also limits erosion of the Lake coastal geography, and provides birds and other biota with habitat. The biota and the birds are critical participants in the food chain of the Lake. Loss of the wetland by filling or other land-use change would impact these inter-related phenomena. It would also impact the ecology of the Lake and the Basin. An ecosystem-based approach to the Basin would attend to these changes; manage their negative impacts, both past and future.

Multiple official agreements and documents express the position that the Great Lakes Basin is a single, unified ecosystem. For instance, the Great Lakes Charter calls the Basin a "single hydrologic system" which should be "considered as a unified whole."[27] The Great Lakes Water Quality Agreement of 1978 formally recognized an "ecosystem" approach to the Basin, calling for the development of environmental indicators to monitor and protect the ecosystem of the Lakes.[28] The IJC's Final Report also reflects this view of the Basin in discussing the need to protect it from uncontrolled water transfers:

> The Great Lakes Basin is an integrated and fragile ecosystem. Its surface and groundwater resources are part of a single hydrologic system and should be dealt with as a unified whole in ways that take into account water quantity, water quality, and ecosystem integrity.[29]

The litigation concerning the Chicago Diversion gives some judicial recognition to the notion that the Basin is a connected ecosystem, in that removal of waters from southern Lake Michigan affects the interests of states bordering not just Lake Michigan, but the other Lakes as well. In essence, the Chicago Diversion litigation recognizes the Lakes as a connected, common resource.

It is generally recognized that the Basin's ecosystem includes groundwater and tributary surface streams in addition to the surface waters of the Lakes themselves. However, there is no general scientific or legal consensus as to the specific extent of the ecosystem, its constituent parts, or the full body of indicators for measuring the health and integrity of the ecosystem. As mentioned above, the critical role of ground water to the Basin ecosystem is accepted, but there are only rough calculations of what the contribution of ground water actually is to the Basin.[30] There is considerable lacuna as to the configuration, storage capacity and pathways of much of the ground water systems in the Great Lakes region. Similarly, there is no comprehensive agreement or scientific understanding regarding surface waters that are tributary to the Lakes, and thus part of the Basin ecosystem.

Despite these limitations, however, there is a broad agreement that the Great Lakes Basin constitutes a single, unified ecosystem and this critical principle is reflected in official agreements and (to some extent) in litigation.

B. Current Governance Structures Improperly Fragment the Basin Ecosystem

The many documents asserting that the Great Lakes are a single, unified ecosystem express a profound wish that they should be treated as such. They do not make the wish a reality. There exists no enforceable definition of the extent and constituent parts of the "single ecosystem" of the Great Lakes. There exists no single set of enforceable standards, established procedures or jurisdictional entity to apply an ecosystem regime to the Basin.[31]

Against the wish for "Ecosystemhood" and a coherent approach to the resource stand a multitude of governments and administrative units that break the Basin into discrete, unrelated elements and jurisdictions.[32]

This fragmentation has many manifestations. Jurisdiction is divided among national, state, provincial and local governments, into territorial districts that have no relation to underlying ecology. Multiple, separate administrative agencies in state, provincial and national levels, have power over distinct parts of the hydrological system, and exercise their powers with little or no reference to the impacts their actions have on other parts of the water system.[33] For instance, storm water is treated separately from ground water, which is treated separately from surface water, and tributary waters are often not treated as part of the watershed of the Lakes they serve.

The Boundary Waters Treaty of 1909, which is the most far-reaching of the governance arrangements regarding the Great Lakes, and which established the IJC, does not include tributary waters, the Chicago Diversion, or the use of Great lakes water for domestic or sanitary purposes. Accordingly, very large elements of the “single, unified ecosystem” are outside the purview of the most far-reaching agreement relating to the Basin, and its administrative arm, the IJC.

Further, land use decisions, which significantly affect water resources, are made without reference to their water impacts, by agencies with little or no jurisdiction over water issues. Water agencies set policy and implement programs in isolation from the impacts these activities will have on land use. Serious transformations of water quality, quantity and availability occur that are often unrecognized, and impossible to address within the fragmented structures that presently govern the waters of the Basin.

This situation reflects a distant past when the nature of water cycles and systems was dimly understood, and significantly different from the knowledge of hydrological systems today. These limited, fragmented administrative arrangements are not up to the task of managing the Great Lakes Basin as a unified resource, comprised of surface water, deep aquifers, shallow ground water, wetlands, tributary streams, complex coastal communities, upland environments, subject to multiple human interventions, invasion by aggressive non-native species, shared among multiple political jurisdictions, and under growing commercial pressure in a global economy where water is scarce and growing in value.

In view of the foregoing, it is understandable that the February 10, 1999, Reference to the IJC by Canada and the United States specifically requested a review of “current laws and policies as may affect the sustainability of the water resources in boundary and transboundary basins.” [34] The resulting IJC Final Report recognizes that the current policies governing the Great Lakes are insufficient. For example, the Report notes some of the deficiencies in the Boundary Waters Treaty of 1909 in the following:

> Under the treaty, boundary waters are treated differently from transboundary rivers or tributaries. Thus, the treaty does not deal with all waters of the Great Lakes Basin in the same way. With some exceptions, Article III provides that the use, diversion, or obstruction of boundary waters must be approved by the Commission of water levels or flows on the other side of the boundary are to be affected. With respect to tributaries of boundary waters and transboundary rivers, however, Article II states that each nation reserves “the exclusive jurisdiction and control over [their] use and diversion.” The treaty does not explicitly refer to groundwater.[35]

Although “the treaty has been effective in assisting Canada and the U.S. to avoid and resolve disputes over freshwater,” [36] it does not represent a comprehensive, legally-binding authority over the Great Lakes watershed. Instead, fragmented and uncoordinated government bodies and jurisdictions stand in the way of managing the Basin as a single, unified ecosystem.

C. The Ecology of the Basin Has Been Transformed By Multiple Human Interventions

Human settlement, economic exploitation and use of the Great Lakes have fundamentally transformed the ecology of the Basin. Large portions of the watershed have been deforested, wetlands filled, floodplains occupied, ground water and recharge areas interrupted. Native fish and birds made extinct threatened or endangered. Alien species such as purple loosetrife, zebra mussels, round gobies and sea lampreys have been introduced into the Lakes and their tributaries through international commerce and settlement. Pollutants have been introduced into the waters, as the natural processes that purify and restore the Lakes have been transformed and even obliterated. Coastal processes have been changed. These interventions have affected drainage, flow rates, species and habitat configurations and contaminant loads. They have occurred throughout the Basin, continue to this day, and will into the future.[37]

It is within this context of far-reaching ecological transformation already accomplished that proposals for removal of Lake water must be analyzed. Similarly, the needs, goals, and expectations for governing the Basin as a unified ecosystem are conditioned by this environmental/economic legacy, and the governance structure must be premised on an acknowledgement of this reality, if it is to work and sustain the Basin.

Given the damaged nature of the Basin, governance focused on simply limiting damage will commit the Basin to perpetual decline. Sustainability of the Basin requires a reversal of the conditions contributing to decline, based on governance standards and procedures that enhance the ecology of the Basin.

D. Water is a Commercial Good [38], With Unique Ecological Features

Water is recognized as an essential resource, with unique "public" value, reflected in the legal doctrines and institutions developed to protect and conserve communities' interests in water. Commenting on the concept of water as "common capital" [39] and the "community's capital stock" [40] developed by water scholar Joseph Sax, Barton Thompson, Jr., points to:

> the inescapable importance of water to the development and sustainability of society. Water not only sustains life itself, but it is also the essential basis for all developed or developing economies. Waterways are primary sources of transportation and sustenance...Virtually all major commercial production, from agriculture to computer chips, also relies on water, and often on good quality water. Moreover, unlike most other major resources, such as petroleum or even irrigable land, water enjoys no substitute. The quantity and quality of water available to a community thus supports and constrains the community's economy and lifestyle, and thus as a corollary, the rules governing its use and protection can 'affect the fate of the whole community.' [41]

Among the interesting aspects of Sax's and Barton's discussion of the unique nature of water, is that this uniqueness is directly related to its commercial value, sustaining the vitality of industry and trade, as well as individual life. There is a strong unease in the Great Lakes community with the view that water is a commodity in commerce, for fear that acknowledgement that water is a subject to commercial law will ease the way to uncontrolled exploitation of the water in a global market place. The approach of Sax and Barton indicate that the unique importance of water to a community need not be sacrificed by recognizing that water is a commercial good, and indeed may strengthen the community's ability to manage the water in environmentally beneficial ways.[42]

The landmark case of Sporhase v. Nebraska,[43] concerning the use and transfer of water outside of its basin of origin, establishes that under United States Constitutional law water is a commercial good, subject to commercial law. Sporhase also establishes that water has unique properties that allow broad protection against uncontrolled exploitation if regulations are properly drafted coherent to the Commerce Clause.

Sporhase concerns the power of a state to control the transfer of water out of its place of origin, across state boundaries. In this case, Nebraska regulated such transfers by a permit system, requiring anyone seeking to withdraw water from Nebraska for transfer to another state, to obtain a permit from the Director of the Nebraska Department of Water Resources. The Director would review the permit application, to determine whether the requested withdrawal and proposed transfer was (1) reasonable, (2) consistent with conservation of water resources, and (3) not detrimental to the public welfare. If these standards were met, the Director was to issue the permit, but only if the state to which the water was to be transported and used granted reciprocal rights to withdraw and transport water from its territory into Nebraska for use.[44] Joy Sporhase withdrew water from a well located in Nebraska and transported it across state lines for use in Colorado, without a permit. A permit could not have been obtained, because the state of Colorado did not have a reciprocity provision for withdrawal of water in Colorado and use in Nebraska, as required by Nebraska law. The State of Nebraska filed suit against Sporhase to enjoin the withdrawal and transfer of water out of state. Sporhase raised a defense against Nebraska, claiming that the permit requirement placed an unconstitutional burden on interstate commerce. The Nebraska trial court rejected the defense, and granted the injunction to the state. The Nebraska Supreme Court affirmed the trial court, and held that, under Nebraska law, water is not "a market item freely transferable for value among private parties, and therefor [is] not an article of commerce."[45] Sporhase appealed to the United States Supreme Court, which accepted the case.

The United States Supreme Court overturned the Nebraska Courts, explicitly holding "that water is an article of commerce."[46] At the same time, however, the Court recognized that water is a vital resource, with special qualities. The fact that water is an article of commerce, does not subject it to uncontrolled transfer and use. Indeed, the Court recognized "legitimate reasons for special treatment accorded" to withdrawals of water and transfer out of places of origin, including across state lines.[47] These reasons center on the appropriate public concern to conserve water, and protect it from unreasonable uses that compromise public welfare. The Court found that the permit standards reflecting these concerns were appropriate and within the State's power.[48] The unconstitutional provision of Nebraska's permit law was the requirement that water could not be transferred out of state unless the state to which the water is transported had provided for export of water from its territory into Nebraska. The Court found that "the reciprocity provision operates as an explicit barrier to commerce,"[49] and held that it "does not survive the 'strictest scrutiny' reserved for facially discriminatory legislation."[50]

In short, the lesson of Sporhase is that water is an article in commerce, with unique features deriving from its essential importance to individual life, the welfare of the community, and its vital contribution to the economy. These features can be protected by regulations that are tailored to conserve the quality and quantity of water as a public good. Indeed, the fact that water is an "article in commerce" has been a critical element to advancing environmental protections of water under the Clean Water Act and Superfund. Releases of contaminants into surface and ground water have been subject to these environmental laws, and thus remediated under federal law, because the water is a commodity in the stream of commerce.[51] But, regulations that simply bar out-of-state transfers of water and are not tailored to reasonable conservation goals, will not withstand scrutiny.

E. The Basin is Subject to National and International Commercial Law.

The foregoing discussion of Sporhase v. Nebraska makes it clear that water is subject to the Commerce Clause of the United States Constitution, which regulates commerce between nations and among the states.[52] The construction of the Commerce Clause has established the nation as a single economic unit, not divided into distinct insular markets by the diverse states. Regulation of articles in commerce must be consistent with this single, national unit, and smaller units cannot be constructed to hold economic value and advantage within themselves, distinct from the nation.[53] The principle of a national, unified market place applies to environmental goods.[54] Sporhase makes it clear that it applies to water, and discriminatory prohibitions of the transfer of water across political boundaries, will run afoul of the Commerce Clause.

The General Agreement on Tariffs and Trade (GATT) prohibits "arbitrary or unjustifiable discrimination between countries" of goods in commerce, and thus stands in the way of blanket restrictions of transfers of water outside the Great Lakes Basin.[55] The North American Free Trade Agreement incorporates this provision of GATT by reference.[56]

Thus, national and international commercial authorities prohibit blanket restrictions on transfer of water out of the Great Lakes Basin. The stance of "just say no" to out-of-Basin transfers will not withstand legal challenge.[57] Currently, there is no general standard or set of principles for considering out-of-Basin use of Great Lakes water, and the federal regulation of transfers allows the Great Lakes Governors an unconditional veto of all transfers, subject to no standards, procedures or principles for review.[58]

F. Commercial Law Can Enhance the Ecological Integrity of the Basin.

There is a great reluctance among officials and environmentalists to accept that water is a commercial good governed by commercial law and free trade agreements. It is perceived as a threat to the economic interests and environmental integrity of the Basin. To the contrary, proper understanding of water as a special commodity, as discussed above, presents a great opportunity to bolster both the economy and ecology of the Basin. Rather than being a threat to the ecological integrity of the Great Lakes Basin, the framework of commercial law and free trade agreements provides the basis for constructing a genuine integrated, ecosystem approach to the Great Lakes, that is secure as a legal structure.

This paper has already examined how Commerce Clause jurisprudence will allow regulatory protections and conservation of water. The Sporhase opinion explicitly recognized water as a uniquely valuable commodity, subject to public control. Restrictions on withdrawal and use of the resource are acceptable, so long as they are tailored to the public purposes of conservation and protection, apply evenhandedly without discrimination across political borders, and are subject to clear procedures.

GATT and NAFTA provide similar conditions for the creation of a regulatory regime to protect the water of the Basin within an ecosystem management structure. Article XX (b) and (g) of GATT (incorporated by reference in NAFTA) provide:

"Subject to the requirement that such measures are not applied in a manner which would constitute a means of arbitrary or unjustifiable discrimination between countries…nothing in this agreement shall be construed to prevent the adoption or enforcement by any contracting party of measures…

(b) necessary to protect human, animal or plant life or health;…

(g) relating to the conservation of exhaustible natural resources if such measures are made effective in conjunction with restrictions on domestic production or consumption."

A carefully drawn, Basin-wide, ecosystem management structure, that applies to all waters of the Basin including tributary surface and ground water, as well as the water of the Lakes, and has restrictions applied equally to both in-Basin and out-of-Basin uses and withdrawals, will comport with these terms of GATT. But it must be a genuinely broad-based approach that takes into full account the multiple, environmentally compromising interventions that have already occurred as part of the economic exploitation of its water resources.

For instance, the impacts of the diversions of water both into and out of the Basin have had ecologically transforming impacts on the Great Lakes, changing flow rates, volumes and composition of the water. They have been the pathways for invasive species to enter the Great Lakes. Understanding these impacts, and formulating standards and programs that respond to the transformations will be a critical part of a genuine ecosystem management structure within which control of water withdrawals must be located.

Identification of ground water paths, recharge areas and carrying capacity, in order to calculate the extent of the Great Lakes Ecosystem, and establish protection for such constituent parts, will be a part of the regime. Similarly, determination of the contribution that reforestation, rehabilitation of wetlands, prairies and other open space can make to water quality and quantity will be a part of the ecosystem plan. Being part of a system that recognizes the economic value of the water at the heart of the management system will take "ecological restoration" out of the realm of mere aesthetic preference, and make it part of the economic sustainability of the region.

Simply choosing "water withdrawals and transfers" as the focus, content and soul of an ecosystem management program will not pass scrutiny under GATT. A broad, scientifically based integrated economic/ecological system will be required. This is why GATT, NAFTA and the Commerce Clause present an opportunity to establish ecosystem governance of the Great Lakes, in order to meet the challenge of commercial trade in Basin water, and use it to leverage investment in environmental enhancement of the Basin.

G. New Governance Structure is Needed to Protect the Basin

The IJC Final Report on governance over water withdrawals from the Basin discusses the relation of GATT and NAFTA to restrictions on out of Basin water transfers. It notes the prohibition of discriminatory restrictions, and the "environmentally friendly" exceptions to trade restrictions set forth in Article XX of GATT. It concludes that: "the achievement of a coherent and consistent approach to water conservation and management in the Great Lakes Basin—an approach clearly grounded in environmental policy—would be an important step in addressing any trade-related concerns with respect to the use of Basin waters." [59]

This passage is interesting in two ways. First, it reaches the conclusion that international trade laws provide direction and inducement to managing the Basin as a single, unified ecosystem, which is correct. Second, it acknowledges that such a regime does not in fact exist.

It is telling that the recognition of the lack of environmental coherence in current governance of the Basin comes in the context of a discussion of GATT and the implications of free trade on the fate of the Basin. It is the contemplation of including water, as a uniquely valuable resource, within the context of a free trade regime that makes it possible to both calculate the environmental benefits of a genuine ecosystem management structure for the Basin, and recognize that such an arrangement does not currently exist. The current costs of mismanaging the Basin are hidden, and the value of environmentally sound practices, are not understood within a fair economic vision that identifies the costs of environmentally ruinous conditions and actions. These hidden costs damage the "common capital" of water, and are paid by the general public, not the particular interests that exploit the water. The threat to the water does not come from "free trade" that identifies the value of water, but rather from the "free lunch" system that now governs the Great Lakes water.[60]

To establish such a regime requires a new governance structure, that evenhandedly treats in-Basin and out-of-Basin transfers of water equally, operates with clear standards and procedures, and is based on solid, comprehensive scientific data and understanding. It is important that the structure be based within the Basin, as a new function of the Great Lakes states and provinces, growing out of the current, partial attempts at shared governance reflected in the Boundary Waters treaty and the great Lakes Charter. While the new governance must be recognized and supported by the national governments of Canada and the United States, it should not be based within the national governments. Removal of Basin governance to the national governments would create inappropriate distance from the particular ecology, economy and local conditions that a genuine integrated ecosystem approach requires. The unique nature of water for the health and safety of the public makes regulation of water a classic function of state and local government police power. This is fully recognized in the Sporhase decision.[61] The Public Trust doctrine also recognizes the importance of local input in the management of water, given the central role of water in the identity and self-definition of local communities.[62]

Further, a key part of the new governance structure requires the integration of land-use decisions with water regulations. Land use decisions are traditionally, and appropriately, matters of local control and governance. The notion of nationalizing the decision-making process over land use makes no sense from the point of view of ecology, economic development or political practicality. An integration of local decision-making processes on land use, water use, water infrastructure investment and economic development, with state and provincial decision-making on water resource management, is what is called for. This will be complicated, but it is consistent with ecological concerns, economic need and the broad public interest.

The IJC, in responding to the request of the Canadian and United States governments for advice on the adequacy of current governance structures for the Basin, should advise that laws and policies are not adequate to assure the sustainability of Great Lakes water resources, and that the ecosystem approach to the Basin reflected in the Boundary Waters Treaty and the Great Lakes Charter should be established. The IJC should then recommend the convening of a Basin convention, constituted by the Great Lakes states and provinces, in conjunction with their local governments, to create a Basin-wide management structure for the Basin, attentive to the environmental and economic realities of the Great Lakes.

The efforts of the Governors and Premiers of the Great Lakes States and Provinces in the aftermath of the IJC Final Report have focused on developing the standards, data, procedures and decision-support system for governing the waters of the Basin in accord with ecologically sound policies that would meet the terms of the Commerce Clause and GATT.

In June 2000 the Great Lakes Governors and Premiers issued a joint announcement that they would revive the Great Lakes Charter by adding a new Annex that would commit them to the development of a new standard and decision-making process for protecting the waters of the Basin based on improvement to the waters and water dependent natural resources of the Basin. In October 2000, the Congress amended the Water Resources Development Act to include a provision encouraging the Great Lakes States, in consultation with Canadian Great Lakes Provinces, "to develop and implement a mechanism that provides for a common conservation standard embodying the principles of water conservation and resource improvement for making decisions concerning the withdrawal and use of water from the Great Lakes Basin," and directing the Secretary of State to work with Canada to develop and implement a "mechanism and standard concerning the withdrawal and use of water from the Great Lakes Basin consistent with those mechanisms and standards developed by the Great Lakes States."[63]

In December 2000, the Governors and Premiers issued for public review and comment a draft of proposed Annex 2001 to reflect the conservation and resource improvement standard as part of the Great Lakes Charter. In June 2001, the Governors and Premiers issued Charter Annex 2001, committing to establish a framework for binding agreements among the Great Lakes States and Provinces to manage the Lakes as a unified ecosystem, pursuant to resource conservation and improvement standards.

Annex 2001 provides the chance to realize objectives set forth in the Great Lakes Charter, but not pursued: collection and analysis of data on the conjoined water, air and land resources of the Basin; development of decision support systems for policy makers and officials; investigation of the connections between water quality and water quantity; and the development of governance processes and binding standards for decision making.

III. Conclusion

The Twenty-first Century will be the Century of Water. Scarcity of the commodity is growing, and the demands for access to the Great Lakes Basin will grow with international demand. The Basin is currently governed in a haphazard, incoherent manner, from state to state and from province to province. Though bi-national organizations established by Canada and the United States rhetorically acknowledge the Basin as a "single, unified ecosystem," there is no coherent governance structure, set of standards or body of comprehensive scientific data to make this rhetoric a reality. The pressure of commercial interest in Basin waters from out side the Basin has been felt, but the economic realities of the growing market for water have not been fully acknowledged.

Current laws of the states, provinces and national governments generally fail to recognize the economic nature of Great Lakes water. They fail to acknowledge and adjust for the jurisdiction of trade laws and treaties that govern the water as a commodity within a global commercial system. They fail to acknowledge the integrated economic and ecological nature of the water and the Great Lakes Basin. As such, the laws are an impediment to environmental protection of the water, and are vulnerable to economic attack under governing commercial laws and treaties. The current patchwork of incoherent regulations is opposed to export of water but content with extensive, economically driven, uses of the water within the Basin's contiguous states. This configuration of regulations cannot withstand a challenge to withdraw and use the water outside the Basin. If a genuine ecosystem management regime, established within the terms of governing commercial laws and treaties, is not put in place for the Great Lakes, the Basin waters will be exposed to uncontrolled transfer outside the Basin.

Endnotes

1. The International Joint Commission was created by Canada and the US as part of the Boundary Waters Treaty of 1909. The February 10, 1999, communication to the IJC was an official "Reference" under the Boundary Waters Treaty. For information regarding the IJC generally, and the February 10, 1999 Reference in particular, see the IJC website at www.ijc.org.

2. International Joint Commission. "Protection of the Waters of the Great Lakes: Final Report to the Governments of Canada and the United States." February 22, 2000.

3. United Nations Commission on Sustainable Development. 1997. "Comprehensive Assessment of the Freshwater Resources of the World." Accessed Online October 16, 2001: www.un.org/esa/sustdev/freshwat.htm. See also, Paul Simon, *Tapped Out: The Coming World Crisis in Water and What We Can Do About It*, (1998) Welcome Rain Publishers, New York, NY.

4. Population Action International. 2001. "Why Population Matters to Freshwater Availability." Accessed Online October 16, 2001: www.populationaction.org/resources/factsheets/factsheet_6.htm.

5. Burgess, Carmona & Kolstee, "Contemporary Urban Environmental Strategies and Policies in Developing Countries: A Critical Review," pg. 80, in Burgess, et al. (eds.) *The Challenge of Sustainable Cities*, (1997). Zed Books, London. (Hereinafter, "Burgess et al.").

6. "The regions most vulnerable to domestic water shortages include those that presently have poor access to water, and have rapid population growth, uncontrolled urbanization, financial problems and lack of a skilled work force. Even if the world maintained the pace of the 1990s in water supply development, it would not be enough to ensure that everyone had access to safe drinking water by 2025. The challenge is particularly critical in Africa. Sanitation development is even more difficult to achieve. If everyone is to have sanitation facilities by 2025, this means providing services for more than 5 billion people in 30 years." -United Nations, 1997.

7. Deforestation and loss of vegetation "brings water shortages, for when water from rain or snow isn't stored in the land, the water table will drop. Without tress, there are fewer leaves and less total surface area for evapotranspiration, so there's less moisture in the air. Without a protective canopy of leaves, the soil is struck with the full force of the storm. Individual raindrops are like little bombs, gouging, beating, and battering the soil, lifting and splashing it back and forth, churning it into a pasty mud that clogs the pores and passages in the soil. There is less biological activity in the soil…so the earth is less tunneled and less water percolates down into the groundwater. As the groundwater recedes, the springs falter, the streamflow slows, and some streambeds will eventually run dry." Alice Outwater, *Water: A Natural History*, p. 65 (Basic Books, New York, 1996). When this process occurs in dense, improvised urban communities without sewers and engineered water systems, this process spreads sewage and other contaminants in the water and environment generally. See also, Turner et al., (eds.), *The Earth As Transformed by Human Action*, (Cambridge Press, 1997).

8. Burgess et al., op.cit. pp. 66-72. G. Gardner and Payal Sampat, "Forging a Sustainable Materials Economy," pp. 46-47, in L. Brown et al. (eds.) *State of the World, 1999*, (1999). Norton & Co., New York. R. Platt, "The Ecological City," pp.1-17, and O. Loucks, "Sustainability in Urban Ecosystems," pp. 49-82, in Platt et al. (eds.) *The Ecological City*, (Univ. of Mass. Press, Amherst, 1994); Departamento del Distrito federal, Gobierno del Estado de Mexico y

Secretaria de Medio Ambiente, *Recursos Naturales y Pesca, Programa Metropolitano de Recursos Naturales*, (1997). Ciudad de Mexico y SEMARNAP, Mexico.

9. Patricia McCarney, "World Cities and the Environment: The Five Cities Consultation Project," pp. 80-84, *Ecodecision*, Decemb re/December, 1991. Burgess et al., op. cit.

10. Participants in the Water conference have worked on the intellectual and infrastructural tools for managing water in the Middle East, an area where the need for effective, accurate and equitable decision-making regarding water will be central to peace and stability in the region. See Paul Simon, "Water Problems Will Be the Cause of War in the Middle East," October 9, 2001, *The Chicago Tribune*, A25. See also Stephen Kinzer, "Where Kurds Seek a Land, Turks Want the Water," *The New York Times*, February 28, 1999, quoting Turkish businessman, Ishak Alaton, "Water has been used as a means of pressure…It can also be used for peace…You can't overstate its importance. I firmly believe that just as the 20th century was the century of oil, the 21st century will be the century of water."

11. See generally, L. Botts and B. Krushelnicki, The Great Lakes – An Environmental Atlas and Resource Book, Jointly Produced by the Government of Canada and United States Environmental Protection Agency, Great Lakes National Program Office, (Third Edition, 1995). (Hereinafter, "Great Lakes Atlas"); W.D. Ellis, *Land of the Inland Seas*, (Palo Alto, 1974); J. Rousmaniere (ed.), *The Enduring Great Lakes*, (1980, New York.).

12. *Great Lakes Atlas* at p. 3.

13. The actual amount of water in the Great Lakes and tributary waters has not been measured. See Grannemann et al. The Importance of Ground Water in the Great Lakes Region, *USGS Water Resources Investigations Report 00-4008*; Holtschlag and Nichols, Indirect Ground-water Discharge to the Great Lakes, *USGS Open-File Report 98-579* (1998). This is a major gap in basic data for understanding the Lakes as an ecosystem, and limits the ability of officials charged with protecting the Basin to formulate effective and binding policies and programs. For instance, the IJC claims that there is never a surplus of water in the Basin and that withdrawals of water form the Basin should be prohibited as a potential damage to the Lakes. Without a basic measurement of the actual amount of water contained in the Basin and its tributaries, the robustness of this position is questionable.

14. See, Cameron Davis, "Lake Michigan: A Limited Resource," *Chicago Life*, pp. 40-43 (Fall, 1999). Mr. Davis, the Executive Director of the Lake Michigan Federation, attacks the Nova Group's proposed shipment of water out of the Great Lakes as "preposterous" from an environmental perspective, but emphasizes the economics of water as a threat to the ecology of the Basin: "Fresh water is becoming as valuable as gold. A close call last year over water in our sibling waterbody, Lake Superior, proves that 'diversions' – the draining away of water from the Great Lakes to places outside of the Great Lakes – is a real possibility." p. 40.

15. See John Cronin, "It's Time We Got Smart About Drought," New York Times, August 5, 1999, A23. Cronin observes: "In a typical year, 10 percent to 15 percent of the country suffers severe drought and 8 percent to 10 percent experiences moderate drought conditions. Currently, severe conditions exist from Maine to the Carolinas, with the impact extending beyond farm country to municipal water supplies." For water use in the western United States, and the implications of continuing population growth, municipal expansion and economic transformations, see A. Dan Tarlock and Sarah B. Van de Wetering, "Growth Management and Western Water Law," *West-Northwest*, Vol. 5, No. 2, pp163-188, Winter, 1999;William Riebsame, *Western Water Use Trends* 65, Western Water Policy Advisory Review Commission (1997).

16. Final Report, pp 10-11.

17. Final Report, p.6. Climate change is critical to the future of the Great Lakes, given that climatic conditions control precipitation (and thus groundwater recharge), runoff, and direct supply to the lakes as well as rate of evaporation. These are the primary driving factors in determining water levels."

18. L 'Vovich and White, "Use and Transformation of Terrestrial Water Systems, in Turner et al. (eds), *The Earth Transformed by Human Action*, (Cambridge 1997).

19. *Sanitary District of Chicago v. United States*, 266 U.S. 405 (1925). Further litigation on this dispute, see, *Wisconsin v. Illinois*, 388 U.S. 426 (1967), modified 449 U.S. 48 (1980). See also *Missouri v. Illinois*, 200 U.S. 496 (1906), considering the impacts of the reversal of the River on downstream communities. The State of Missouri challenged the reversal of the Chicago River, seeking to have the reversal enjoined as a public nuisance. The Court, in an opinion by Justice Holmes, denied Missouri's request on equitable grounds. The case is an interesting treatment of a complex environmental/political dispute from a common law perspective, prior to the development of national environmental legislation.

20 "'Bubbly Creek' is an arm of the Chicago River, and forms the southern boundary of the yards; all the drainage of the square mile of packing houses empties into it, so that it is really a great open sewer a hundred or two feet wide…The grease and chemicals that are poured into it undergo all sorts of strange transformations, which are the cause of its name; it is constantly in motion, as if huge fish were feeding in it…Bubbles of carbonic acid gas will rise to

the surface and burst, and make rings two or three feet wide. Here and there the grease and filth have caked solid, and the creek looks like a bed of lava; chickens walk about on it feeding, and many times an unwary stranger has started to stroll across, and vanished temporarily." Upton Sinclair, *The Jungle*, (1906. Reprint, New York: Penguin, 1985) p. 115.

21. Louis Cain, "The Creation of Chicago's Sanitary District and Construction of the Sanitary and Ship Canal," in R.K. Adams (ed.), *A Wild Kind of Boldness*, (Eerdmans Publishing, Grand Rapids, 1998). Prior to the 1900 opening of the Ship & Sanitary Canal, Chicago constructed a smaller canal for commercial shipping, connecting the Chicago River to the Des Plaines River, and thus into the Illinois and Mississippi Rivers. This canal, known as the Illinois & Michigan Canal, opened in 1848. The I&M Canal was intended only for commercial traffic, and was not large enough to affect the flow of the Chicago River into or away from Lake Michigan. The I&M was critical in establishing Chicago as a major commercial center. Indeed, even the early plans for the canal "helped trigger the city's real estate boom in the 1830's" and the canal's opening in 1848 "brought striking changes to the regional economy. During its first season of operations, eastern corn shipments from Chicago multiplied eightfold." William Cronon, *Nature's Metropolis: Chicago and the Great West*, pp. 63-64 (Norton & Co., New York, 1991). See also: Donald Miller, *City of the Century: The Epic of Chicago and the Making of America*, pp. 71-88 (Simon & Schuster, New York, 1996); John Lamb, "Early Days on the Illinois & Michigan Canal," in Adams (ed.), *A Wild Kind of Boldness*, pp.37-45 (Eerdmans, Grand Rapids, 1998); Henry L. Henderson, "The City and the Environment," in J. Bloomfield and D. Prior (eds.), *Summit of the Cities: Developing a Common Agenda*, pp. 7-13 (Birmingham City Council, Birmingham, UK, 1998).

22. Wisconsin v. Illinois, 388 U.S. 426 (1967) as modified by 449 U.S. 48 (1980).

23. Northeastern Illinois Planning Commission, 2001. "Toward 2020: Population, Household, and Employment Forecasts for Counties and Municipalities in Northeastern Illinois." Accessed Online October 16, 2001: www.nipc.cog.il.us/fore2020.htm

24. Originally, the area occupied by Chicago had approximately 25,000 acres of wetlands. With the development of the City there are now under 5,000 acres. With this 80% loss of wetlands "came a reduction in the functions provided by wetlands, including absorbing and storing floodwater and regulating water quality." Henderson and Eubanks, "The Benefits of Urban Wetlands," *Great Lakes Wetlands*, Vol. 7, No. 3, at pg. 2 (Fall, 1996). See also, James Schmid, "Wetlands in the Urban Landscape of the United States," in Platt et al. (eds.), *The Ecological City*, pp.106-133, (Univ. Mass, Amherst, 1994). Of Mass., Amherst, 1994).

25. See James C. Scott, *Seeing like a State: How Certain Schemes to Improve the Human Condition Have Failed*, (New Haven, Yale University Press, 1998); Michael Oakeshott, *Rationalism In Politics and Other Essays*, (New York, Basic Books, 1962); Isaiah Berlin, *The Sense of Reality*, pp. 1-53 (New York, Farrar, Strauss & Giroux, 1996).

26. Burgess, et al., at pg. 81.

27. Council of Great Lakes Governors. "1985 Great Lakes Charter." Accessed Online May 31, 2001: www.cglg.org/pub/charter/index.html.

28. International Joint Commission, *Revised Great Lakes Water Quality Agreement of 1978, As Amended by Protocol Signed November 18, 1987*. The 1987 Revision to the Agreement called for the development of broader ecosystem indicators, beyond the chemical indicators provided for in the original Agreement, thus expanding the scope of the ecosystem approach to the Lakes. See, Organization for Economic Co-operation and Development, *Environmental Performance Reviews: United States*, pp. 195-214 (OECD, Paris, 1996).

29. Final Report, p. 46.

30. See, Granneman et al., The Importance of Ground Water in the Great Lakes Region, *USGS Water Resources Investigations Report 00-4008* (2000). See also, *The Great Lakes Atlas*, pp. 9-13, 38.

31. In this regard, the Great Lakes governance structure reflects conditions worldwide. "The objective of sustainable development and the integrated nature of the global environmental/development challenges pose problems for institutions…that were established on the basis of narrow preoccupations and compartmentalized concerns…The challenges are both interdependent and integrated, requiring comprehensive approaches…Yet most of the institutions facing those challenges tend to be independent, fragmented, working to relatively narrow mandates with closed decision processes. Those responsible for managing natural resources and protecting the environment are institutionally separated from those responsible for managing the economy. The real world of interlocked economic and ecological systems will not change; the policies and institutions concerned must." *World Commission on Environment and Development, Our Common Future*, (Oxford Press, New York, 1987) (Reprinted in Percival et al. (eds.) *Law and the Environment*, p.374-75, (Temple, Philadelphia, 1997).

32. Peter Rogers, *America's Water: Federal Roles and Responsibilities*, pp. 1-23, 45-73, 151-197. (MIT, Cambridge, 1996).

33. This situation is not unique to the Great Lakes Basin, but the state of governance over water resources generally. As the Western Governors Association commented: Water policy lacks a unifying vision or even a set of guiding principles. This state of events is not appropriate in an era in which supplies are threatened by chronic drought, likely aggravated by global warming, while demand continues to grow. A host of on-the-ground problems are created by, or at least related to, the absence of a unifying vision, including redundance of functions across programs, protracted disputes, interagency turf battles, absence of policies, and lack of finality of many water disputes." Western Governors Association, *White Paper on Federal Water Policy Coordination*, pg. 1 (Denver, May 11).

34. Reference, item "d"; reprinted in Appendix 1 to the Final Report.

35. Final Report, pp. 31.

36. Ibid. However, the Final Report does not consider the complications of multiple national, provincial, state and local agencies with limited, fragmented jurisdiction over aspects of water, and the separation of water from land-use regulations.

37. See, Cronon, *Nature's Metropolis*, (Norton, New York, 1991); *Great Lakes Atlas*; William Ashworth, *The Late, Great Lakes*, (Knopf, New York, 1986).

38. The Nova Group proposed withdrawal caused a flurry of legal analyses of the status of water as a commercial good, and the adequacy of the current governance structure to protect Great Lakes water in connection with commercial regulations. Principal among these is the analysis prepared for the Great Lakes Protection Fund by a team headed by James S. Lockhead. *See*, Lockhead et al., *Governing the Withdrawal of Water From the Great Lakes, Report to the Council of Great Lakes Governors*, (May, 1999). This study greatly influenced the subsequent development of the Great Lakes Governors of the Annex 2001 to the Great Lakes Charter, discussed below. A highly critical response to the Lockhead report was prepared for the National Wildlife Federation. *See*, Chris Shafer, *Great Lakes Diversions Revisited: Legal Constraints and Opportunities For State Regulations*, *Final Report*, Prepared for the Great Lakes Natural Resources Center of the National Wildlife Federation, July 28, 2000.

39. Joseph Sax, "The Constitution, Property rights, and the Future of Water Law," 61 U.Colo.L.Rev 257 at 276 (1990).

40. Ibid, at 282.

41. Barton H. Thompson, "Water as a Pragmatic Exercise: Professor Joseph Sax's Water Scholarship," 25 Ecology Law Quarterly 363, at 367-368, (1998), quoting Joseph Sax, "The Constitution, Property Rights, and the Future of Water Law," 61 U.Colo.L.Rev. 257 at 276 (1990). Discussing the history of legal and social structures for managing water, Lon Fuller underscored the extraordinary importance of water for individual and communal life, by commenting: "We may indeed describe the law relating to the control of waters as the most ancient branch of administrative law." Lon L. Fuller, "Irrigation and Tyranny," The Principles of Social Order: Selected Essays of Lon L. Fuller, p. 188, at 209 (Duke Unv. Press, Durham, 1981).

42. See also, Joseph Sax, "The Limits of Private Rights in Public Water," 19 Environmental Law 473 (1989); Sax, " Understanding Transfers: Community Rights and the Privatization of Water," 1 West-Northwest 13 (1994); Molly Selvin, *This Tender and Delicate Business: The Public Trust Doctrine in American Law and Economic Policy 1789-1920* , (Garland Publishing, New York, 1987).

43. Sporhase v. Nebraska, 458 U.S. 941 (1982).

44. Sporhase, at 944, citing Nebraska Revised Statutes, Section 46-613.01 (1978).

45. 208 Neb. 703 at 705 (1981).

46. Sporhase, at 954.

47. Sporhase, at 955.

48. Sporhase, at 957.

49. Sporhase, at 957.

50. Sporhase, at 958.

51. See City of Milwaukee v. Illinois and Michigan, 451 U.S. 304 (1981); United States v. N.L. Industries, Inc., 936 F. Supp. 545 (S.D. Ill. 1996). Citing Sporhase, the court stated: "there is no doubt that surface waters, especially those that border on or traverse through more than one state, are an integral part of interstate commerce." 936 F. Supp. At 558.

52. Article I, Section 8 [3]: The Congress shall have power "to regulate Commerce with foreign Nations, and among the several States, and with the Indian Tribes."

53. H.P. Hood & Sons, Inc. v. DuMond, 336 U.S. 525 (1949).

54. See City of Philadelphia v. New Jersey, 437 U.S. 617 (1977).

55. Article XI of GATT.

56. An Official Statement of the Governments of Canada, Mexico and the United States, adopted on December 2,

1993, states that NAFTA “creates no rights to natural water resources of any Party to the Agreement” and that NAFTA will not “oblige any NAFTA Party to either exploit its water for commercial use or to begin exporting it in any form.” The implications of these statements are unclear, in that both the United States and Canada already exploit the waters of the Great Lakes commercial use, and water is presently exported from the Basin for use by Great Lakes interests. It is difficult to conceive how this would not compromise the usefulness of the Official Statement for barring out of Basin commercial use of the water. At any rate, the Official Statement applies only to the three NAFTA parties, not to other countries under GATT, which prohibits “arbitrary...discrimination between countries.”

57. State laws restricting transfer of water can not prevail over GATT and other free trade treaties, as treaties has supremacy over state law. Missouri v. Holland, 252 U.S. 416 (1920).

58. 1986 Water Resources Development Act, 42 U.S.C. Sec. 192d-20: “No water shall be diverted from any portion of the Great Lakes within the United States, or from any tributary within the United States of any of the Great Lakes, for use outside the Great Lakes Basin unless such diversion is approved by the Governor of each of the Great Lakes States.”

59. Final Report, pp. 33.

60. Paul Krugman, *The Accidental Theorist and Other Dispatches from the Dismal Science*, p. 178 (Norton & Co., New York, 1998).

61. See, e.g., Sporhase at 956-957.

62. See, Sax, “Understanding Transfers: Community Rights and the Privatization of Water,” 1 *West-Northwest 13* (1994); Tarlock and Van de Wetering, “Growth Management and Western Water Law,” 5 *West-Northwest* 2 (1999); Thompson, “Pragmatism and Policy: The Case of Water,” in Light & Katz (Eds.) *Environmental Pragmatism*, pp.187-208 (Routledge, New York, 1996); Crawford *Mayordomo: Chronicle of an Acequia in Northern New Mexico,* (Univ. New Mexico Press, Albuquerque, 1988).

63. WRDA, Sec. 504, PL 106-541.

"A lake is the landscape's most beautiful and expressive feature. It is the earth's eye, looking into which the beholder measures the depth of his own nature."

Henry David Thoreau

Discussion on "Change in the Water: Sustainable Governance of the Great Lakes Basin"

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Henry Henderson's paper "Change in the Water: Sustainable Governance of the Great Lakes Basin" eloquently calls for a recognition by the governing bodies in the Great Lakes watershed to do what is necessary to ensure the sustainability of the Great Lakes ecosystem. I've yet to meet anyone that would strike up an argument against the principles of sustainable use of the Great Lakes regions' water resources and the protection and enhancement of the Great Lakes ecosystem. For all of us who appreciate the beauty and uniqueness of the Great Lakes region, this is an issue worth fighting for.

However, as we find in most of life's experiences, the difficulty in implementing sustainability in water use management lies in the details. For example, how do you (the 'you' includes regulators, developers, environmental groups, municipal planners, etc.) incorporate sustainable governance in deciding whether a permit should be issued for a new subdivision development in southeastern Wisconsin? This is a rapidly growing area and the desirability of Lake Michigan water is creating pressures to cross the basin boundary. How different is it to look at sustainability on a small watershed scale compared to the Great Lakes basin?

I suspect we would all agree that a 10,000 cubic feet per second (cfs) diversion to replenish the Ogallala aquifer or augment diminishing flows in the Colorado River would be an unwise and an unsustainable use of Great Lakes water. But what about a 2 cfs diversion for a Great Lakes municipality just outside the Great Lakes basin boundary? What are the impacts to the basin's ecosystem? Does anybody know?

As a long term observer and participant in the discussions about diversions and protecting the integrity of the Great Lakes, I have become convinced that the region needs to do a much better job in developing a credible, science based defense of the Great Lakes. Henry's paper makes that assertion, which, unfortunately, is quite easy to illustrate.

The Great Lakes Charter was signed by all eight Great Lakes governors and the two premiers in 1985. The Charter called for the development of a regional Great Lakes water data base and the development of a basin-wide management program. Over 14 years have passed, and the region is still unable to accurately report on yearly withdrawals. Studies and actual data on consumptive uses is almost non existent; all reported data is estimated. No work has begun on the basin-wide management program, and there has been no concerted effort to implement water conservation programs throughout the basin.

All of these shortcomings hamper the region's ability to resist unwise transfers of water out of the basin, when, and if proposed. But in my view, the region has a much bigger issue that it must address. That is, what do we say about the net surplus of water in the Great Lakes? It is common knowledge that the lakes receive, from the Canadian Long Lake/Ogoki diversions, an annual average flow of about 5,580 cfs, while here in Chicago we remove an annual average flow of 3200 cfs. These are the only hydrologically significant diversions in and out of the Great Lakes basin. Based on these long term average flow rates, the Great Lakes receive a net surplus flow of 2,380 cfs, over 1.5 billion gallons per day! This is enough water to supply over 12 million people! Yet nobody in the region seems willing to acknowledge that it exists. The recently released International Joint Commission (IJC) Interim Report concludes "If all interests in the basin are considered, there is never a 'surplus' of water in the Great Lakes system." Have we concluded, and correctly, that the Great Lakes basin ecosystem now depends on this artificial surplus? With this artificial surplus how can we begin to evaluate the impact of any proposed removal of Great Lakes water on the integrity of the Great Lakes ecosystem? How do you practice sustainable governance? I believe these are just some of the questions and arguments that would be raised by a potential diversion proponent. Unfortunately, I don't think that we have a technically sound response to these questions.

Another issue that constrains our ability to manage the Great Lakes as a single, integrated ecological system is its sheer size and complexity. For example, when reporting on the flows entering and leaving the lakes, National Oceanic and Atmospheric Administration (NOAA) scientists round to the nearest one thousand cfs. While statistically an appropriate measure, it nonetheless introduces a potential uncertainty in each reported flow of $\pm$ 500 cfs. In addition, the limitations in the accuracy of the flow measurement devices used to determine outflows introduce uncertainties that dwarf all of the recent proposals for small scale diversions combined.

The reported outflow from Lake Superior for the month of July was 78,000 cfs. A 5% error in flow measurement (typical error range for open channel measurement) yields a range of $\pm$ 3,900 cfs! For outflows from Lake Ontario, the potential error in flow measurement can approach $\pm$ 13,000 cfs! For comparison, the Nova Group requested approval for an average annual removal from Lake Superior of 0.68 cfs.

My point in all this is not to illustrate the futility of trying to evaluate a diversion proposals' impact on the Great Lakes ecosystem, but rather to remind us that we need to recognize these issues in developing a meaningful, valid argument to resist unwise, uneconomical proposals to divert Great Lakes water to other parts of the country.

Henry's paper calls for the creation of a new governance structure. Towards that end I agree with his call for a management system that "evenhandedly treats in-Basin and out-of Basin transfers of water equally, operates with clear standards and procedures, and is based on solid, comprehensive scientific data and understanding." As already discussed, the last part of his recommendation will require a substantial effort by the region, and perhaps the realization that we may never understand the complexities of the Great Lakes and the vast ecosystem it supports to the extent that we would like to make informed, sustainable use decisions. But I am convinced that beginning to develop a basin-wide management program, to improve our collection and analysis of water withdrawals, to expand our efforts to do serious study of the vast, complicated ecosystem will send a clear message that the region is serious about good stewardship of our Great Lakes water resources. And that is a good thing.

The first part of Henry's recommendation, however, is more problematic. The history of politics in this region, when the issue is diversion, is that we don't want to treat in-basin and out-of-basin uses equally. Similar to that time honored advice parents give their children, when it comes to water resource management we have to realize that "we have to treat ourselves like we would like to treat others". The region is most comfortable with a "just say no" policy. I think there is the fear that 'even-handed' treatment of all proposed uses of Great Lakes water would in fact open the door for new diversions. Do we really want to apply the same criteria and restrictions on in-basin uses that we would apply to an out-of-basin use? In this regard I agree with Henry that until the region does so it is vulnerable, and will not have the control over our Great Lakes water resources that we'd like.

I would also like to comment on Henry's call for "an integration of local decision-making processes on land use, water use, water infrastructure investment and economic development, with state and provincial decision making on water resource management." In my experience working with units of local government for 22 years, Henry's acknowledgment that this will be difficult is perhaps his greatest understatement! Local governments have, over the long term, gotten the message about flood plain management, stormwater management and the need for open space in the zoning and planning efforts. These issues profoundly impact communities. However, I think the prevalent viewpoint is that the provision of water and wastewater services is strictly an engineering issue, and sustainable use of water is not perceived as a pressing local problem. For evidence, look at northeastern Illinois, which continues to suburbanize the landscape. With almost no state land use control, local governments have been unable, or unwilling, to put the brakes on growth. Over the last 20 years, the expansion of the Lake Michigan water service area has facilitated this growth. State law does not direct the Department of Natural Resources to use Lake Michigan water allocations as a tool to regulate growth. As Henry has pointed out, in our case the U.S. Supreme Court does that job for us, though its limitations are just beginning to be felt.

With this bleak assessment of the situation now behind me, I want to wrap up my comments with a few positive observations that taken together give me reason to remain an optimist.

The Great Lakes states and provinces, from the governors and premiers, down to agency field personnel have expressed a commitment to work together as a region to protect, restore and enhance the Great Lakes ecosystem. The Great Lakes Charter, the Ecosystem Charter for the Great Lakes, and numerous Great Lakes institutions have, despite our differences, brought this huge region closer together. Illinois and the other Great Lakes states were able to avoid new litigation at the Supreme Court level over our diversion; instead we entered into a Memorandum of Understanding to resolve the dispute. While Henry is right in that there are "multiple jurisdictions with narrow preoccupations and compartmentalized concerns", I think that overall the region cooperates and communicates much better today. Regional bodies such as the Council of Great Lakes Governors and the Great Lakes Commission have been quite successful in this area.

I am hopeful that work will get underway this year to begin the long, arduous process of establishing a basin-wide management program. Products of this effort should include an improved data base for withdrawals, diversions and consumptive uses, the establishment of a coordinated research agenda for basic research on quantity/quality relationships, the development of improved criteria for reviewing diversion proposals, and the implementation of a basic water conservation program by all Great Lakes jurisdictions.

Improvements in water use and efficiency are popping up all over; even here in Chicago where water use is down by over 100 million gallons per day (mgd) compared to consumption rates in 1990! Improvements in efficiency of water use in Chicago and other municipalities play an important role in meeting the growing demand for water as northeastern Illinois continues to grow while still keeping our total diversion below the Court's limit. This past July the Department issued a new water allocation order (LMO 99-3) that modified the allocations of most of our Lake Michigan permittees. One of our prime objectives was to review the projections of future growth and resultant water demand in the existing Lake Michigan service area to ensure that we will have an adequate supply of water and that Illinois will be able to live within the allowable diversion limit that has been set by the Supreme Court. I can report that Illinois is committed to undertaking improvements in our use and management of Lake Michigan water and is spending $20 million to achieve this goal.

The Great Lakes region is fortunate that there have been no serious proposals for significant diversions of Great Lakes water. While the region continues its' efforts to strengthen its management programs, one additional recommendation I would offer is that we should continue to insist that any future water projects be wholly supported financially by the proposed users. Knowing the cost to deliver Lake Michigan water to distant suburbs of Chicago, it is difficult to conceive of a cost effective Great Lakes diversion project to another part of the country. For Henry and those of us who anticipate that the 21st Century may well bring new demands to divert Great Lakes waters to far off places, we need to keep careful watch on Washington, for it is there that pressure for federal financial assistance to make uneconomical water projects feasible will appear.

On Smart, Benign Drinking Water, Wastewater, and Storm Water Infrastructure for a Less Unsustainable Future – A Personal Vision

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Abstract

In the belief that true sustainability of water systems of large cities is unfortunately implausible, this paper seeks merely to present concepts with the lesser goal of reducing the unsustainability of future infrastructure.

Our drinking water, wastewater, and storm water infrastructure ("infrastructure") is truly complex and requires constant and expensive repair and monitoring. Such investments warrant good information systems. In the future, infrastructure information systems will integrate sensors with GIS data systems and management models. Future water systems will be smarter, having intelligence distributed throughout the network. Such intelligence will eventually be continuously available on line to all categories of users of the web, with the water network performance information displayed at a complexity optimized to suit the user.

Just as information networks distribute information to local computer storage, future infrastructure will use storage distributed around the network. Principles of distributed storage will be used in water supply, wastewater collection and stormwater drainage systems. Intelligent use of distributed storage and weather forecasts will eliminate combined sewer overflows, initially from hazardous industrial and other point sources. Users will save money because charges will be adjusted.

Artificial institutional barriers now exist between the departments that plan, design, build, operate and maintain the three water systems and related infrastructure such as permeable pavement. Management of these four currently distinct infrastructures will be integrated, showing several improvements. Computer models for planning, design and operating the four systems will also be seamlessly integrated, allowing design and operation of local recycling of water and wastes.

Physical sizes of future infrastructure will depend more on the requirements of autonomous robots, the collection, transmission and processing of intelligence relating to the network performance, evolving synthetic pipeline materials and multi-service cable-pipes. Use of local recycling and pressure sewers will permit downsizing of infrastructure.

Four controversial issues will arise: 1. For less unsustainability of urban, suburban and rural communities, future systems will use minimum non-renewable energy. Energy economy is derived from recycling water as locally as possible. 2. New sanitary systems for treating human liquid and solid wastes separately will substantially reduce ecosystem impacts. 3. Even better for ecosystems will be the gradual conversion of

the public to vegetable-dominated diets (this impact is not immediately obvious). 4. Logically, a consequence of the pursuit of reduced unsustainability is that the size of the human and its domestic animal populations and their associated water demand and concomitant waste load will have to be managed. Just how we might start to consider the implications of these four issues in our modern confrontational political climate is not clear.

In the near future, drinking water, wastewater, and storm water infrastructure systems are unlikely to look very different from those of today, unless we see more procedural interventions. The free, democratic marketplace seems to focus on short-term objectives. Evolving build-operate-transfer arrangements for new infrastructure will be extended into the infrastructure rehabilitation business.

More immediately, possible solutions will be presented in a portfolio of aesthetically-pleasing infrastructure inspired by that recently installed around the world. The portfolio will include visions of holistic watershed management and facilities for generating attitudes favoring less unsustainability.

Finally, one can imagine that some of the changes listed here will make life in future mega-cities somewhat less unsustainable. This personal vision includes both (a) what I can imagine might happen under favorable conditions, and (b) what I hope will happen. Critics are left to enjoy the exercise of distinguishing between the two.

Key words

Water infrastructure, sustainability, smart water infrastructure, optimal complexity, urban water conservation, autonomous pipeline robots, water demand management, urban populations, future trends

I. Introduction

For a start, let me clarify that by “infrastructure” I mean the basic water facilities, services and installations required for a society to function, including dams, reservoirs, buildings, pipelines, treatment plants, pump stations, sewers, drainage systems etc. In my use of the term, it includes innumerable appurtenances such as gutters, inlets, manholes, and connections in private ownership such as toilets. Quality infrastructure is critical to a region’s economic future, quality of life, and productivity because it is essential for our daily activities.[1]

Also at the outset let me explain that an honest interpretation of “sustainability” will require that no non-renewable energy be consumed, nor should any water or energy be imported from remote areas, and also no by-products such as chemical contaminants should be exported or accumulated locally. For the population density evident in (say) Chicago, sustainability in the strict sense of the word seems, regrettably, implausible. I take it that politicians use the term to mean “reduced unsustainability” though it does not sound so catchy that way.[2]

From the early correspondence that I received about this conference, I understand that our general focus is to motivate a new agenda for local and regional water research and management. Outcomes of the meeting should include directions for integrating into local and regional decision-making, concerns of groundwater aquifers, surface water systems and contiguous ecological structures.[3]

Conference literature hints that infrastructure failures are universally topical. Growing metropolitan regions are perceived to struggle to (a) mitigate water impairments and impacts and (b) provide sufficient water of the quality necessary for regional economic growth and competitiveness.[4] Chicago, I was told in my invitation, is a particularly appropriate venue. Apparently the issues here are livelier than elsewhere, as a number of serious local, regional, national, and international disputes have arisen. Certainly the infrastructure seems unimaginably complex, with seven water reclamation plants, and 125 local communities owning much of the pipe infrastructure. Chicago is recognized for its innovative infrastructure such as water parks, and The Metropolitan Water Reclamation District of Greater Chicago has built decorative aeration waterfalls in small public parks. One dispute originated in 1848 with the construction of the Illinois and Michigan Canal to provide navigation. Outbreaks of typhoid during the 1870s and 1880s were attributed to lake water, and the Chicago Sanitary and Ship Canal was completed in 1900 to solve contamination, drainage and flooding problems (Espey et al., 1994). In 1910 the North Shore Canal and in 1922 the Calumet Sag Canal were built to facilitate the conveyance of sewage. Flow of the Chicago River was reversed, diverting shared, international water from Lake Michigan into the Illinois and Mississippi River systems. On April 13, 1992 a section of the 100-yr old underground freight tunnel was breached where the tunnel crosses under the Chicago River in the downtown area. Utility services to more than 100 buildings in downtown Chicago were lost, several hundred thousand workers were sent home, and the entire subway system and a major expressway in the Loop were shut down (Oberg and Schmidt, 1993). Now, The People of the State of Illinois, I learned from the conference publicity, have been ordered by the U.S. Supreme Court to put back into Lake Michigan an equal number of gallons of water that has been "over-pumped" since 1980. Further, I learned that Illinois and the Chicago metropolitan region have no intelligent decision framework to rebuild their infrastructure economically and ecologically to accomplish this charge. Chicago's central concept, the deep tunnel, after serious scrutiny, is now said to represent society's failed philosophy towards water resources management.[5,6]

Urban water difficulties are indeed widespread, and, closer to home, Toronto is typical, implementing its own deep tunnel for flow balancing (Green, 1997). Like other cities, Toronto's 150-year old sewer system was originally developed as a combined system, whose capacity was soon exceeded, so that basement flooding was a recurrent problem. Storm sewers were constructed in the 1960's, separating some 70% of road drainage. Annually 5 million cubic metres of combined sewage overflows from 24 outfalls, resulting in frequent beach closing by the medical officer of health. Now under construction, the new tunnel will reduce overflows to less than one per year at a cost of $370 million (1996Cdn$).[7]

Fundamentally this paper argues that both our behavior and our infrastructure must become smarter. Hopefully some conflicts may benefit from the argument provoked by the (largely conjectural) concepts reviewed below, and this paper is humbly offered in the spirit of that hope.

II. Developing Smart Sewers and Pipes

In the U.S., the $1.8 trillion system of drinking water, wastewater, and storm water infrastructure requires constant and expensive repair and monitoring ($280 billion over the next 20 years). Investments of this magnitude warrant the very best information systems.

Effectiveness and efficiency are dependent on good information flow as well as effective task assignment. Good decision support and information systems will become widely used and integrated into the water network, and water system administration will be rearranged to fit the new databases and decision support.

In some cases infrastructure will itself be laid out to facilitate improved information flow. Water treatment and distribution systems and wastewater treatment plants are becoming highly instrumented and are well advanced over wastewater collection systems. Stormwater drainage clearly lacks computerization, as does the management of receiving waters. In the future all these systems will not only be better instrumented, but operated and controlled from a unified web-oriented information management system.

Even old, existing systems need updated monitoring equipment. LeFebvre (1988) describes a compliance schedule for planning, design and construction of major permanent improvements to Pump Station 64 in San Diego County, California. Improvements included a parallel force main, pumping capacity expansion, alternate power source and, significantly, sensing devices on all motors, bearings and vibrating components. Extending this idea to all North American infrastructure will create a large market, conceivably installing millions of sensors, to keep watch over us.

Future urban water systems will be smarter, having intelligence distributed throughout the network, and will incorporate many advantages over our current (dumb) systems (James et al., 1993b). The term *intelligent drains* is coined to mean an urban drainage system retrofitted with real time control designed to support a pollution prevention strategy. Real time control of urban drainage can be designed to reduce the number and duration of overflow events, reduce basement flooding, reduce downstream environmental impacts, and monitor and enforce water quality. Real time control depends on good rain sensors. High-resolution rain data is already available at many North American cities, and provides real advantages for fitting convective storm models to compute spatially- and time-averaged rain rates over the urban area (James and James, 1999).

Such intelligence will be continuously shared on line with all users of the web. Water network performance information will be displayed at optimal complexity for example to managers, water consumers, and general members of the public, such as school classes. Already available are 3-D GIS data systems that perform over the web. Public-oriented urban water information systems will counter the "out-of-sight-out-of-mind" attitudes that heretofore have hindered attempts to rationalize investment in water infrastructure systems.

In a fierce anti-technologist call for improved information flow, Roy (1999) demands on behalf of the vast, underrepresented population, the right to information on the planning, financing, building, and operation of infrastructure. In the future, even small communities will share their information with the public, who will take more control of their own water resources and water re-use. Roy firmly blames arrogant and secretive "urban engineers" (this presumably includes me) for water infrastructure failures.[8]

As a further example of information dissemination, Stockholm has a conspicuous on-line display in a popular public park, depicting the city's present and accumulated discharge of pollutants into the environment – a startling monument to human self-indulgence, and I think a stark contrast to attitudes prevailing among infrastructure administrators in Ontario.

Current engineering approaches that are widely used today for planning, design, operation and control of complex infrastructure have serious shortcomings, including their narrow and simplistic focus (James, 1999). Computer models, the third theme of this conference, are an essential part of smart infrastructure. Useful multi-disciplinary models will continue to be developed co-operatively by scholars, researchers and practitioners, and used by state, provincial, federal and municipal officials, and relevant organizations. Because of the complexities of the real situation, models that are integrated, area-wide, and technically correct will become the dominant decision-making tools for infrastructure development, management and optimization. Such models will incorporate engineering, economic and ecological concerns, and interactions between each of them, and will be aggressively promoted by their developers (whose claims will include sustainability).

Gradilone (1988) describes an early use of geographical information systems (GIS), then termed a geo-coding process, and explains how the geo-coded customer database is used for customer service operations, and for distribution main rehabilitation. How right he was! Urban water managers will become entirely dependent on their facilities management information networks: the more complex the system, the more computer dependent it will become.

Burke (1993) discusses an information management system used in Australia and Japan that combines modeling with the integrated management of water, sewerage and storm water infrastructure. Future computer-based support systems will provide comprehensive information management combining engineering, maintenance, accounting, automatic data collection, and impact assessment (Utrecht, 1991).

Management will come to rely more and more on computer control in the future. There is scope for innovation. Skilled management will be required and will emerge, if only to provide a working environment in which problems and effectiveness can be improved through these types of innovation. Infrastructure innovation is needed because it benefits both our quality of life and economic prosperity.

R&D goes hand-in-hand with the provision of innovative infrastructure. Research for innovative infrastructure and development and commercialization of innovations has been discussed in three recent reports by the Civil Engineering Research Foundation (CERF, 1993, 1994, 1997). Data from U.S. federal laboratories indicates that public works (which is much more than just water) infrastructure R&D activity ranged between $1.026 and $1.386 billion in 1992, about 1.6% of total federal R&D expenditures. However no federal agency has been assigned or taken the lead role, with the result that public works infrastructure R&D lacks guidance of a comprehensive, coordinated, and integrated national policy. CERF (1993) recommended the cooperative development of a national public works research agenda by federal, state, and local entities, together with the private sector.

In a comparative study of European and American R&D, it was found that the U.S. led in high performance concrete, waste and wastewater treatment, computer-aided design, solid and hazardous waste disposal, global positioning systems (GPS) and GIS technology, and integrated databases (CERF, 1994). Europe on the other hand led in tunneling, and energy conservation (while Japan led in automation, field computer use, safety and building systems). Europeans may soon lead in innovative infrastructure because they lack the concern for liability issues that so plagues North America. In Europe new technology from R&D has a better chance of application in practice, and this encourages positive payback from R&D investment. Generally in Europe the vision for infrastructure innovation springs from the private sector, and European contractors maintain larger R&D departments than do their American counterparts. The report aims several recommendations at the U.S. federal government to improve U.S. R&D, based on perceived European advances.

The present writer has noted other, significant differences. Europe charges for local telephone calls, making the web more expensive. Europe has a larger mix of official languages, making communication more expensive. Commercial software costs more in Europe and Japan, so that, at least in their engineering communities, there is an unwillingness to share source code. Population densities in those two places are higher, with the result that their natural water quality is lower than (say) Canada, and they obviously have less space for development.

For these reasons, I believe that Europe leads in water conservation (Guelph may well be one of the worst conserving communities), Japan in large-scale computer control and Canada in building attractive, safe, livable urban areas of high quality.

In perhaps the most prescient of the publications reviewed here, Nakamura et al. (1995) describe two new composite submarine umbilicals supplying (a) 66kV power, and fiber optic communications, and (b) fiber-optic communications and water. Manufactured in continuous lengths of 4.4 km, both were laid below the sea bottom to service construction of the Trans-Tokyo Bay Highway. It is precisely the future use of this exciting new technology that will facilitate the intelligent water infrastructure envisioned in this paper.

In fact, and in the long-term, worldwide demand for innovative infrastructure technologies promises to be strong, and the rapid commercialization, or translation of an idea into a marketable product, is critical to maintaining and improving infrastructure. Public dividends include more reliable, more efficient, safer and less costly public facilities and services. Regrettably, the U.S (probably applies equally to Canadian) construction industry is not considered to be a progressive adopter of new technology (CERF, 1997). CERF consequently set up the partnership for the advancement of infrastructure and its renewal between industry, government and academia, to accelerate the comprehensive renewal and advancement of infrastructure towards a "truly sustainable" system (see URL 1 in the list of reference URLs at the end of the paper). The next section covers technology that is being adopted very slowly, even though its effectiveness has been demonstrated for some time.

III. Intelligent Management of Distributed Storage

Somewhat analogous to information networks, which distribute information in packages at slacker times to local computer storage, future infrastructure will be designed to serve the particular needs of domestic, commercial, industrial and recreational sectors by using storage distributed around the water network. Storage for the three water systems varies in scale (sanitary smaller than storm water; smaller water tanks and ponds at the point of use, larger for neighborhoods, larger raw water storages for fire-fighting) with size optimized against variability and required volume rate of flow. In this way, networks will operate continuously at near optimal efficiency.

For example, users will abstract potable water from the network into their local storage at times and cost that depend on availability. In these systems a small storage tank and pressure pump is installed in each home, and high peak flows in the distribution network are eliminated. Smaller diameter water mains are required and may be constructed from high-density polyethylene pipes at significantly reduced costs. When local in-line pressure falls in the distribution network, owing for example to a high demand, or a pipe break, water is supplied from storage at or near the point of consumption. Such systems have been designed for the arctic (James and Robinson, 1979), and will likely first find application in special areas where the technology can be effectively managed.

On the wastewater side, smaller-diameter, shallow-buried, low-pressure effluent sanitary sewer systems are similar in concept, and more economical than traditional gravity systems. Many different systems are available commercially. In one application, when pressure in the low-pressure sewer network falls, the user's in-line pump delivers effluent from a storage or septic tank to the sanitary collection system, resulting in the delivery of a more constant stream to the treatment plant.

Efficiency depends on sensors, controls and reliable electrical power sources, necessary ingredients of intelligent infrastructure.

Intelligence of this type, coupled to weather forecast information, will eliminate combined sewer overflows, at least from hazardous point sources such as hospitals (James et al., 1993a). Weather radar applications are increasing in Japan, and Chicago itself was a pioneer in the application of this technology.

Of course these digital information systems will incur costs that will be charged back. Charging algorithms for computing individual water and sewer rates will change so that the savings from operational efficiencies will be passed back to users. System integration will be an important source of improved efficiency.

IV. Integrating the Human Concept of the Four Water Subsystems

Management structures and their regulations have evolved over the past century from an original condition of plenty, but water availability, quality, consumption and demand have gradually changed.

Modern infrastructure is used for disposal of sanitary products at loads of 5-8 gm per cap-day (Ashley et al., 1999). For Chicago this translates to about 15000 tonnes per year. Females in the 18-44 yr age group are responsible for 75% of all sanitary waste flushed down sewers. Items most commonly flushed were tampons (flushed by 79% of an interviewed cohort), applicators (36%), sanitary towels (50%), panty liners (32%), cotton buds (7%), cotton wool (15%), and condoms (24%). Disposing of sanitary waste via the solid stream is more sustainable than the water borne route. Users who understand these benefits as well as those of separating their own bodily waste streams (described below) will demand appropriate jurisdictions and infrastructure.

In the first theme for this conference (governance) it is claimed that fragmentation by competing government agencies, jurisdictions, and regulations exacerbate the problems (a) of accommodating demand for water, (b) of preserving water quality, and (c) of managing storm water flows. I agree to the extent that artificial barriers exist between management's views of the three water systems (water supply, wastewater collection and disposal, stormwater management), and that these are reflected in different executive departments, perhaps all the way up to the federal cabinet (in Canada). Distinctions in the way that the three sets of planners, designers, constructors and operators work, and those of a related (fourth) infrastructure, pavement (especially permeable), will be eliminated in the future.

When management of these four currently distinct water infrastructure systems is integrated, the arrangement of the resulting system will show several improvements, for example:

1. local storage and use of storm water and urine for garden watering,
2. recycling of gray water for flushing etc. (URL 2),
3. use of local raw surface water for fire-fighting,
4. treatment of heavily-polluted first flush stormwater,
5. permeable pavement for treating stormwater (Pitt et al., 1998),
6. zero surface runoff (100% groundwater replenishment) from new developments,
7. aquifer storage and recovery of urban stormwater and recycled water (Dillon et al., undated).

Only after the currently distinct engineering computer models for planning, design and operation of these four systems are integrated seamlessly, will such issues be effectively discussed, and implemented.

Some of this is already in hand. Heaney et al., (1998) also view urban stormwater management as a subsystem of watershed management systems, and present results of an extensive literature review with preliminary evaluations of alternative future scenarios.

To summarize this section, we may re-phrase the pre-conference promotional material in a positive note as follows. Because of increasing societal awareness of water infrastructure problems, and because of governmental and non-governmental efforts, cities will improve their legal and institutional structures governing the management of water resources, to better address water as an integrated system.

Of course these developments require that new infrastructure will be built to new physical specifications.

V. Sizes and Layout of Future Infrastructure

Geometrical details such as minimum diameters, longitudinal radii and maximum runs may change (trenches may be shallower, diameters may be smaller, layout radii and transitions may be smoother, and runs may be longer). Currently, sizing is for human entry and manual maintenance via manholes of e.g. sewer networks. Future sizing and longitudinal geometry will depend more on the requirements of autonomous robots for inspection and repair, and on collection, transmission and processing of intelligence relating to the network performance. Evolving synthetic materials for pipes will reduce costs (Boon, 1996). Autonomous devices for inspection and repair will require smaller manholes and probably larger longitudinal radii (horizontal and vertical curves and transitions).

Several types of autonomous robots for pipeline inspection and repair are available on the market. Larger diameter (2 m) long-penetration tunnel inspection robots require a maximum distance of 10^4 m and small diameter (150 mm) pipeline robots require 300 m (URL 3).

Many appurtenances such as manholes, bends, drops etc. will be re-designed. For instance, valves on water distribution systems are frequently in a deteriorated state (Federico, 1988). Installed valves will be re-designed to facilitate passage of autonomous inspection and repair devices, and new materials will be used for their fabrication. For the latter reason, for better disease prevention, and for improved distribution security, dead-end mains will be eliminated.

Pressure and vacuum (i.e. the special case where pressure is less than atmospheric) sewer systems require much smaller infrastructure. Concerns relating to transitions between sub- and super-critical flow, which cause technical designs to require large conveyances, do not arise in pressure sewer systems. Pressure sewers have already achieved wide usage in North America, and continue to show cost savings. Moreover they are better suited to the separation of personal human wastes as described below.

VI Less Unsustainable Water Systems

"A sufficient quantity of pure and wholesome water" was the rallying cry for development in the mid-19th century (James and James, 1978), and water remains to this day a key to less unsustainable metropolitan communities.

We need to work harder at learning from clever people, wherever they may live. Let us consider the effect of four intellectually challenging issues: 1. Renewable energy, 2. Separation of urine and feces, 3. Diet, and 4. Population management.

Zoreda-Lozano and Cataneda (1998) present a general approach linking urban technologies for water use and sustainable development in Mexico City. They describe a tough situation, advocating among other things new materials, information handling, automation, and miniaturization. For less unsustainable urban, suburban and rural communities, future systems will be designed to use minimum non-renewable energy. Energy economy is derived from recycling water as locally as possible. For instance, stormwater ponds may be used for flushing and fire fighting. Numerous examples exist around the world, especially in regions of water and financial scarcity.

In Sweden a SEK 30 million research program has been initiated collaboratively at eight universities on rendering urban water management sustainable (Malmqvist, 1999). Included in the proposal is a national "urban water research school" which includes practical on-site training, that will be compulsory for all post-graduate students within the research program, to ensure that they are skilled in broad-based inter-disciplinary water management.

History shows us that advances in materials have foreshadowed those of infrastructure, and continually reduced its costs. Polyethylene pipes will be used in order to reduce costs, and also to reduce contamination arising from copper and zinc-plated materials.

Lozar (1993) calls for rethinking our definition of infrastructures, and for discarding our old infrastructure paradigms. Advanced infrastructure design should consider environmental management (creating suburban ecologies in neighborhoods), energy conservation (passive and photovoltaic community systems), material recycling (local reuse of materials and systems), automated infrastructure (robots and sensors), advanced communication technology, pollution reduction and quality of life issues. These concerns should and will be integrated into zoning regulations and building codes.

Enforcement of pollution prevention is indeed an effective path to reduced unsustainability. The City of Toronto is moving forward a new sewer use bylaw that requires pollution prevention planning (URL 4). Enforcement of new regulations, virtually eliminating persistent contaminants, will encourage new infrastructure for recycling human waste as sludge to agricultural areas.

VII. Sharing our Once-Used Food and Nutrients

Here we develop a radical theme (not chosen by the organizers for their keynote lunch address). It will have important benefits to folks who live downstream (i.e. all of us).

These ideas are not new: Victor Hugo wrote a piece on the sewers of Paris marvelously entitled "The entrails of the leviathon". Esrey and Andersson (1999) are critical of conventional sanitary infrastructure, and call for a change in the concept of wastewater. Three main components of environmental sanitation will drive our actions: pathogens, nutrients and water. Most pathogens come from fecal matter, and most nutrients from urine. Most pathogens need both nutrients and water to survive and reproduce. Hence in the future we will separate pathogens (feces) from nutrients (urine) and water. We will do so in order to recycle the nutrients, and not the pathogens (today, our infrastructure aids reproduction and distribution of harmful pathogens, and accumulates nutrients in harmful places). Future infrastructure will return nutrients to the land, and isolate pathogens so that the relatively small amount of harmful material can be easily destroyed. Inputs of water and chemicals for treatment will be reduced. Everything will be cycled continuously, the so-called waste streams (really resources in the wrong place) forming beneficial food for fellow living systems. It is not waste that we should dispose of, rather our concept of waste (Esrey and Andersson, 1999).

Otterpohl et al. (undated) also present forthright arguments in favor of managing differentiated water and waste in urban areas. Central to the task of sanitation, besides maintaining the highest hygienic standards, is soil fertility. Recall that one person can produce as much fertilizer as is necessary for the food needed by one person. Also, nearly all the required nutrients are in the urine stream. Human feces might be described as once-used food. Modern sanitation has mixed the food and water cycles, with the result that substances of soil fertility are being washed away to receiving waters where they accumulate and are extremely harmful. Inevitably, soil fertility is depleted, and drinking water is contaminated. Future sanitation and waste infrastructure will respect the different qualities of human waste matter. Otterpohl et al. present ten different scenarios, some of which include concepts of distributed storage described briefly in the present paper.

The most important piece of infrastructure for source control is the personal toilet. New toilets will separate urine from once-used food, since the two components when separated can be recycled safely and economically (Lange and Otterpohl, 1997). It is the fecal matter that contains pathogenic microbiological contaminants and persistent trace contaminants that are effective at extremely low concentrations, such as residues of medicines and their metabolites, or hormones from birth control. More intelligent use of existing sanitary sewers may involve the transport of urine as timed releases or waves. These proposed new systems will reduce COD, BOD_5 and total N by 75%, total P by 85% and total K even more.

In keeping with these concepts, in a group review of a workshop at Hilterfingen in March 1999, Schertenleib (1999) advocates a household centered approach to environmental sanitation.

From the point of view of less unsustainable sanitation, for food production and transport, and for closer contact of city dwellers to nature, the sizes and shapes of cities will be better managed. Golf courses will be used for groundwater replenishment. Cities of the future will be developed in the shape of stars with green, rural areas between the arms.

As an aside, one cannot help observing that the change of diet towards vegetable rather than animal products will result in considerable improvement of rural/agricultural runoff quality, simply due to the substantial (up to 90%) decrease in land required for food production. Impacts are not obvious: agricultural non-point source pollution contributed to rural drainage will decrease commensurately, substantially restoring the assimilative capacity of the nation's rivers. Requirements for waste water and storm water treatment will then change accordingly. Other downstream benefits include reduced requirements for food processing, refrigeration, disinfection, storage, transportation and preparation (and, arguably, public health).
It seems that in the future informed consumers will require less water. Demand management is not considered in these times to be a good issue for promoting local business development, however, and the implications are discussed the next section.

VIII. Population and Demand Management

Grigg (1986) predicts that demand management will become a recognized part of urban water supply management, and may enter wastewater management as well. Water conservation will become institutionalized as good management practice, rather than remain the emotional, environmental issue that in North America it is today still regarded to be.

Concepts of water value as applied by Harvey (1988) to natural resource damage assessment, water service investment decision making, development of water supply strategies and resource allocation policy, will be further developed. Re-allocation or marketing of existing water sources is a very complicated game (Ten Eyck, 1988; Atwater, 1988). It involves teams of planners, water resources engineers, and experts in demographics, natural resource economics, wildlife and ecology, water attorneys, recreation, agricultural engineering, and other disciplines. Teams will be managed by leaders well versed in negotiation skills and who understand difficulties encountered when some players on other teams work under a different agenda. Nevertheless Duecker (1988) advocates water transfers, and presumably would support Chicago's historical drainage concept. Canadians may have a different perspective. Readers will readily understand why University curricula for professionals will incorporate more management skills.

Mills and Herring (1995) discuss the interaction of energy, population and sustainable development. Increased availability of economic alternatives, improved health conditions, and sustainable energy supplies have a direct effect on the rate of population growth. Reducing population growth to a sustainable steady-state value is partly a product of improved health and living conditions brought about by informed industrialization.

One could propose that the provision of high quality infrastructure is a prerequisite for a community in harmony with its environment, which leads to a high quality of life, and a stable population. Certainly it could be a factor in Canada's negative natural population growth rate.

Logically, a consequence of the concepts discussed in this paper is that the size of the human and its domestic animal populations and their associated water demand will be managed. To some extent, limits will be established by what can be supported by local renewable water and energy (or will we never accept limits to growth in a finite world?). Of course, this argument ignores political realities, with its short-term concerns, but could have some implications for large cities, such as metropolitan Chicago. For example, is 7 million not enough? Is further growth really necessary? How could 70 million possibly be better? Surely the natural environment was in better shape when it was only 7 thousand? Just how we might start to consider these implications is not clear to this writer.[9]

Cities have, according to the Worldwatch Institute, become deathtraps, killing people by the tens of thousands in disasters such as earthquakes (not really a natural disaster when it is concrete buildings that kill) and floods (also not a natural disaster where indigenous forests have been stripped). Millions of city dwellers lack sanitation, choke on unhealthy air, suffer violent crimes and live in abject poverty. Yet cities continue to grow rapidly. Tokyo has grown 3000% in this 20th century, and many of our cities in North America have grown even faster. Simplest of all measures is simply to advise city dwellers to move out. Intending urban migrants will often be safer staying put in the countryside. Interested Web surfers should visit Worldwatch Institute Online at www.worldwatch.org. Worldwatch is a nonprofit public policy research organization dedicated to informing policymakers and the public about emerging global problems and trends and the complex links between the world economy and its environmental support systems. Anomalously, after a couple of years' of human catastrophe, next year marks the end of the UN's international decade for natural disaster reduction (visit: www.idndr.org).

Human population densities seem to be all but irreducible (exceptions may exist, such as the population decrease in downtown Detroit, but the experience is universally regarded negatively rather than as an ecological opportunity). I have qualms about papers like this present one. Though they may indeed contain seeds of good ideas, which if implemented, may reduce impairments of receiving waters, I fear that the improved water environment will simply be used to further increase human population densities. So my reservation is this: that if you take any idea here, you attempt also to deal directly with the root causes of negative impacts, which invariably stem from inconsiderate human behavior. Ultimately it is our human behavior that must be corrected and presumably this includes unlimited breeding, and uncontrollable avarice. In the next century these moral issues will be resolved.

As stated in the pre-conference material for theme three, the fundamental cause of many problems of water systems is urbanization of rural landscapes. Of these the worst problem is loss of natural habitat, which is driven by rapid national and global economic growth, a synonym perhaps for greed. It is a good bet that numerous decision technologies, including macroscopic multi-disciplinary models, will soon be available, claiming to help metropolitan regions simultaneously (a) achieve regional economic goals, (b) preserve the integrity of surface, ground, and coastal water resources, and (c) maintain environmental health and bio-diversity. It is also a safe bet that few of these models will include explicit routines covering the benefits of depopulation and negative growth. The web contains innumerable innovative ideas promoted by the private sector.

IX. Privatization

Privatization, which appears to operate successfully in France and Britain, offers municipalities a way to harness private sector resources to improve their infrastructure (Haarmeyer, 1994). Historical reasons for the involvement of the public sector in the provision of infrastructure are varied. In medieval times, water and drainage was in private hands. In the recent past, especially following the industrial revolution, government has provided most of the funds for infrastructure, usually as capital for new works.

Reading about the social conditions that led to Government participation is quite salutary. One hopes, with this modern move to privatization, that history will not repeat itself. Caution is the catchword. Schilling (1988) cautions against funding that favors new construction over rehabilitation of existing systems. Federal, state and local levels of subsidies that influence (a) project size, (b) project choice, (c) needs, (d) finance estimates, (e) decision making, (f) liability considerations or (g) that in any other way favor new construction over maintenance and rehabilitation, will be re-evaluated. Failure to provide budget line-items for infrastructure operations quickly results in massive accumulated deferred maintenance backlogs.

Insufficient investment in water supply infrastructure poses a public health risk (URL 5). The next few paragraphs list some of the horror stories.

Annually, 7 million cases of mild to moderate water-related illness occur in the U.S, resulting in 1,200 deaths. In 1993 the U.S.E.P.A. reported that 29% or more than 16,000 community water systems were not in compliance with the Safe Drinking Water act, and that 20% of the US population (47 million) drink tap water that does not meet EPA-approved standards for microorganisms. This was the same year (1993) that 100 people died and 400,000 were sickened in Milwaukee when the city's water supply was contaminated by cryptosporidium, which is found in 65% to 95% of US surface water. Milwaukee subsequently spent $89 million to better protect its water.

The U.S. has an estimated 800,000 miles of water supply pipe, and, according to the American Water Works Association, breaks occur once in every 3.5 miles of pipe.

Groundwater is tough to clean. Hundreds of municipal wells have been closed because of groundwater contamination. Contaminated groundwater sites number 300,000 to 400,000, according to a 1994 National Academy of Sciences study. Cleaning them will cost US$1 trillion (URL 6).

Statistics on infrastructure needs and trends are readily available on the web (e.g. URL 7, URL 8), where one quickly discovers that the amount of money required is mind-numbing.

Not unexpectedly, then, existing practice in urban hydrological infrastructure is in certain cases perceived to be failing in its mission. It probably always has and always will, being the difficult, under-valued service that it is. However, innovative infrastructure will continue to effect better stewardship of urban water resources, if management is good enough.

Grigg (1986) defines good management as management that lacks corruption, displays good manners, and motivates and takes good care of its employees. He felt a decade and a half ago, just as we do now, that cost control will be better in the future. He also writes that life-cycle approaches to capital management will be necessary. Life-cycle design requires planning, management and budgeting for both new and replacement facilities (Shen and Feeser, 1997; Siddiqui and Mirza, 1997).

Another way that problems with facilities after they are constructed will reduced, will be by better quality control in construction.

New partnerships are emerging.

Political, economic and business investment climates may need to be further manipulated, in order to bring about the kinds of urban water infrastructure changes suggested. Unless we see more interventions in the free, democratic marketplace, our infrastructure is unlikely to change very soon or dramatically. Politicians and investors seem to focus on short-term motives. On the other hand, currently successful infrastructure has useful life expectancies of up to a century or more. How can the case be made to base infrastructure decisions on such long terms? As government yields its role in water infrastructure to the market place, users need to be alert to a possible bias towards undesirable short-term profit objectives such as programmed obsolescence. One suspects that the pre-cast concrete pipe, asphalt, and pipeline-inspection industries are unlikely to support political issues advocating new materials or maintenance systems that could result in reduced business.

In fact, planning and budgeting for infrastructure replacement is a difficult task that has confounded societies from earliest times, and will grow more complex as the inventory of infrastructure grows. Barbolini and McAloon (1988) suggest a method that tabulates the estimated value of infrastructure and its estimated life, and computes expected expenditures. It is a logical and systematic technique for budgeting monetary and human resources and was developed for the Metropolitan Sanitary District of Greater Chicago. Their paper provides examples illustrating how the technique is used for infrastructure replacement and restoration.

Clearly there is a need for infrastructure management to utilize private sector forces and skills more effectively. Build-operate-transfer arrangements satisfy the need to access private sector finance, by permitting privatization in which infrastructure is funded, built and then operated for a defined period by the private sector. The concept is not new in non-water infrastructure, e.g. telecommunications, Terminal 3 in the Toronto International Airport, and the electronic toll route in Toronto.

Walker and Smith (1995) argue that the belief that private initiative can do better than state bureaucracy is now dismantling government monopolies around the world, and has been accredited by institutions such as the World Bank and the United Nations. A build-operate-transfer arrangement for infrastructure procurement is an approach that addresses real fiscal environments surrounding the demand for new and refurbished infrastructure. The basic criterion is that governments, funders and builders must have a transparent formula that ensures that the risks involved are placed with those best able to carry and price them. To be economically viable, the revenue generated by the project during the period of concession must be high enough to cover all the costs involved. Costs include initial development, financing, maintenance, operation, an acceptable return to debtors and shareholders, payment of any premium to the host government, and an acceptable profit to the operator. Thus the cost/revenue equation must be considered for the whole life cycle of the concession. This formula satisfies the political, financial and construction demands and ensures that revenues generated by the completed entity satisfy all three.

The approach is still undergoing refinement as the public and private sectors become more aware and proficient with the techniques. Financial models must be constructed with decision analysis tools to test the uncertainty of key variables over the extended life of the project. Then the method can and will be extended to infrastructure rehabilitation.

The next section suggests a simple first step.

X. Portfolios of Successful Infrastructure

According to the conference background, infrastructure failures are increasingly apparent. Probably infrastructure has always enjoyed a relatively high failure rate, since the public attitude towards infrastructure is such a good example of Hardin's Tragedy of the Commons (URL 9). I also suspect that the media promotes the topicality of failing infrastructure, possibly helped by the fact that dramatic video footage is relatively easily obtained. Certainly my portfolio of engineering disasters on the web (URL 10.) attracts a gratifying amount of interest. Possible solutions to our infrastructure challenges could be presented in a portfolio of successful and/or aesthetically-pleasing infrastructure, such as that of Geiger and Dreiseitl (1995). The portfolio should include examples recently installed around the world. Several visionary examples of holistic watershed management, and facilities that encourage sustainability values, have recently been developed in North America. They include urban developments that restore cold-water fisheries, and storm water detention systems designed for recreational catch-and-release fishing, and/or bird watching. Web sites of such portfolios designed to stimulate public discussion (such as mine, see URL 11), will become part of an urban region's strategy for reducing ecological unsustainability.

XI. Conclusions

This paper explores a personal vision of infrastructure. In the future we will change many things that affect of infrastructure – most notably we will:

1. Face up to the fact that in a growth-oriented world true sustainability is a pipe-dream.
2. Not distinguish between the human management of the four component water infrastructures.
3. Modify our quest for unlimited growth.
4. Reduce our dependence on end-of-pipe solutions.
5. Build integrated computer-based infrastructure information and control systems.
6. Share this information by publicly posting it on the web.
7. Facilitate innovative infrastructure with better management.
8. Make intelligent use of distributed storage.
9. Build macroscopic models.
10. Use autonomous robots.
11. Use pressure sewers.
12. Understand the true nature of our bodily wastes.
13. Treat urine separately from feces.
14. Separate personal sanitation items from sewers.
15. Recycle water locally.
16. Use renewable energy.
17. Enforce pollution prevention.
18. Eat healthier diets.
19. Eat food grown in soil fertilized by human feces and urine.
20. Return some agricultural land to the natural state.
21. Manage human and animal populations.
22. Eliminate water transfers.
23. Publicize successful, aesthetically-pleasing infrastructure.
24. Learn from regions of financial and water scarcity.
25. Privatize the infrastructure business.
26. Restore cold-water fisheries.
27. Create wild life values in cities.
28. Rearrange financial priorities to favor infrastructure maintenance.

Some of this could feasibly result (conference goal) in a higher level of economic and ecological stewardship of built and natural water resources or (my goal) in attitudinal changes to water infrastructure that will make life in future mega-cities somewhat less unsustainable.

Visions generally comprise both wistful dreams of what *could* be as well as guesses at what *will* be. It is up to the reader of this paper to critically discriminate between concepts that are plausible or implausible, possible or impossible, probable or improbable. It makes interesting discourse, but it seems unlikely that much of it will be realized in my time. To misquote William S. however: *'tis a consummation devoutly to be wish'd.*

Endnotes

1. In this paper I deliberately and perhaps confusingly describe the three water infrastructures (water supply,

wastewater collection and disposal, and stormwater management) as if they were one.

2. I prefer the longer term and use it here.

3. We will challenge our modern, casual attitudes towards waste management with some very futuristic and very old concepts.

4. Evidently we covet more growth, so we wish to build a more competitive infrastructure, but with an improved environment, rather than an impacted one. Perhaps these objectives are self-contradictory, and will remain unattainable, as they have done since the illustrious Romans or even earlier. We will however address research and development and related issues for development of innovative infrastructure.

5. It is of course impossible for me to suggest practical solutions to Chicago's water problem. However Gary Larson has suggested that a descendent of Elsie, Mrs. O'Leary's cow, sabotaged the tunnel system almost a decade ago. I believe that Elsie's descendents may be getting even after being wrongfully maligned for a century-and-a-half. I suggest that The People find and talk to that cow.

6. Seriously, regarding the Supreme Court decision, I might prefer that the good folks of the windy city not discharge their wastes into what is after all my drinking water.

7. Many examples of expensive end-of-pipe facilities exist in North America. Although impacts will be reduced by this strategy, user behavior will not be required to become better informed (sources of the problems will not be eliminated).

8. Not all urban engineers are megalomaniacs – mostly they plan, design, build, operate and refurbish functional infrastructure optimally under severe external constraints imposed by society itself. Clearly engineers should become part of the information flow process.

9. Confrontational politicians will have plenty to talk about.

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3. www.Aquaticsciences.com/tunnel.htm
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Discussion of
"On smart, benign drinking water, wastewater, and storm water infrastructure for a less unsustainable future – a personal vision by William James, D.Sc., P. Eng.

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According to our conference theme, we have a situation whereby:

1. Urban hydrological infrastructure, which is responsible for flood mitigation and the provision of enough water of an appropriate quality to promote regional economic growth, is failing

2. This failure is occurring even though there is a growing societal awareness of the problems and enormous governmental and non-governmental efforts.

Therefore, our conference theme suggests, a new vision is needed that integrates natural systems and cycles.

Dr. James has presented components of his vision for this integration that include the extensive use of monitoring systems, information systems, decision support systems, and operating models, and high speed, real-time communications. He envisions the seamless integration of the four water infrastructure systems, which in addition to drinking water, wastewater, and stormwater, Dr. James includes pavement runoff, and the processes used to configure their arrangements. He identifies some anticipated results in terms of distributive storage and sizes and layout of future infrastructure. He presents some quite visionary ideas with respect to energy, body wastes, diet, and population management and presents both positive and potential negative impacts of private development. He closes with some specific changes that he anticipates and then passes his visions on to us to decide which of his visionary ideas are plausible, possible, and probable. But then, he ends on a pessimistic note, suggesting that it is unlikely that many of his ideas will be realized in his time.

I think that Dr. James has put forth some practical ideas for future development without going to the extremes of the bubble city surrounded by a vast wasteland. Many of his ideas are practical in that they do not assume that the new infrastructure will be built from the ground up but rather will be implemented on top of the existing infrastructure. Some are a little far-fetched – as visions should be.

I totally agree with Dr. James' call for the very best information systems. Today, we have the hardware to collect and transmit data and to analyze the data, so that operation decisions or forecasts can be made. There are at least two problems in translating this capability into sustainability: first, humans have to be smart enough to develop the appropriate software and second, the institutional climate has to be significantly modified to allow the four water systems to operate together.

As much of my experience is international in nature, I know that the major lending institutions recognize these problems and are attempting to solve it. In fact, their emphasis has changed toward institutional strengthening and capacity building to establish a framework under which sustained development can occur. In many cases, the lending institutions look to the private sector as the best way to achieve sustainable development encompassing institutional development, and, in many cases, legal and regulatory reform oriented toward accommodating private development. In most terms of reference for technical assistance issued by these organizations, there are requirements to develop information and decision support systems that will foster sustainable development.

The physical visions put forth by Dr. James, such as distributed storage, pressure sewers, recycling, separate delivery systems for drinking and bathing/flushing water, permeable pavements for treating stormwater, robots, and geometric details are all possible today. Most have been considered and rejected on economic and financial terms. Of course these rejections are based on the results of current decision support models that are, according to Dr. James, for the most part narrow and simplistic. When area-wide and technically correct models become available, and the competing government agencies, jurisdictions, and regulations are integrated, these visions can be revisited. The question is, The question is, do the experts developing and integrating the models know what is necessary to develop these models.

As a practicing engineer, Dr. James' paper causes me to step back a little and think about several of his vision themes. Dr. James asks us to work harder at learning from clever people as his introduction to considering the use of renewable energy, separating urine and feces, changing our diet toward vegetable matter, and population management.

He foresees new systems using a minimum of non-renewable energy and later as using renewable energy. I'm not sure that this is the case. We might be hard pressed in Chicago to develop a new renewable power source to accommodate some of Dr. James' visions. According to another visionary, Jesse Ausubel, who addressed the question of "will there be enough", solar, wind, photovoltaics, biomass and other renewable energies show promise for only small niches. He expects that with his expected increase in the supply of natural gas and the gradual penetration of nuclear energy, there will be an ample supply for the 21st century. Toward the end of that period, nuclear should become the primary source of energy and neat hydrogen will fuel the world's vehicles.

Changing the concept of wastewater to separate out the pathogens will be a market driven issue. The physical equipment to accomplish this would be simple. Changing ones diet to vegetable products is not something I am looking forward to. As with all of the visions presented, I wonder about reciprocal ramifications. For instance, one must wonder about the impact on fisheries if we turn away from animals. Of course the nutrients we gain from changing the concept of wastewater may be used to increase fish production.

Opportunities certainly exist for improving sustainability through demand-side management. Water conservation will work but only if some major event occurs such as in the oil sector in the 70's. As soon as the price began to rise, people and industry found ways to conserve. My water bill, which is about \$1.00/m^3 is high enough that I don't water my lawn unless it is within a day of dying. As for population management, I believe that society is not ready to accept the only way it will work – regulated and enforced birth control.

Privatization is seen as the savior of many water and energy systems. It is a method to harness private sector resources and it appears to operate successfully. As I said before, the international lending agencies see it as a positive step to restoring failing infrastructure. As Dr. James suggests, there are potential problems. To guard against these problems, decision support systems that can consider the whole picture must be used to evaluate the private developers' proposals. Again, I wonder, do we understand the problems well enough to develop these systems?

None of Dr. James' visions are beyond reason and many could be implemented today. Why then, is he pessimistic about their implementation? His pessimism apparently stems from the lack of better information systems, decision support tools, and institutional cooperation. Some questions come to mind as I contemplate Dr. James' vision components and pessimism, *i.e.*,

1. What other barriers are currently in the way of implementing a sustainable infrastructure;
2. What will it take to overcome these barriers; and
3. What can we, as water engineers, do to realize some form of sustainable infrastructure within the near-term?

To answer these questions, I first looked at the conference title to put myself in the right frame of mind. The title suggests that improved decision-making is the key to sustainable development for metropolitan areas. Since we seem to be far from sustainable development, we need to improve our decision making capabilities. To be able to make a decision, we must know what we want – sustainability- and to know when we get there, we must know what it is. Also, as Dr. James is concerned with infrastructure, we also need to know how he defines the term.

I very much appreciated his definition of infrastructure, a word that is so overused that I never know what it is supposed to mean. As infrastructure, he includes the basic water facilities, services, and installations. He includes dams and reservoirs, which I assume is shorthand for surface and groundwater supplies and all of the structures required to collect and regulate these supplies. He includes treatment and distribution to the user, collection and treatment of the used water, reuse of at least a portion of the treated wastewater, and regulation and treatment of stormwater.

I was less enamored of his definition of "sustainability". I think that the concept is gaining acceptance, but the lack of a clear definition, that can be accepted by all of the entities that must contribute in the decision making process, is one of the main barriers to its implementation. Even among those here today, it might be difficult to reach a consensus on the definition of sustainability.

In the case of Dr. James' definition, I am not in favor of the requirement to limit the use of non-renewable energy or the import of water from remote areas. As I said before, I think the future of energy production is in natural gas and nuclear fuel and forcing this constraint on the definition of sustainability is counterproductive. As for restricting water import, I don't think the concept is workable and I think that importation of water is necessary for the optimal use the available supplies. There is plenty of water available in the world – it is just not in the right place at the right time or of the right quality, or being used for the right purpose. Without the ability to move the water around, we might concentrate the people in the source areas which would only exacerbate pollution of the supply.

Dr. James thinks that "true" sustainability that incorporates the limitations described above is implausible, and he is not alone. Opponents would argue that sustainable development is an oxymoron or that it has no meaning at all, or that once we turn the century, it will be passe. Dr. James feels the need to coin a new catchword, "reduced unsustainability". Then, once or if we ever get a definition that we can hang our hats on, will we be able to measure it to the extent that we can claim success?

When I think about a definition for sustainability on a global basis, there are two somewhat competing general, conventional definitions of sustainability that come to mind:

1. A sort of intergenerational equity whereby we preserve resources for future generations and we do not degrade the natural environment, and

2. Improving the quality of life.

To these we might add Dr. James' limitations on the use of no-renewable energy, water import, and the accumulation or export of byproducts. Then, from a system standpoint, it might be defined as the steps needed to ensure that the system can operate continuously as planned. More specifically, in a particular water supply system, we might see reservoirs that don't lose capacity because of sediment deposition, or aquifers that don't lose fresh-water storage due to pollution or saline intrusion. Distribution system losses will be under control and revenues will accrue to the operating agencies so that effective and efficient operation and, especially, maintenance can be performed.

In addition to the lack of a clear definition, another barrier to the implementation of sustainable development is the success and good service realized from the existing infrastructure especially in developed regions of the world. Although Dr. James points out and references a number of infrastructural failures, to most of the people, the failures are an inconvenience that happens to someone else. As long as the infrastructure delivers what is expected, no outcry for a sustainable system will be made. The expectations for the water infrastructure are that water keeps coming out of the tap, no major water pollution related catastrophes occur, and that our basements don't flood too often. The combination of the adaptability of the water users and the insidious impacts of an unsustainable system can almost assure that there will be no quantum leap to sustainable systems.
In developing areas, the people are not worried about sustainable development as anything is better than what they have. In developed areas that have suffered reversals, such as the newly independent states of the former Soviet Union, the opportunities for implementing sustainable development are good. They have seen what happens when the systems are not sustainable, especially in the energy sector, and can appreciate the advantages of a holistic approach to system rehabilitation. Even in these areas, the real opportunity for implementation is poor. Private sector resources are needed and the institutional, legal and regulatory framework is not in place to the extent that private developers are willing to risk their capital.

What can we do to further Dr. James' ideas of a sustainable infrastructure? As water engineers, we are in a good position to influence future development both in the rehabilitation of existing systems and in the construction of new systems. Today, even though most people are satisfied with the operating characteristics of the water, wastewater, and stormwater systems, the concept, if not the practice, of sustainability has caught on. The international attention to ozone depletion, global warming, flooding of the coastal regions of all the continents, and skin cancer provides some understanding for the need for sustainable development. Groundwater contamination, depleted supplies of high-quality drinking water, and bacterial infection are beginning to do the same for water and wastewater systems.

As water engineers, we have to strive for a balance between social, economic, and environmental goals and the organizing principal for this balance is sustainable development. The tool for organizing this balance is management of the water systems – not the narrow focussed approach – but the broad band approach that is now designated as integrated water resources management. In my opinion, the key to sustainable development is the integrated management and the key to the successful integration of management principals is stakeholder participation.

What are we striving to integrate so that we will have a sustainable system? It is not just the integration of competing government agencies, jurisdictions, and regulations, it is not just the integration of the planning, design, construction, and operation, and it is not just the integration of computer models. What we must integrate are the strategies and policies that are proposed to resolve the stakeholders issues and concerns. It is important to note that people interpret impacts to their lives and communities differently. These interpretations can depend of a host of variables such as attitudes, historical experience, cultural beliefs, and group membership. The stakeholder groups are necessary to assist in determining which are the key variables for understanding the likely affects and the social meanings associated with alternative strategies and policies. Before we start implementing any new vision concepts, we must develop a broad support for what is considered to be important.

Once we have decided what is important, we can then attack the issue of how important is it relative to the other important issues. Each alternative strategy (*e.g.* distributive storage) or policy (*e.g.* population management) will have a cost and a benefit. With the concept of integrated development, the planning process will require that the impact of any alternative on the other social and economic sectors be considered. For example, consideration would be given to economic tradeoffs, the equity of distributional impacts on various social groups, the demographic impact on the population, revenue and expenditure impacts on local and central governments and others.

Therefore, I suggest that decision making systems necessary for sustainable development be coordinated not only with the scholars, researchers, and practitioners, but also with the stakeholders. Once they are on board, sustainable development will be achieved. This interaction could be the topic of your next conference.

The Ecology and Culture of Water:
New Directions for Urban Hydrological Infrastructure (Revised July, 1999)

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Abstract

The two free resources that drive all biotic and abiotic processes, sustaining all life on earth, are water and light energy. All places and things can be defined by the way they handle these two resources, the processes of which are grounded in complex interactions with local biological and mineral resources. As a society, we are becoming increasingly aware that the earth's natural ecosystems are not limitless. It is less understood, however, that the ability for the earth's natural ecosystems to mitigate the changes we impose, and still be able to continue functioning sustainably, is also limited. Short of inexorable geologic change, the extent to which we mismanage natural systems, either intentionally or through a failure to comprehend the rules and inherent capacities of our surrounding natural systems, is the extent to which these systems become more dysfunctional.

Mismanagement of water is a primary factor in this increasing level of ecosystem dysfunction. The range of adverse impacts associated with inattentiveness to the relationships of water in built and natural environments is profound. When we are unaware of, ignore, or are wasteful in our relationship to the interaction of water with other natural resources, water becomes a waste product and potentially a powerful source of destruction. Many "natural disasters", such as floods, erosion, landslides, and other changes, including climatic change, loss of biodiversity, aquifer depletion, and natural systems degradation can be traced to our failure to comprehend the ecology and culture of water.

We believe that sustainability is an overarching principle for all land use. To support the hydrologic cycle, ecosystem stability, and other critical natural processes, it is necessary to consider local, regional, or even global issues on land use of all sizes. In contrast to a sustainable approach, much of our contemporary infrastructure and conventional planning methodologies are products of a contrived visual aesthetic with little understanding, relationship, or grounding in the unique realities of place. They represent a cultural indifference to the function of natural systems, or even the energy required to maintain this infrastructure, much less any long term consequences.

Understanding the human relationship to the interaction of water with the geology, soils, topography, flora and fauna unique to a place is a first step by which a culture can learn to live sustainably. The purpose of this paper is to examine current problems associated with the human relationship to land and water, and to suggest creative and economically crucial solutions are available. These solutions involve innovative land use and water resource management approaches, in association with ecological restoration, that are designed to restore hydrologic stability in built and natural environments.

Key Words

Sustainable Water Resource Management, Restoration of Historic Patterns of Hydrology, Integration of Native Landscape Systems, Groundwater as Predominant Form of Hydrology, Celebration of Water as a Resource, not a Waste Product, Problems with Standard Water Resource Engineering Practices

I. Introduction

Two free resources that drive all biotic and abiotic processes, sustaining all life on earth, are water and light energy. All places and living things can be defined by the way they handle these two resources, the processes of which are grounded in complex interactions with local biological and mineral resources. The entire surficial environment of the earth--geology, soil, topography, flora, fauna--is mediated by water. All living things develop in an aqueous medium in their own genetically defined ways.

As a society, we are becoming increasingly aware that the earth's resources are not limitless. It is less understood, however, that the ability for the earth's natural ecosystems to mitigate the changes we impose, and still be able to continue functioning sustainably, is also limited. Jean Prior (1991) discusses this concept clearly: "People may modify the land to suit their purposes, but it is wise to remember that the land must be used in accordance with its capacities as established by geologic history and expressed in landscape shapes and underlying deposits, including groundwater and mineral resources."

Although vitally important to all life systems, water remains one of the most misunderstood and mismanaged resources on earth. When we are unaware of, ignore, or are wasteful in our relationship to the interaction of water with other natural resources, water can become a waste product and potentially a powerful source of destruction.

Our culture, however, has become functionally detached from how the natural world around us works, unaware of its realities, and unmindful of its capacities. We have lost touch with the importance of a sustainable cultural relationship with land and water, and largely forsaken the human relationship with the natural environment. Our technologies permit us to extract resources from distant places, and import them at great expense, allowing us to defer accountability for unsustainable behavior insofar as our limited resources are concerned. This curious capacity to deflect or defer accountability for our own relationships with land and water appears to be born of a belief that there are no real rules in nature.

Short of inexorable geologic change, the extent to which we mismanage natural systems, either intentionally or through a failure to comprehend the rules and inherent capacities of our surrounding natural systems, is the extent to which these systems become more dysfunctional. Mismanagement of water is a primary factor in this increasing level of ecosystem dysfunction. The range of adverse impacts associated with inattentiveness to the relationships of water in built and natural environments is profound.

Many "natural disasters," such as floods, landslides, erosion, and other changes, such as loss of biodiversity, aquifer depletion, and climatic change can be traced to our failure to understand the ecology of water.

Understanding the human relationship to the interaction of water with the geology, soils, topography, flora, and fauna unique to a place is a first step by which a culture can learn to live sustainably. The purpose of this paper is to examine current problems associated with the human relationship to land and water and to suggest that there are creative and economically crucial solutions. It will focus on the ecology of water within the physical context of the Chicago region and the Midwest, and while the basic principles evaluated here are adaptable to other geographic contexts, the specific applications of solutions will vary.

II. Nature's Hydrology

Throughout the glaciated regions of the upper Midwest, most natural wetlands and aquatic systems, including the lakes, streams, and rivers were formed either from direct precipitation or from groundwater discharge. In our biome, aquifer recharge occurred prevailingly in upland landscapes, and few natural wetlands were formed from surface runoff water.

Historically, water infiltrated the deep-rooted vegetation of prairies and woodlands, setting up a flownet relationship below the surface that is dependent on topography and the characteristics of the underlying till stratigraphy. According to Richardson, Wilding, and Daniels (1992), there are four kinds of water movement dominant in soil development in the glaciated Midwest: 1) recharge, or water movement to the water table; 2) flowthrough, or lateral groundwater movement; 3) discharge, or movement from the water table either to or near the soil surface; and 4) stagnation, or slow water movement creating water table mounds.

The glacial geology of the upper Midwest is characterized by limestone or dolomitic bedrock, overlain by gravels, sands, silts, and clays derived from such bedrock. When water moves through these substrates, carbonates can dissolve in the slow-moving groundwater, and the discharge will tend to be rich in bicarbonates. Bicarbonate-rich water that discharges through upward movement due to evapotranspiration potentials will precipitate carbonates near the soil surface, whereas water that discharges near the water table, such as in seeps and fens, will remain both bicarbonate-rich and iso-thermic. Either method of groundwater discharge provides a surface habitat that is virtually stable in its physicochemical and hydrologic properties.

Although water in local wetlands varied enormously with regard to the mixture of groundwater discharge and direct precipitation, most of our more than 700 native wetland plant species are adapted to the stable habitats created by the blend of groundwater discharge and precipitation. Most of these species are denizens of either alkaline or circumneutral conditions.

According to Swink and Wilhelm (1994), there are five basic types of wetlands in the region of southern Lake Michigan. These wetlands can be classified generally as aquatic, marsh, fen, bog, and swamp. Unfortunately, few of these wetland habitats remain intact today, and few people are aware of their natural attributes, either their inherent biodiversity or their ineffable beauty. To help the reader appreciate the diversity of our local wetland habitats and the varied roles of water distribution in their formation and sustenance, the major community types are described below. (Note that surface runoff water, other than clean spring snow melt, is not a significant factor in healthy wetland systems.)

Aquatic plant communities are occasional throughout the region. They formed in potholes and in lacustrine plains where there was little or no surface discharge. Aquatic communities are sustained by waters from a surrounding watershed greater than that provided by rain over their surfaces. Generally, these excess waters filter down through vegetated ambient ground into the underlying soil until they reach impervious material, and exit by way of springs, rills, or seeps. Along our major streams, aquatic plant communities developed in alluvial sloughs and ponds derived from surface melt or tributary streams. Depending upon the groundwater contribution, aquatic waters ranged from hard to soft, or else they consisted of still-flowing alluvial waters.

Marsh plant communities generally occur along the transition between aquatic communities and drier communities, or in large flats that are regularly inundated by shallow surface waters for much of the growing season. Marshes are best developed locally in the lake plain, in lacustrine flats, and along the lower reaches of the Des Plaines and Kankakee river drainages. The sedge meadow, a community with affinities to fens and wet prairies, develops in large, shallow, lacustrine flats, and is dominated by sedge hummocks. The kinds of surface waters suitable for marshes are those received directly from rain, or as a combination of rain and the essentially clean overflow from streams fed prevailingly by base flow or snow melt.

Fens are wetland communities that occur in areas where the glacial formations are such that bicarbonate-rich ground water discharges at a constant rate and temperature along the slopes of kames, eskers, moraines, river bluffs, or even dunes, or in flats associated with these formations, provided the material through which the waters traveled is rich in carbonates. Depending on the circumstances, fens can occur where marl is at or near the surface or where peats are constantly bathed in minerotrophic ground water. Such areas can be wooded or open. Marly fens are generally found on open prairie slopes, and commonly produce constantly flowing rills discharging over the surface. Related to these hillside fens are the wooded seeps that occur sporadically on steep bluffs. As fens become peatier, there is a tendency for cation exchange to damp off, causing circumneutral or even acidic conditions, which can occur in the flat, black-soil prairies and in certain morainic depressions.

As the cation exchange capacity damps off further, bog conditions can begin to develop. Commonly, the peatland floats on a minerotrophic head of water. The deeper roots are thus exposed to calcareous or circumneutral conditions, and the shallower roots are imbedded in the upper sphagnum mat, probably in a more acidic environment. In large basins or in areas where the influence of minerotrophic waters is insignificant, acid bogs can develop. Related to the acid bog, often in sand flats or basins, are floating sedge mats that rise and fall with the water table.

Swamps are wetlands characterized by trees growing in large flats or basins that are poorly drained; most of the water leaves through evapotranspiration. They can occur in the backwaters of large, slow-moving rivers, such as the Kankakee, or in wet sandy flats in the Kankakee Sand Section south of the Valparaiso Moraine. They can also occur on moraines in wet depressions. North of the Valparaiso Moraine, in the lake plain, they are best developed in the large flats behind the high dunes, where lies one of the richest and most complicated forested systems in our region. It is characterized by a complex hydrology and is interspersed by gentle rises, shallow depressions, and hummocks, and consists of an inseparable mixture of wooded fen, bog, and mesic forest.

It is important to understand that the clear line of demarcation (edge) we often search for and identify between upland and wetland habitats in contemporary landscapes is of far less importance in the natural landscape, where the wetland/upland distinction is highly undifferentiated. Such concepts as wetland edge are more artifacts of a regulatory mandate than observable manifestations of the natural landscape.

III. Regional Hydrology

In natural areas, the primary recharge occurs in upland to mesic habitats, and discharge can occur anywhere along the spectrum from higher to lower gradients, depending on the relationship of geology, soils, surface and groundwater gradients, and other factors. Imagine the ecological attributes of a landscape mediated by a combination of flora, fauna, soils, and geology, such that groundwater was the dominant form of hydrology, as once occurred throughout most of Illinois and the upper Midwest.

At the time of European settlement, the Illinois River, draining more than one half of the land within the state of Illinois, was virtually still-flowing, with little perceivable discharge into the Mississippi River. According to Barrows (1910), the average fall between Hennepin and Pekin, a distance of 55.8 miles, is 0.82 inches per mile. "The Illinois is a river of relatively insignificant volume. Its natural low-water discharge is but a small fraction of that of the upper Mississippi and Ohio rivers. The nearly level channel and the small volume result in a very sluggish river, which has been described as a stream that more nearly resembles the Great Lakes than an ordinary river, and again as one that partakes more of the nature of an estuary than of a river."

Consider these accounts of the now beleaguered Illinois River, once one of the most beautiful and biologically fecund rivers in North America.

> The placid Illinois traverses this territory in a southwestern direction, nearly 400 miles . . . Unlike the other great rivers of the western country, its current is mild and unbroken by rapids, meandering at leisure through one of the finest countries in the world . . . upwards of 400 yards wide at its mouth . . The banks of the Illinois are generally high. The bed of the river being a white marble, or clay, or sand, the waters are remarkably clear. It abounds with beautiful islands, . . . It passes through one lake, two hundred and ten miles from its mouth, which is twenty miles in length, and three or four miles in breadth, called Illinois Lake [Lake Peoria]. (Brown 1817).

> The Illinois river . . . presents to the eye a smooth and sluggish current, bordered on each side by an exuberant growth of aquatic plants, which, in some places, reach nearly across the channel. We soon found the water tepid and unpalatable, and oftentimes filled with decomposed vegetation . . . There is perhaps no stream in America whose current offers so little resistance in the ascent . . . Both banks are bordered by a dense forest of cottonwood, sycamore, and other species common to the best western bottom-lands. Of the fertility of the soil, no person of the least observation can for a moment doubt . . . (Schoolcraft 1821).

> We have seen nothing like this river that we enter, as regards its fertility of soil, its prairies and woods; its cattle, elk, deer, wildcats, bustards, swans, ducks, parroquets, and even beaver. There are many small lakes and rivers. That on which we sailed is wide, deep and still, for 65 leagues. In the spring and during part of the summer there is only one portage of half a league." (Thwaites 1900, from Jacques Marquette, around 1674).

It is also significant that this portion of the continent, referred to by Transeau (1935) as the "Prairie Peninsula," lies within a physiographic region where the ratio of rainfall to potential evaporation ranges from 0.6:1 to 1:1. In contrast, in regions where the ratios are greater than 1:1, the tendency is for mesophytic forest to develop. Therefore, when Barrows did his study in 1910, of the approximately 37 inches of rainfall that fell annually across northeast and central Illinois, very little was discharged as surface runoff into the Illinois River. Instead, water either percolated into the aquifers, discharged slowly and evenly to seepage areas and fens or evapotranspired. Simple arithmetic tells us that a balanced system receiving a given amount of precipitation per year cannot continue indefinitely to evapotranspire the same amount and lose an additional amount to runoff without a considerable increase in dryness.

Weaver and Noll (1935) documented the absorption capabilities of prairie ecosystems and their unique relationship of water, vegetation, and soils, during their grassland studies. According to their findings, "The porosity of . . . moist grassland soil into which the water sinks is impressive. It accounts for the fact that on fully vegetated lands practically no erosion occurs except, possibly during storms of unusual violence, and even then erosion is seldom serious." In a study involving interceptometers in Nebraska, they noted that eleven rainfall events over a year resulted in the loss of about 1% of the total rainfall from a prairie dominated by *Andropogon scoparius* (little bluestem grass) and with a slope of five degrees. A wheat field under the same conditions lost more than seven times that percentage of water volume, and a fallow field lost more than nine times that of the prairie, or 10.2% of the rain that fell.

Such observations are further supported by an ongoing study at Iowa State University (Bharati 1996), where, based on eight sampling measurements, a five-year-old planting of *Panicum virgatum* (switch grass) exhibited the capacity to infiltrate, on average, more than 7.5 inches of rainfall per hour; an adjacent rowcrop on the same soil infiltrated 2 inches per hour.

IV. Water in the Contemporary Landscape

If we wish to influence water infiltration positively, improve water quality, reduce flooding and restore wetland and aquatic habitats, the intricate surface and groundwater relationships of our natural hydrology must be understood and incorporated into planning and land use. It is essential that practitioners responsible for all forms of land use--architects, landscape architects, engineers, planners, developers, contractors, agricultural producers, and government regulators--consider the natural hydrologic patterns not only of the site, but also of the surrounding area or watershed.

Stormwater management is a consideration in nearly every development project, but traditionally, water is viewed either as a burden or as a purely utilitarian commodity. Professionals are trained to collect and convey surface waters quickly and efficiently from the site to areas remote from their purview, presumably to be dealt with by somebody else. They analyze, design, and construct storm drainage and detention/retention systems that attempt to confine site and regional impacts of surface water-generated storm flows. It is rare, however, for these evaluations to consider the natural hydrologic character of the area, or the hydrologic context in which the site and surrounding natural systems formed over geologic time: time measured not by decades or lifetimes, but by thousands of years of system development.

Every tract of land, no matter how large or small, is affected by and interacts with water. We are often frustrated by the fact that precipitation falls everywhere, not just in wetlands or in places designated by engineers and ecologists. Precipitation in the Chicago area amounts to about 37 inches, or about one million gallons of non-compressible fluid per acre per year. When it falls, two things can happen. It can infiltrate the soil and become an asset to local life, or it can run off and become a liability to life downstream.

Site development generally results in an increase of impervious surfaces associated with the construction of buildings, roadways, and walks. Even landscape systems, particularly those areas dominated by a typical turf grass lawn, can generate significant volumes of dirty surface water runoff. Nearly all of the intercepted water is collected and shunted away from the site. Most development sites contain an extensive, costly storm sewer network that quickly conveys a large portion of every precipitation event, discharging its flow into the mandatory detention basin, where its focused energy is released into the nearest stream corridor, or possibly a larger storm sewer system.

Discharged water carries with it sediments, greases, and oils from roadways and parking lots, and excess fertilizers and pesticides from conventional lawn care. Other areas have no detention at all, allowing runoff to flow uncontrolled and untreated into area sewers or drainage ways. In all cases, most of it is passed downstream to somebody else.

Much of the water falling on the ambient landscape is no longer able to infiltrate into the ground, where it once provided a constant source of groundwater seepage to sustain a stable stream hydrology, even during periods of prolonged drought. Instead of a stable watershed and associated groundwater hydrology, many systems are now dominated by erratic surface water hydrology. Waterways experience rapid fluctuations in streamflow velocity and volume, generated almost completely in response to surface water discharges. The force of these combined stormwater flows is focused on a landscape, with its inherent soils, fauna, and flora, formed with a completely different type of hydrology. The erosive power of this shift in hydrology is impressive.

Drainage ditches are gouged into the landscape where no surface drainage existed before. The collective runoff acts to carve out existing streams and rivers, resulting in deeply incised stream banks, subject to constant erosion and sedimentation at rates not seen since the glaciers receded. The loss of infiltration and groundwater recharge in the surrounding watershed, coupled with the depression of normal water levels in the stream system, combine to lower the regional water table, and starve the stream during periods of drought. On the opposite extreme, intense periods of rainfall, once mediated by a landscape highly capable of absorbing and using the water as a resource, now regularly result in flash floods in areas that were not historically subject to flooding. The economic, environmental, and cultural impacts of flooding are significant, and often catastrophic.

The instability of streamflow, coupled with degraded water quality, make it difficult for aquatic life to adjust. Desirable species of fish, birds, and other aquatic organisms must struggle for survival in a stream system that may experience virtual or complete desiccation during dry periods that exhibit increased water temperature and altered water chemistry, including low dissolved oxygen. Habitat availability becomes critically limiting to many species.

Whole sections of stream bank become overgrown with dense stands of trees and shrubs, effectively shading out the deep-rooted perennial forbs and grasses that are necessary to stabilize the soil layer. With the loss of a deep-rooted cover to secure the soil, the bare ground becomes increasingly exposed to erosive forces, resulting in accelerated streambank erosion. A new industry, streambank bio-engineering, has emerged to deal with this phenomenon. Unfortunately, many well-designed and potentially useful solutions are likely doomed to long-term failure unless we find intelligent ways of dealing also with the root cause: mismanaged water.

We have forgotten that floodplains, as we know them today, are not a natural phenomenon, but an engineering term created to describe a zone of flood-prone land that can change just as rapidly as the next upstream development. With each passing generation the culture becomes more distant from reality. Its words take on new meanings in accordance to the real experience of the young.

"River." What image does the word evoke? We picture a long channel, with steep muddy banks, that surges with brown roiling water after the rains, and during the "droughts," a scarcely wet ditch with shallow pools of gulping carp, discarded appliances, and abandoned grocery carts.

V. The Plight of Wetlands

Our society's failure to comprehend and synthesize natural hydrologic processes into all forms of land use is epitomized by our management of wetlands. It is a common misconception that wetland systems throughout our region rely on surface water hydrology for sustenance, or that they are *stormwater driven*. Most modern wetland literature asserts that the basic value of wetlands is related to their ability to provide flood storage and to serve as a cleansing mechanism for filtering stormwater pollutants.

Yet, these two factors are most directly responsible for the degradation or outright destruction of our remnant wetland habitats and the poor performance of most wetland mitigation projects. Imagine requiring our kidneys and livers constantly to store and filter a random suite of toxicants. This problem occurs only because we have failed to take advantage of water where it falls, turning it instead into a destabilizing force to be dealt with elsewhere.

We are aware of no scientific evidence to suggest that naturally occurring remnant or recreated wetland habitats located throughout this region benefit from direct surface water discharge and inundation. To the contrary, there is overwhelming scientific evidence that illustrates that surface water inundation of wetland habitats will result directly in their degradation. Research indicates that changes in water quality, water quantity, and physicochemistry can significantly impact the function and sustainability of wetland systems.

The USEPA publication *Natural Wetlands and Urban Stormwater: Potential Impacts and Management* (1993), summarizes research findings describing stormwater impacts to wetland habitats. According to this document, changes in vegetative community structure, productivity, water quality, and hydrology are inseparable. Changes in vegetative community structure appear to be correlated with the time of year, water depth changes, and frequency and duration of inundation experienced in the wetland from excess stormwater discharge (Azous 1991; Cooke 1991; Stockdale 1991; USEPA 1985). Changes in water quality (chemistry and sediment loading) have the potential to affect the vegetative community structure and productivity, thereby reducing the availability of plant species preferred by fish, mammals, birds and amphibians for food and shelter (Lloyd-Evans 1989; Mitsch and Gosselink 1986; Weller 1987).

Wetland plant species are generally specific in their requirements for germination, and many are sensitive to flooding. Horner (1988) found that emergent zones of palustrine wetlands receiving urban runoff in the Pacific Northwest were dominated by the opportunistic non-native, *Phalaris arundinacea* (reed canary grass), whereas unimpacted wetland plant communities were composed of a more diverse group of native species. Ehrenfeld and Schneider (1990) discuss the relationship between stormwater discharge and changes in plant community composition. They found a reduction in indigenous wetland species and an increase in the colonization of exotic species due to changes in hydrology, water quality, or both. Van der Valk (1991) noted that wetland species may have limited ability to migrate in the face of persistently raised water levels; many species can spread only through vegetative methods under such conditions. The result may be lowered plant diversity in the wetland-to-upland gradient. This is evident in many remnant wetland systems, where the lower gradient zones subjected to longer periods of surface water inundation have exhibited more substantial degradation than the edges of the wetland.

Studies have been conducted to evaluate hydro-period impacts on individual species. Stockdale (1991) found that *Typha* spp. (cattails) survive well under fluctuating conditions, and that *Phalaris arundinacea* (reed canary grass) has a wide tolerance to water level fluctuations, though it does not survive long periods of inundation during the growing season. In contrast, *Carex* spp. (sedges) are highly specific with regard to hydrologic preferences. According to Frederickson (1982), modifying natural wetlands with impoundments may result in radically different hydrologic regimes that are not ecologically sound. The introduction of stormwater runoff or water control objectives, causing hydrological disturbances in impounded wetlands, could result in the development of stressful habitat conditions.

Changes in the pH of water associated with management practices or the introduction of stormwater also can have an effect on the biota in impounded systems. Most organisms are adapted to function within particular pH ranges, and abrupt or substantial variations in pH can have adverse effects on aquatic life, usually in the form of reduced productivity and increased mortality (Newton 1989). Urban stormwater can vary significantly in pH, so the variable nature of stormwater inflow could result in abrupt changes in pH in an impoundment. Since only a few species can adapt to conditions of changing salinity, pH, temperature, and dissolved oxygen, low species richness could result (Devoe and Baughman 1986). Given the predisposition of most native species to either ombrotrophic or minerotrophic conditions (Swink and Wilhelm 1994), wetlands dominated by waters with fluctuating physicochemistry and volumes are depauperate in species richness.

Another point to be considered is that the environment least capable of handling excess water is a wetland habitat that is already saturated. This is often the case in detention and wetland mitigation projects that involve the excavation and creation of emergent and shallow water marshland habitats that rely primarily on surface water hydrology for sustenance. Except perhaps for marshes filled pre-jurisdictionally or illegally, the creation of such habitats is not an appropriate form of mitigation. A wide range of factors must be evaluated to determine the appropriate restoration or water management strategy for any specific project or site. The solution must be one that renders the hydrologic condition more stable, and reduces runoff waters to a level that fosters ecosystem stability.

These findings, which are supported by many other studies, help to shape an understanding of the types of impacts and wetland degradation that are occurring in varying degrees to nearly all the remnant or created wetland systems throughout our region, particularly those that are most directly exposed to rural or urban stormwater runoff. Changes in surrounding land use and vegetative cover have altered the natural hydrology of our wetlands from habitats formed and sustained almost completely by groundwater discharge and direct precipitation, to wetland systems almost totally dominated by surface water hydrology.

As a result of these changes, increased runoff exposes surrounding wetland systems to periodic, repeated inundation. With accelerated erosion, surface water flows carry sediments that are then deposited within the wetland, altering the chemistry, nutrient cycling, root zone, germination conditions, and other critical growth factors. The combination of excess ponded water and sedimentation result in the obliteration of the more conservative native wetland species, those plants with strict physiological parameters that constitute complex systems. The high diversity of species that favor isothermic, groundwater-fed alkaline conditions and a very specific hydrological regime yield to a few weeds such as *Phalaris arundinacea* (reed canary grass), *Typha* spp. (cattails), *Phragmites australis* (common reed), *Lythrum salicaria* (purple loosestrife), and a handful of other species.

This default weed flora is tolerant of direct surface water inundation, rapid fluctuations in water levels, poor water quality, and sedimentation. The tremendous biodiversity, system stability, and biological function of our region's natural wetland habitats are lost.

VI. The "Outdoor Rug" Phenomenon

A trademark of nearly every cultural landscape across the country is the turf grass lawn. The aesthetic dictated by the lawn implies a landscape that requires regular watering, yet can never be wet, that must at once be short, yet lives on fertilizer. The landscape is essentially designed to divest itself of water and resources, the two input components it needs most. This is the legacy of a cultural attempt to create a water-loving landscape that cannot abide water.

To achieve this design, the topsoil is typically removed, the underlying clay is compacted and a thin layer of topsoil and sod is rolled out over it. Such sod commonly consists of Kentucky blue grass, *Poa pratensis*, which is not native to Kentucky or even the Americas. In the typical context, the root system is but a few inches deep, and the whole layer represents little more than a drug-dependent "rug" with an exaggerated floor pad. Because water cannot penetrate the clay floor and the shallow root system will die if it sits in water, the "floor" is tilted at no less than a 2% slope, often a requirement in local ordinances. More expensive or elaborate designs will include bumps or berms placed artistically throughout the landscape, and storm drains situated cleverly so that water drains quickly from the site, discharging into detention basins at all deliberate speed.

Current fashion makes it important to maintain the height of the Kentucky blue grass as low as is physiologically possible and still have something that looks like a green rug. This requires virtually constant mowing, lest grass blades here or there get taller than others. Mowing, of itself, might be relatively harmless if it did not use fossil fuel in unremediated internal combustion engines. For every gallon of gas burned, about 15 pounds of various oxides (mostly carbon dioxide, and other worse things), which the ecosystem of the earth has not seen since the Paleozoic (200 million years ago), are produced and given over to our atmosphere.

Since it is culturally important to grow Kentucky blue grass short, it must be fertilized regularly, which makes it grow fast, so that it must be mowed often. Inasmuch as no other living things are allowed in the lawn, the full aesthetic requires the application of as much broad-leaf herbicide and pesticide as the landscape maintenance budget will permit. When it rains, water quickly saturates the rug, inducing runoff that begins its course down the slope, carrying with it herbicides, extra fertilizer, and anything else added to the lawn.

To control the flow into local streams, engineers and designers of such landscapes have fashioned huge holes in the ground placed tactically to receive such waters and any toxicants, pollutants, or unused nutrients. There the water sits, its volume and any dissolved or suspended components to be metered into the nearest stream. Water from such landscapes throughout the watershed accumulates in massive storm surges, filling the rivers with filthy water, eventually passing it along the Mississippi River to the Gulf of Mexico.

This regular movement of huge volumes of dirty water into the estuarine regions of the Mississippi River delta is contributing to a catastrophic decline in the productivity of the spawning grounds of the Gulf of

Mexico. Meanwhile, having sent our rainwater downstream, we no longer have the water to recharge our landscapes. Since water continues to evaporate and transpire, our landscapes are soon dry and sear, often within hours of the last rain. The solution, inevitably, has been to install expensive irrigation networks to mine water from deep within the ground, a supply that is the largess of a landscape far away that still infiltrates and stores water in net amounts.

This contrived "living" rug phenomenon has lead to a curious infrastructural aesthetic: few other living things are acceptable on the rug. Only certain shrubs, planted in artistic groupings of 5s and 7s, and even-sized, lollipop-shaped trees planted in rows are allowed. Expensive plantings include huge clumps of mulch placed in small rings at the bases of the trees and shrubs. Trees growing in clay holes on bumps commonly do not live long, partly because the holes have either too much or too little water in them. In order to forestall the mortality of ill-fated trees planted out of place, a new industry has developed to provide underdrainage for the clay holes. The relevant point here is that such trees and shrubs are not really alive in the sense that they are members of a community and participate in the annual replication and stability of that community.

Other than mowing, fertilizing, and pesticiding, the only human involvement in such a landscape consists of workers who replace dead trees. Such landscapes are largely devoid of other living things as well, save, perhaps, gaggles of sedentary urban geese that have lost the capacity to migrate, . . . but not the capacity for other bodily functions.

Considering the sterility and lifelessness of our contemporary landscapes, one could get the impression that our culture regards the outdoors as little more than living rooms to be designed only with attention to the vagaries and vicissitudes of the design aesthetic of its day. The people of the culture no longer can see that there really is such a thing as an outdoors, or that it matters. Nevertheless, water remains a real thing, a noncompressible item that flows downhill. The more of it there is, the greater the volume; the greater the volume, the greater the potential flow energy. The greater the energy, the more resources it can carry with it. Water is one of the few resources that winds up on the top of the hill free, as a result of evaporation and condensation, rain, dew, or snow. Other resources, such as nutrients and soil, are less easily restored to the top of the hill. For them, the energy required is not sunlight energy, which mediates water restoration, but some other energy source, and, on the scale of the human lifetime, usually one that involves money and labor.

Water flowing downhill and carrying resources with it leaves the top of the hill bereft of resources, and render the bottom of the hill surfeited with them. The same force that brings water free to the top of the hill enforces evaporation potentials such that, in the Chicago area, about one million gallons of water are evaporated from each acre per year, which is approximately the amount that falls annually. The first principle of our contemporary culture seems to be: *get as much water out of sight as fast as possible.* Depending on local ordinances, the rate of disposal can vary, but all of it must leave. Just how the downstream neighbors handle it is *their* problem.

It is not sufficient, once the liabilities associated with the contemporary aesthetic are understood, simply to stop all the mowing, watering, fertilizing, and pesticiding, and “let nature take its course.” This contemporary landscape has nowhere near the stability or biodiversity to coalesce into a self-sustaining, self-replicating ecosystem. If current human involvement were simply to disappear, the landscape would not “succeed” into some pre-Columbian Eden. Rather, if the Kentucky blue grass went unmowed, a few other weeds like bull thistle and dandelion would flourish along with the grass for a few years, eventually giving way to weedy shrubs and trees, such as buckthorn, box elder, Amur honeysuckle, and black locust. Over time, the few ground cover weeds would be shaded out, soil would erode, and the roots of the trees and shrubs would become exposed and begin to topple. There would be few butterflies, birds, or anything else, other than perhaps some roving gangs of starlings feeding on box elder bugs. All the while, water, soil, and other resources will run downhill, polluting the rivers.

It should be noted that the authors are not opposed to the use of turf grass lawns. There are many useful applications for turf grass. We are opposed, however, to the contemporary mores that demand we default the entire outdoor landscape to turf grass, particularly when other landscape treatments are available that are far more ecologically and economically sensible.

What would be so wrong, so unattractive, so heretical to look out upon, indeed, walk within, a landscape inhabited by a profusion of native grasses and sedges, replete with comely perennials and colorful butterflies, infused with flowering shrubs, and dominated here and there by groves of trees--trees with futures? Would it be so radical to propose that trees be free to grow branches in whatever manner the habitat permits, and to grow broad, expansive root systems with a diversely populated rhizosphere rich in water and mycorrhizal fungi? Would we be so unable to countenance clean streams and rivers that flourish with fish and mussels and abound with birds?

VII. The Agricultural Dilemma

Water in nearby agricultural lands is disposed of just as foolishly. Prairie lands, with their deep roots and water holding root systems, once stored net amounts of fixed carbon each year in the creation of deep black soils. Very little water ran off the surface of the land. Most of the water either transpired through the living tissues of hundreds of different species of plants or seeped at a constant rate into the groundwater, only to discharge finally in fens and springs far from where it fell. The richness and fertility of Midwestern soils owes its properties to the hydrology of the grasslands, where subterranean reduction exceeded oxidation.

Weaver and Noll (1935) described the erosive effects of tillage on prairie soils.

> . . . on bared or sparsely vegetated slopes both run-off and erosion may occur after relatively light showers. It soon becomes clear that the most important factor tending to decrease erosion in non-tilled lands is the maintenance of a plant cover.
>
> The quantities of water lost during torrential rains even from small areas are impressive and naturally lead to calculations of the amounts running off from whole hillsides, the total amount of soil removed, the effects of this run-off in forming gullies and ditches, and of the sediment finally silting up the fertile lowlands. The water is lost to ground storage; the deepening of gullies and ditches lowers the water table, which results in a constant tendency of the water in the upper layers to sink to lower levels. The habitat is gradually changed. The hard, compact, poor absorbing surface left after severe erosion is always impressive. That the water holding capacity is reduced is not difficult to understand . . . erosion can be held largely accountable for disastrous floods, on the one hand, and drought on the other.

This is hardly a new phenomenon. Amos Sawyer (1874) noted that:

> During the last twenty years our climate [in Illinois] has been slowly but surely changing from wet to dry. . . . But the most important agent [of this change]--one that is yet to produce greater mischief--seems to have escaped [our] attention: it is the aqueous. The chemical and mechanical effects of this agency are constantly at work, and the result is plainly visible in the deepening of the channel of all our small streams. [It] is hard at work night and day, summer and winter, overcoming every obstacle placed by nature or man to impede its progress. The work marked out for it to do is no less than the complete drainage of the ponds and lakes of our prairies: and so surely as the world stands, so surely will the task be accomplished. . . . Every little streamlet has its miniature Niagara Falls: but, unlike their giant relation, they are making visible progress every year, and are consequently (strange as the language may seem) more instructive. The 'hard-pan,' which only yields after repeated blows from the sturdy laborer's pick, and grinds off its steel at the rate of two inches per day, crumbles and gives way under the combined agency of frost and water: the largest trees in the forest yield to the conquering element. . . . Every little streamlet is bringing its bed down to a level with its parent stream, and the merry rippling of their little cascades greets the ear on every side, and tells you in language not to be misunderstood that they will in time accomplish the work allotted them to perform--the thorough drainage of the land through which they pass.

Illinois's topsoil, once fertile beyond imagination, now chokes the last of life from the Illinois River. Demissie and Bhowmik (1987) note that the average depth of Lake Peoria in 1903 was 8.0 feet, but by 1985 it was no more than 2.6 feet deep. The huge fishery along the Illinois, which, in 1908, at its peak yielded 24 million pounds of fish, by 1964 yielded only 1.5 million pounds (Emge et al. 1974). The mussel-fishing industry, once huge, no longer exists. The reasons for this decline are many and complex, and Illinois biologists have been writing about the effects of man on the Illinois River for many years (Bellrose et al. 1979; Mills, Starrett and Bellrose 1966; Starrett 1972). For the first half of this century, the Peoria Lake filled at a rate of about 0.05 foot per year, which was too fast to sustain a diversity of life forms. From 1965 to 1975 it was filling at a rate of 0.1 foot per year, and from 1975 to 1985 the Lake Peoria section of the Illinois River was gagging on 0.12 foot per year.

The Heartland Water Resources Council estimates that by the year 2040, Lake Peoria will have vanished as a water body, leaving little more than a narrow and muddy navigation channel. Mike Platt, executive director of the council, sees a grim future, the lake having "turned into willow thickets and mudflats by 2016, swarming with mosquitoes, with only a narrow, muddy barge channel open for boating. Marinas will have become ghost towns. Waterfowl will have fled and fish will have declined. Property values will have plummeted. What will properties along the river be worth when (people) look out over willow thickets and mudflats?" (Peoria Journal Star, August 7, 1996).

Soil erosion and hydrologic alterations to the landscape associated with conventional tillage practices trigger other detrimental side effects. A recent SCS study (1990) concluded that, of the original average 18 inches of topsoil across the state of Iowa at the time of settlement, 10 have been lost to wind and water erosion, and that, of the remaining 8, half the tilth (related to soil organic carbon) is gone. When soil loses tilth, it loses its organic matter, and therefore its ability to absorb water. The corollary to lost water absorption is increased erosion, and therefore exaggerated divestment of erodible resources, which then accumulate in somebody else's back yard in amounts too great to be useful, if not actually destructive. The long-term consequences on both the local and broader economy are frightening.

As the water in the soil is drained away, the reduction/oxidation relationships change dramatically. Whereas once the prairies held their water, and carbon was fixed beneath the surface in net amounts, annual row crop tillage now causes carbon to be oxidized more rapidly than it is fixed, a situation exacerbated by the constant drain of water through the tile systems and into the ditches. Consequently, during each growing season, carbon dioxide that was fixed millenia ago is now released into the atmosphere in amounts greater than it is taken up, potentially contributing to the problem known as global warning. This net release of soil organic carbon (SOC) is not a minor concern. Recent studies on the amounts of carbon stored in the Conservation Reserve Program (CRP), in which deep-rooted native grasses are planted in some of the less productive or more erodible soils, have shown that nearly ten years of SOC storage can be oxidized within a single growing season after tilling. These amounts can be impressive, since land in CRP, over a broad geographic area, can gain an average of 0.5 tons of organic carbon/acre/year (Gebhart et al. 1994).

Water is even overlooked as a factor in the interpretation of natural areas. In a polemic on the management of remnant natural woodlands in Illinois, Wilhelm (1991) points to the hydrologic changes occurring deep within the shade of Midwestern woodland areas. Much of the change can be attributed to the cessation of annual fire, which was practiced by the native people for millennia before European settlement.

> Already . . . where shade has become the most extreme and herbaceous ground-layer the thinnest, the forest floor is open to sheet erosion. It is evident that the increasingly species-poor community of the [woods] no longer can hold water or soil. Recent and dramatic increases in the number, depth, and width of erosional ditches, though not yet quantified, are obvious to those who have been watching. It is yet to be determined just how much water is running off the slopes, but indirect evidence suggests that it is a significant percentage of the annual precipitation. . . Because summer and fall vegetation on the forest floor of the [woods] is sparse, much annual precipitation sheet-flows toward ever deeper erosional ditches and carries with it soil, native plant seeds, and diaspores. Tree buttresses are wholly exposed and some have been undercut by loss of soil. Many small maples are undercut and propped on their roots, 5 cm or so of soil having washed away since their germination 10-15 years ago. . . Although woody mesophytes are the prevailing species at this time, simple arithmetic tells us that no balanced system receiving a given amount of rain per year can continue indefinitely to evapotranspire the same amount and lose an additional amount to runoff. Indeed, as the water table lowers these mesophytes will be less and less able to draw upon the deep ground water accumulated in the presettlement [period]. Droughts and episodic rainfall events inevitably will begin to take their toll on a system that has become overstocked with phreatophytes [water-loving plants] and no longer has sufficient means for holding precipitation. The cumulative negative effects of such natural system collapses are now felt throughout the streams and rivers of the prairie province, ultimately to degrade and diminish estuaries of the Mississippi River delta region, spawning ground for many fishes of the Gulf of Mexico.

Hydrological impacts associated with shortsighted land management practices are not limited to the Midwest. Note the following citation:

> The trees are large and noble in aspect and stand widely apart except in the highest parts of the plateau where the spruces predominate. Instead of dense thickets where we are shut in by im-

> penetrable foliage, we can look far beyond and see the tree trunks vanishing away like an infinite colonnade. The ground is unobstructed and inviting. There is a constant succession of parks and glades--dreamy avenues of grass and flowers winding between sylvan walls, or spreading out in broad open meadows. From June until September there is a display of wildflowers which is quite beyond description. The valley sides and platforms above are resplendent with dense masses of scarlet, white, purple, and yellow. It is noteworthy that while the trees exhibit but few species the humbler plants present a very great number both of species and genera. . .

Dutton (1887) wrote this in his physical geology report on the Grand Canyon district in Arizona. Since then, overgrazing and fire suppression have so depleted the Colorado River watershed of its capacity to absorb water that the dramatic topography is able to conduct massive amounts of precipitation rapidly to this once beautiful canyon. The immense flow energies and scouring capacity of the water have rendered the canyon little more than a deep and wondrous landscape, bereft of the verdure described by Dutton. The uplands, once blessed with the deep root systems of bunch grasses and many flowers, are now heavily eroded and largely defaulted to compacted soils, shallow-rooted Asian brome grasses, and sage-brushes.

Consider the plight of the western valleys and bays. Currently, stands of pine, juniper, or oak, undisciplined by regular controlled burns, according to the custom of the native peoples, become ever more dense, and their leaves accumulate for years beneath them, unable to decompose as fast as they fall in the dry climate. The leaves shade away the ground cover vegetation, and therefore reduce the slopes' capacity to hold water. Finally, when the winds are high and the humidities are low, the inevitable uncontrolled fire starts, with catastrophic results. The heat produced is tremendous--many trees are killed, the ground is laid bare, and life and property are lost. When the rains come, waters flow freely over the erosive, exposed soils, and fill the streams with brown, scouring, roiling waters that immediately debauch into the bays, befouling them as well. Soaked slopes without a stabilizing root architecture slip away, carrying everything upon them, including houses and roads.

Imagine the coastal ranges and the Sierras of the western states, currently so bedeviled by catastrophic wildfires, mud slides, and water shortages, again replete with healthy pines, flower-rich slopes and chaparrals, and streams again filled with base flow waters. Today, people fear the fires and resent the mud slides, complain of water shortages, and decry the pollution of the bays, as if there were nothing that could be done about it. Attentiveness to the fire practices of the native people, the natural hydrology, and the local ecology could be incorporated generally into all manner of landscape designs to render a land rich in flowers, safe from uncontrolled fires, unsusceptible to mud slides, and nurturing to the major rivers and bays. As the awareness and correlative ethics of the people grew, so also would the health and safety of the land.

VIII. The Nature of Landscape Evolution

Impacts to historic biological systems, as a result of processes associated with European settlement, have occurred with a magnitude and rapidity without precedent in the history of the continent's biota. In plant communities, for example, there is a striking difference between areas inhabited by a full component of locally native species and those inhabited predominantly by weeds. The conservative systems contain native biodiversity that is suited to the processes, and they will exhibit long-term stability.

Weed communities, by comparison, are adapted either to catastrophic disturbance or the kinds of activities associated with traditional cultural landscapes. These weed communities contain neither the biodiversity nor the aggregate adaptive ability to coalesce into self-replicating, sustainable systems.

In our contemporary, fragmented landscapes, the conservative elements of our native systems, supplanted in place, have neither refuge, effective migration routes, nor the time to adapt or move. Rather, their populations are decimated time and time again until their local extirpation or ultimate extinction occurs. The destiny of many systems dominated by weeds is further destabilization, during which resources such as water, soil, and nutrients are often lost at rates faster than they are replaced. (Swink and Wilhelm 1994)

IX. Restoring a Cultural Relationship with the Land and Water

What do we mean when we say we want to restore the landscape, or restore the health of the earth? What is it that needs to be restored? How do we know when the land is healthy? Such questions can be hard to answer for a people who have become so distant and removed from the idea that their relationship with the earth is integral both to the long-term perpetuation of their culture and the renewability of the earth's living surface.

One way of approaching the answers to these questions in human societies, for example, is to regard a culture healthy so long as it continues to renew itself with each new generation of individuals and families. The health of a culture is dependent upon the behavior of the individuals within it.

Each individual is born with a unique combination of genes that the culture has never experienced before, and is born into a time and circumstance that has never been before or will be again. Individuals are reared in the ways of their people by the family within the culture, and draw strength and experience from the knowledge and wisdom of their elders.

With an eye toward tomorrow, these elders have tested the knowledge and wisdom of their forebears, made scarcely detectable modifications in response to their own experience with their people and their land, and passed it along to young ones. In this way, the health of the culture is assured, as the people, utterly respectful of the experience of the past, respond to the subtle vicissitudes of an ever changing earth, so that their culture might perpetuate itself and replicate the full potential of human experience with each passing year.

Take the metaphor of the Turtle Mother, as propagated by many of the native peoples of eastern North America. The elder tells the story, a care-worn hand touching the shoulder of the young one. "The earth is on the back of the turtle. So goes the turtle, goes to earth." The young one can see that if he befouls the waters wherein the turtle lives, so also he befouls his own world. If the turtle dies, so also the people die. The circle of life is broken, and the earth falls off the back of the turtle.

So it is with the ecosystems of the earth with which human cultures interact. The warp and weft of life and human culture on any remnant acre of the earth is unique to the earth. No other complex of genetic expressions has such an experience of the singular geological, historical, and climatic definition of a place, as do the organisms that have long residency in it. With each passing season there is a propagation of young with genes that are at once nearly identical to those of their parents, yet manifesting combinations of genes that have never been before. With the inborn "experience" of long-time residency in their habitat, the next generation is at the same time equipped to accommodate subtle shifts in climate and the gradual changes brought on by mountains and seas rising and falling.

This coevolution of life forms with the geological and meteorological transformations of the earth occurs at a time scale that is inextricably linked with the regular cycles of the earth around the sun, and the time periods necessary for individuals of populations both to transmit the experience of the place to subsequent generations and yet to allow small genetic changes to satisfy subtly new conditions.

Rates of change in human cultures and ecosystems are buffered against catastrophic collapse by an internal diversity that works to protect the whole against the development of exaggerated, untested individual behaviors or genetic malformations. Without such protections, rapid, system-wide changes can cripple the system's ability to renew itself and conserve its local knowledge of the place.

The health of an ecosystem or a culture degrades in accordance with the degree to which it destabilizes or simplifies itself, and there comes a time when there is not enough diversity within the system, with either enough memory of the past or enough potential for the future, to continue. The evolution of a system so compromised ceases.

Establishing a sustainable relationship with the living earth requires the reintroduction of a *capacity* for change. Water out of place is a primary agent in both cultural and ecological instability; therefore, our relationship with water is related to our ability to sustain a culture and the culture's ability to sustain the living fabric of the earth.

X. The Challenge to Ourselves

We believe that sustainability is an overarching principle for all land use. To support the hydrologic cycle, ecosystem stability, and other critical natural processes, it is necessary to consider local, regional, or even global issues on land use of all sizes. In contrast to a sustainable approach, much of our contemporary infrastructure and conventional planning methodologies are products of a contrived visual aesthetic with little understanding, relationship, or grounding in the unique realities of place.

Such methodologies represent a cultural indifference to the function of natural systems, or even the energy required to maintain this infrastructure, much less any long-term consequences. This is especially true with respect to the dynamics of water. Site planning and development, as a whole, must evaluate local natural systems and integrate their essential aspects into problem solving techniques, such that design is based on historical patterns of terrain, water, and climate.

A primary obstacle facing sustainable planning and design is that no one profession has the depth of training and skills necessary to do it alone. Sustainability requires a multi-disciplinary approach. Traditional academic degrees and professional training lead us to believe we have earned the competence to solve very specific types of problems. As David Orr (1995) points out: "The ideal of a broadly informed, renaissance mind has given way to the far smaller idea of the academic specialist."

To overcome this impediment, the challenge to planning and design professionals is to synthesize a broad spectrum of expertise. The leaders of future sustainable development must be able to facilitate a dialogue between environmental scientists, landscape architects, engineers, builders, planners, architects, local, state and national decision makers, and a public that expects quality of life to be supported by its environment. It is encouraging to see that the seeds of sustainable planning, design, and development are emerging from a variety of disciplines.

If we are to shift toward sustainability successfully, we must first address several basic shortcomings that are pervasive in the planning and design professions, including landscape architecture. Design professionals must learn to recognize the drawbacks associated with continued reliance on the standard default, an unwieldy combination of visual aesthetics.

"If it comes down to a decision between good design and the environment, I'll always opt for good design." Thus proclaimed a design practitioner in one of the professional design journals several years ago. This is a curious, disturbing statement, but unfortunately, it is a sentiment too commonly expressed among contemporary design professionals. How do the criteria for "good design" differ from those for "the environment"?

What is the controlling factor in aircraft design--performance and safety, or just aesthetics? Is not the performance of the land on which we live and depend just as important as the performance of a transportation vehicle? A safe, high-performance airplane is inherently attractive. So also would be a building and landscape well integrated into the *place*.

Sustainable design is more than artwork, and more than a painting or a piece of sculpture. It is the achievement of artistic goals within the parameters set by the chain of an unfolding past and future. Every form of development on the land, no matter how small, requires an understanding of the relationship between land use and its impact on water and other resources. The implications of this understanding must be disciplined by a cultural ethic that mandates a response that accommodates ecological and cultural stability.

Fellow humans have voices, and are subject to whims and temporal urges. They have faces and money. Too often it is easy to be seduced into believing that the exigencies of the day are paramount. Few people see the faces of plants and animals. Plants and animals have no money. Yet, attentiveness to the exigencies of their survival is profoundly informative in regard to the requisite relationship we must develop with the living earth.

Building a sustainable relationship with the living earth requires that our actions be grounded in environmental realities. In a culture-driven society, this requires an ethic. Since the beginning of the Holocene, and perhaps for much of the Quaternary, an important component in the shaping of the landscape has been mankind. Human beings are governed not only by random interactions within the ecosystem, but by choice. Fundamental interactions such as predation, competition, and foraging are complicated by the fact that humans can *decide* how to act, often with no immediate ecological parameter coming to bear on this decision, other than a human ethic. According to Leopold (1966),

> All ethics so far evolved rest upon a single premise: that the individual is a member of a community of individual parts. His instincts prompt him to compete for his place in the community, but his ethics prompt him also to cooperate. The land ethic simply enlarges the boundaries of the community to include soils, water, plants and animals, or collectively: the land. We can be ethical only in relation to

> something we can see, feel, understand, love and otherwise have faith in. A land ethic, then reflects the existence of an ecological conscience, and this in turn reflects a conviction of individual responsibility for the health of the land.

The design of environments where humans and other organisms interact, where actions create reactions, where the future is built on an understanding and appreciation of the past, requires that good design and the environment is synonymous. Regardless of scale, the design of sustainable environments means facilitating human purposes in concert with natural processes.

Once we understand the realities of place, there are infinite opportunities for creative expression; true design freedom is possible only within these limits. Since every place is unique, every design will require new creativity, innovation, and technology. A new aesthetic, encompassing every aspect of infrastructure, will emerge as we become more successful at designing whole systems. This requires a design process based on the interconnection of natural systems, and an increased understanding of the relationship between an individual site, the surrounding region, and beyond. The products of such design will be both visually interesting and sustainable if they integrate basic physical and behavioral factors into the solution. (Patchett and Wilhelm 1995)

As our awareness of the reality of sustainability expands, the attributes of environmentally grounded design will be simply and clearly expressed, without hindrance to a formal and purely aesthetic design paradigm. As Orr (1995) contends, "When human artifacts and systems are well designed, they are in harmony with the ecological patterns in which they are embedded. When poorly designed, they undermine those larger patterns, creating pollution, higher costs, and social stress."

In our opinion, if sustainability is to be achieved, it will require a collaboration of philosophy, science, ethics, and creativity. Water management is a key touchstone of sustainability. There is no other resource or form of energy, with the ability both to sustain or destroy, more powerful than water.

XI. Summary

We were dismayed, although not surprised, to hear the conclusions of a recent report presented to the president of the United States by a so-called "flood expert," proclaiming that floods are a natural phenomenon, and that nothing can be done about them; that we can only plan ahead to save lives. To the contrary, floods, as we know them today, are not a "natural" phenomenon. In presettlement landscapes in the Midwest, the only substantial form of flooding generally occurred during the spring snow melt, when grounds were still frozen and incapable of absorbing the meltwater. It tended to create expansive, placid, still-flowing pools, quite a different form of hydrology from the snow melt dynamic in today's urban, suburban, and rural landscape, the volumes and characteristics much altered by numerous hydrologic and hydraulic modifications in the land.

Until our people can comprehend that the devastating floods of 1993 in the Mississippi River valley were not caused by an unusual and excessive amount of rainfall, but rather, by an unusual and excessive amount of rain falling on a landscape sorely needing water, but stripped of its capacity to absorb it, both droughts and floods will continue to become more frequent and catastrophic.

A principal cause of many of our water problems is directly related to the self-deception built into land use policies of all kinds. Many policies consist of agendas that are characterized by unrelated values and narrowly focused priorities. For example, local stormwater management ordinances routinely focus on water quantity issues, because many voters live in flood-prone areas. Such ordinances reflect little understanding of water quality or the implications of how water is dispersed throughout the landscape, because few voters are aware of the ecology of water so long as it is not in their basement or inundating their roads.

Decisions made in such contexts may appear to be economically sound because they are supported in part by a series of federal, state, and local programs, but the long-term economic and ecological consequences of such actions are rarely recognized. A redirection in these programs that integrates sustainable economic and environmental objectives will give decision makers better choices and solutions.

Another barrier to sound policy is a lack of knowledge within the citizenry and their elected representatives regarding their environment and sustainable economic alternatives (DuPage County Environmental Commission 1993). No one factor will guide future sustainable land use and site development more than education. Making informed decisions is paramount to preserving the quality and quantity of the earth's resources.

A primary goal of sustainable design in building and site development should be, wherever possible, to retain water where it falls, treating the water as a resource, not discharging it as a waste product. This will require new design innovations throughout the urban and rural environment in the form of buildings that detain and use water, redesigned site drainage systems that replicate surrounding natural hydrological patterns, and the integration of landscape systems with agricultural crops that have specific water holding capabilities and are uniquely adapted to the region. Many of these ideas, in various forms, have already or are currently being introduced in a wide range of areas around the globe.

Since precipitation is universal, our relationship with water must be developed everywhere. Every form of land use, whether urban, suburban, rural, or otherwise, must be based upon a clear understanding of the relationships of water within the physical characteristics unique to each place. Whatever the context of human inhabitancy or nature's hydrology, the manor in which water is incorporated into the design, development, and management of the land should be such that water does not act as a depleter of resources. It is our proposition that a sustained economy and culture are most assured if priority is given to developing new paradigms that incorporate water into our lives in ways that sustain life and nurture our precious resources.

Today, we divest ourselves of natural resources and sterilize our imaginations in regard to creating economic growth, jobs, and prosperity. Envision, instead, a new economy, defined by the extent to which we reinvest in natural resources, as industrial, urban, residential, and agricultural North America is redesigned and rebuilt sustainably. Children who now are born into a world feeling that there is no hope for a sustained future can be enlisted into a cultural recovery program based on reality and a sense of tomorrow. Whatever their particular bent or special gift, their youthful energies, and natural openness toward tomorrow can be deployed within a new cultural ethic, one that engenders hope and a sense of self-worth–a world in which elders pass along *wisdom*, as well as knowledge.

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It's a Matter of Scale: Comments on the Paper "The Ecology and Culture of Water: New Directions for Urban Hydrological Infrastructure"

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International Joint Commission
Washington, DC [1]

"[Canada and the United States are] reshaping a continent, completing the job that nature had begun thousands of years ago…Man is conquering another of nature's challenges."

Walter Cronkite in film describing the construction of the St. Lawrence Seaway, ca 1957

"…the ecological view...shows the way, for man would be…its steward, enhancing the creative fit of man-environment, realizing man's design with nature."

Ian McHarg, *Design with Nature*, 1969

In their paper, "The Ecology and Culture of Water," James Patchett and Gerould Wilhelm deal with the contrast between what many see as a need to finish nature's work and what others identify as acts that destroy the natural environment. They offer us valuable philosophical insights into the manner in which society has chosen to deal with water in its hydrological context. They posit that " a sustained economy and culture are most assured if priority is given to developing new paradigms that incorporate water into our lives in ways that sustain life and nurture our precious resources." They further note that a "…primary goal of sustainable building and site design development should be wherever possible to retain water where it falls, treating water as a resource, not discharging it as a waste product."

I could not agree more and applaud their efforts to make their vision a reality in the urban landscape.

They then suggest that an urban landscape goal should be the capture of all water that falls to earth and then imply that this urban approach could be extrapolated to more mega-environments. It is in the application and extension of these theses that I begin to part company with the authors.

Before discussing my concern with some of their findings, let me note those conclusions and positions with which I agree, and they are the majority. They note:

- The complex interrelationship between surface water, ground water and wetlands and the value of wetlands to the urban ecosystem. Sound approaches to development require a clear understanding of these interrelationships. (USGS; Mitsch)

- That modern society has failed to adequately capture water where it falls, and that by not doing so it has turned water into a destabilizing force that takes with it many valuable resources. I would add that only a certain amount of the water can be captured and that some destabilization is natural.

- That the environment least capable of handling excess runoff is a saturated wetland habitat. In many respects, wetlands act like sponges and we all recognize that sponges can only hold so much water.

- Society is obsessed with getting as much water out of sight as a fast as possible. Much of today's landscape is designed to divest itself of all water that falls upon it. I was taken by their description of our modern communities and their 'drug dependent rugs.' You don't have to drive very far to see that this situation exists and is getting worse.

- Much of the water that runs off the land contains harmful products and results in stressful habitat conditions in wetlands and can cause their eventual demise.

- In agricultural areas, erosion robs the land of topsoil. What farmers would let someone drive on to their property and carry off topsoil in trucks? Yet, through poor farming practices, they create such theft.

They also offer us some wise counsel:

- The health of a society's culture is dependent on generational renewal and that we are losing our ability to properly renew. We of this generation are providing the wrong lessons to those who are coming after us.

- We need to operate within an interdisciplinary environment and that much of what we do in the academy in our apprentice years moves us in the opposite direction. Here I should stand to applaud for history is replete with examples of discipline-comfortable solutions to landscape issues that have satisfied the discipline but not the society. Their call for broad based interdisciplinary education is something I have strongly supported for some period of time. I don't believe we work together as well as we should. We are separated by disciplinary intolerance and prejudices learned during our academic experience. Engineers enjoy destroying the environment don't they? Ecologists must hug trees and are out of touch with reality. We must find ways for engineers, biologists, architects and builders to work together each and every day.
- The land ethic reflects the existence of an ecological conscience and individual responsibility.

Their descriptions of the present day urban environment and our approach to dealing with many of its water related problems are right on target.

When the authors attempt to upscale these urban findings and approaches to the regional and national scale and offer broad principles, I begin to get uncomfortable. As a matter of fact, this discomfort became most apparent when I read their summary comment that they were dismayed to hear that a so-called "flood expert," had proclaimed to the President that floods are natural events and that nothing can be done about them.

Since I am that so-called 'expert' I must take issue on three counts. First, I doubt if anyone proclaims anything to the President – he does the proclaiming. Second, I do believe that floods are natural events, and third, I did not say that nothing could be dome to reduce the magnitude and impacts of floods. As a matter of fact, I did note that while floods are natural events, the damages associated with then are largely human-induced. [2]

The authors leave the impression that, in an ideal world, all water falling to earth would be captured by the land and that with this capture, most of the problems of erosion would disappear and our rivers would run clear. In some locales, those conditions might prevail, but in most, the fundamental forces of nature operate in a different manner. In the world in which we live, the forces of aggradation – tectonic forces struggling mightily to build up the earth, spar with the forces of degradation - the constant interaction of water and soil. In his 1795 *Theory of the Earth*, James Hutton described erosion as a natural process that is constantly transferring material from the lands to the seas. This natural erosion is influenced by vegetation, the topography of the landscape and the intensity of the rainfall that brings the water to the earth. The steeper the slope, the less the infiltration. The heavier the rainfall, the more the erosion. Long before the human intervention, the Missouri was muddy and the delta of the Mississippi was being formed by sediments carried from the Appalachians and the Rockies. Even the Illinois River must carry its share of sediments (Bhowmik).

A system in which all water is captured by the ground is not the normal natural system. While streams are supported by groundwater flows, these groundwater elements generally do not constitute the majority of source water for streams. Direct surface water runoff plays many important roles in nature (USGS)

The authors comment that floodplains, as we know them today, are also not natural phenomena. Again I would argue that floodplains are the most natural of phenomena and we must learn to live with and respect the functions of floodplains. Today, through unwise human intervention, we have increased the frequency of inundation of floodplains and in many cases the magnitude of this inundation. While the approach suggested by the authors – capturing more waters where they fall - will assist in reducing the magnitude of inundation, it will not eliminate this inundation.

The authors jumped from their description of urban hydrology and micro-impacts and relationships to the conclusion that the devastating Flood of 1993 was not caused by unusual and excessive rainfall but by unusual and excessive amount of rainfall falling on a landscape sorely needing water but stripped of its capacity to absorb it. For their statements to be true, one would have to then assume that had the landscape been its natural form, such a flood would not have occurred. Studies conducted after the1993 Mississippi Flood have indicated that floodplain and upland wetlands do capture rainfall; however, during major rainfall events, they quickly fill and surface flow into streams and rivers begins (U.S. Interagency Floodplain Management Review Committee). For more frequent flood events, wetlands eliminate or greatly reduce flooding. For larger events, wetlands only shave the top off the peak of the flood stage. Nature tells us we will always have floodplains. Both paleo-history and the writings of early visitors to this country tell us of major flood events well prior to any significant anthropogenic influence on the landscape. DeSoto's expedition to the Mississippi in 1543 encountered a flood that filled the valley near Memphis, Tennessee for over 60 days.

We live in a world in which the human race must co-exist with nature. We must grow food. We must be housed. We must travel. And, we must provide the infrastructure that will permit these events to occur. Because most of us have observed our mistakes and recognized the logic of sustainable development, we have begun to change our relationship with nature. In the field I know best, floodplain management, the period since the 1993 Flood has seen a marked redirection of national focus in dealing with the floodplain. People are more aware that the floodplain must be shared with the river. Over 25,000 families have been relocated from the floodplain. Thousands of others have adjusted the landscape around their homes to allow for the passage of flood waters. People are turning to land restoration as a tool in reducing flood impacts (Galloway). Last month the Congress passed a bill authorizing the Corps of Engineers to place nonstructural flood projects on the same pedestal as structural ones. Levees generally are not the only solution. (I say 'generally' because there are situations in which, even today, the only correct solution might be structural.)

The authors have spoken well to the improvement of the micro-landscape and called for all of us to adopt their new paradigm. Were we all to move in that direction –perhaps with a few green rugs still in existence – the landscape generally would be a better place. However, we should not believe that applications of their new landscape designs are everywhere possible and always desirable.

As the authors suggest, it is the development of an ecological conscience that will lead us to proper stewardship of the resources with which we must live and work.

A land ethic then reflects the existence of an ecological conscience, and this in turn reflects a conviction of individual responsibility for the health of the land.

Aldo Leopold, *A Sand County Almanac*

Endnotes

1. The views in this paper are those of the author and do not necessarily reflect those of the International Joint Commission.

2. This is not a new concept. See House Document 465, 89th Congress, 2nd Session (1966).

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Using Integrated Dynamic Modeling to Scope Environmental Problems and Build Consensus

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Abstract

This paper assesses the changing role of dynamic modeling for understanding and managing complex ecological economic systems. It discusses new modeling tools for problem scoping and consensus building among a broad range of stakeholders, and describes case studies in which dynamic modeling has been used to collect and organize data, synthesize knowledge and build consensus about the management of complex ecological economic systems. The case studies range from natural ecosystems (Louisiana coastal wetlands and Fynbos ecosystems in South Africa) to linked ecological economic systems (Maryland's Patuxent River basin and the Gwynns Falls urban watershed in Baltimore). They illustrate uses of dynamic modeling to include stakeholders in all stages of consensus building, ranging from initial problem scoping to model development and testing. The resultant models were built using a three stage modeling process, which includes scoping, research, and management models.

Key Words
Dynamic Modeling, Scoping, Consensus Building, Environmental Management, Ecosystem Management, Policy Making, Graphical Programming Languages

I. Types and Uses of Models

In environmental systems, nonlinearities and spatial and temporal lags prevail. However, all too often these system features are moved to the sidelines of scientific investigations. As a consequence, the presence of nonlinearities and spatial and temporal lags significantly reduce the ability of these investigations to provide insights that are necessary to make proper decisions about the management of complex ecological-economic systems. New modeling approaches are required to effectively identify, collect and relate the information that is relevant for understanding those systems, to make consensus building an integral part of the modeling process, and to guide management decisions.

Model building is an essential prerequisite for comprehension and for choosing among alternative actions. Humans build mental models in virtually all decision situations, by abstracting from observations that are deemed irrelevant for understanding that situation and by relating the relevant parts with each other. Language itself is an expression of mental modeling and one could argue that without modeling there could be no rational thought at all. For many everyday decisions, mental models are sufficiently detailed and accurate to be reliably used. Our experiences with these models are passed on to others through verbal and written accounts that frequently generate a common group understanding of the workings of a system.

In building mental models, humans typically simplify systems in particular ways. We base most of our mental modeling on qualitative rather than quantitative relationships; we linearize the relationships among system components, disregard temporal and spatial lags, treat systems as isolated from their surroundings or limit our investigations to the system's equilibrium domain. When problems become more complex, and when quantitative relationships, nonlinearities, and time and space lags are important, we encounter limits to our ability to properly anticipate system change. In such cases, our mental models need to be supplemented.

Statistical approaches based on historical or cross-sectional data often are used to quantify the relationships among system components. To be able to deal with multiple feedbacks among system components and with spatial and temporal lags requires the availability of rich data sets and elaborate statistical models. Recent advances in statistical methods have significantly improved the ability to test for the goodness of fit of alternative model specifications, and have even attempted to test for causality in statistical models (Granger, 1969, 1993). Typically little attention is given to first principles in attempts to use statistical models to arrive at a better understanding of the cause-effect relationships that lead to system change. Model results are driven by data, the convenience of estimation techniques, and statistical criteria—none of which ensure that the fundamental drivers for system change are satisfactorily identified (Leontief 1982, Leamer 1983). By the same token, a statistical modeling exercise can only provide insight into the empirical relationships over a system's history or at a point in time, but are of limited use for analyses of a system's future development path under alternative management schemes (Allen 1988). In many cases, those alternative management schemes include decisions that have not been chosen in the past, and their effects are therefore not captured in the data of the system's history or present state.

Dynamic modeling is distinct from statistical modeling by building into the representation of a phenomenon those aspects of a system that we know actually exist—such as the physical laws of material and energy conservation that describe input-output relationships in industrial and biological processes (Hannon and Ruth 1994, 1997). Dynamic modeling therefore starts with an advantage over the purely statistical or empirical modeling schema. It does not rely on historic or cross-sectional data to reveal those relationships. This advantage also allows dynamic models to be used in a wider range of related applications than empirical models. Dynamic models are more transferable to new applications because the fundamental concepts on which they are built are present in many other systems.

Computers have come to play a large role in developing dynamic models for decision-making support in complex systems. Computer models can numerically solve for complex non-linear relationships among system components, and can deal with time and space lags and disequilibrium conditions.

It is inappropriate to think of models as anything but crude (yet in many cases absolutely essential) abstract representations of complex interrelationships among system components (Levins 1966, Robinson 1991, Ruth and Cleveland 1996). Their usefulness can be judged by their ability to help solve decision problems as the dynamics of the real system unfold (Ruth and Hannon 1997). The dynamic models presented in this paper are designed with that criterion in mind. They are interactive tools that reflect the processes that determine system change and respond to the choices made by a decision maker.

Models are essential for policy evaluation, but, unfortunately, they can also be misused since there is "...the tendency to use such models as a means of legitimizing rather than informing policy decisions. By cloaking a policy decision in the ostensibly neutral aura of scientific forecasting, policy-makers can deflect attention from the normative nature of that decision..." (Robinson 1993). The misguided quest for "objective" model building highlights the need to recognize, and more effectively deal with, the inherent subjectivity of the model development process. In this paper we wish to put computer modeling in its proper perspective: as an inherently "subjective" but absolutely essential tool useful in supplementing our existing mental modeling capabilities in order to make more informed decisions, both individually and in groups.

In the case of modeling ecological and economic systems, purposes can range from developing simple conceptual models, in order to provide a general understanding of system behavior, to detailed realistic applications aimed at evaluating specific policy proposals. It is inappropriate to judge this whole range of models by the same criteria. At minimum, the three criteria of *realism* (simulating system behavior in a qualitatively realistic way), *precision* (simulating behavior in a quantitatively precise way), and *generality* (representing a broad range of systems' behaviors with the same model) are necessary (Holling 1964, Levins 1966). No single model can maximize all three of these goals and the choice of which objectives to pursue depends on the fundamental purposes of the model.

In this paper we propose a three step process for developing computer models of a situation that begins with an initial scoping and consensus building stage aimed at producing very simplified, high generality models, and then moving to a more realistic research modeling stage, and only then coming to a high precision management model stage. We elaborate this process further on.

II. Using Models to Build Consensus

In order to effectively use models to support decisions it is not enough for groups of academic "experts" to build integrated dynamic computer models. What is required is a new role for modeling as a tool in building a broad consensus not only across academic disciplines, but also between science and policy (Yankelovich 1991, Weisbord 1992, Weisbord and Janoff 1995). More broadly, involving a wide range of parties interested in or affected by decisions on environmental investments and problems is key to achieving fairness and sustainability (Rawls 1971, 1987) and to developing policies that are actually implementable.

Integrated modeling of large systems, from watersheds to continental scale systems and ultimately to the global scale, requires input from a very broad range of people. We need to see the modeling process as one that involves not only the technical aspects, but also the sociological aspects involved with using the process to help build consensus about the way the system works and which management options are most effective. This consensus needs to extend both across the gulf separating the relevant academic disciplines and across the even broader gulf separating the science and policy communities, and the public. Appropriately designed and appropriately used integrated modeling exercises can help us bridge these gulfs.

The process of modeling can (and must) also serve this consensus building function. It can help to build mutual understanding, solicit input from a broad range of stakeholder groups, and maintain a substantive dialogue between members of these groups. Integrated modeling and consensus building are essential components in the process of adaptive management (Gunderson et al. 1995).

III. Modeling Tools for Scoping and Consensus Building

Various computer tools for scoping and consensus building have been developed for business management applications (Roberts 1978, Lyneis 1980, Westenholme 1990, 1994, Morecroft et al. 1991, Vennix and Gubbels 1994, Morecroft and van der Heijden 1994, 1994, Senge and Sterman 1994). In the past, emphasis was placed on the provision of computer hardware and software to support group communication (Kraemer and King 1988). More recent trends are to facilitate problem structuring methods and group decision support (Checkland 1989, Rosenhead 1989, Phillips 1990). The use of computers to structure problems and provide group decision support has been spurred by the recognition that in complex decision settings bounds on human rationality can create persistent judgmental biases and systematic errors (Simon 1956, 1979, Kahnemann and Tversky 1974, Kahnemann et al. 1982, Hogarth 1987). To identify relevant information sources, assess relationships among decisions, actions and results, and hence to facilitate learning requires that cause and effect be closely related in space and time. Dynamic modeling is one tool that helps us close spatial and temporal gaps between decisions, actions and results.

Dynamic modeling has increasingly become a part of executive debate and dialog to help avoid judgmental biases and systematic errors in business management decision making (Senge 1990, Morecroft 1994). It has also penetrated, albeit to a lesser extent, the assessment of environmental investments and problems (Ruth 1993). Both areas of application of dynamic modeling have significantly benefited from the use of graphical programming languages. One of the main strengths of these programming languages is to enable scientists and decision makers to focus and clarify the mental model they have of a particular phenomenon, to augment this model, elaborate it and then to do something they cannot otherwise do: to run the model and let it yield the inevitable dynamic consequences hidden in their assumptions and their understanding of a system. With their relative ease of use, these graphical programming languages offer powerful

tools for intellectual inquiry into the workings of complex ecological-economic systems (Hannon and Ruth 1994, 1997).

To model and better understand nonlinear dynamic systems requires that we describe the main system components and their interactions. System components can be described by a set of state variables—or stocks—such as the capital stock in an economy or the amount of sediment accumulated on a landscape. These state variables are influenced by controls—or flows, such as annual investment in new capital or seasonal sediment fluxes. The extent of the controls—the size of the flows—in turn may depend on the stocks themselves and other parameters of the system.

There are various graphical programming languages available that are specifically designed to facilitate modeling of nonlinear, dynamic systems. Among the most versatile of these languages is the graphical programming language STELLA (Costanza 1987, Richmond and Peterson 1994, Hannon and Ruth 1994). STELLA runs in the Macintosh and Windows environments. A STELLA dynamic systems model consists of three communicating layers that contain progressively more detailed information on the structure and functioning of the model (Figure 1). The high-level mapping and input-output layer provides tools to lay out the structure of the model and to enable non-modelers to easily grasp that structure, to interactively run the model and to view and interpret its results. The ease of use of the model at this aggregate level of detail thus enables individuals to become intellectually and emotionally involved with the model (Peterson 1994).

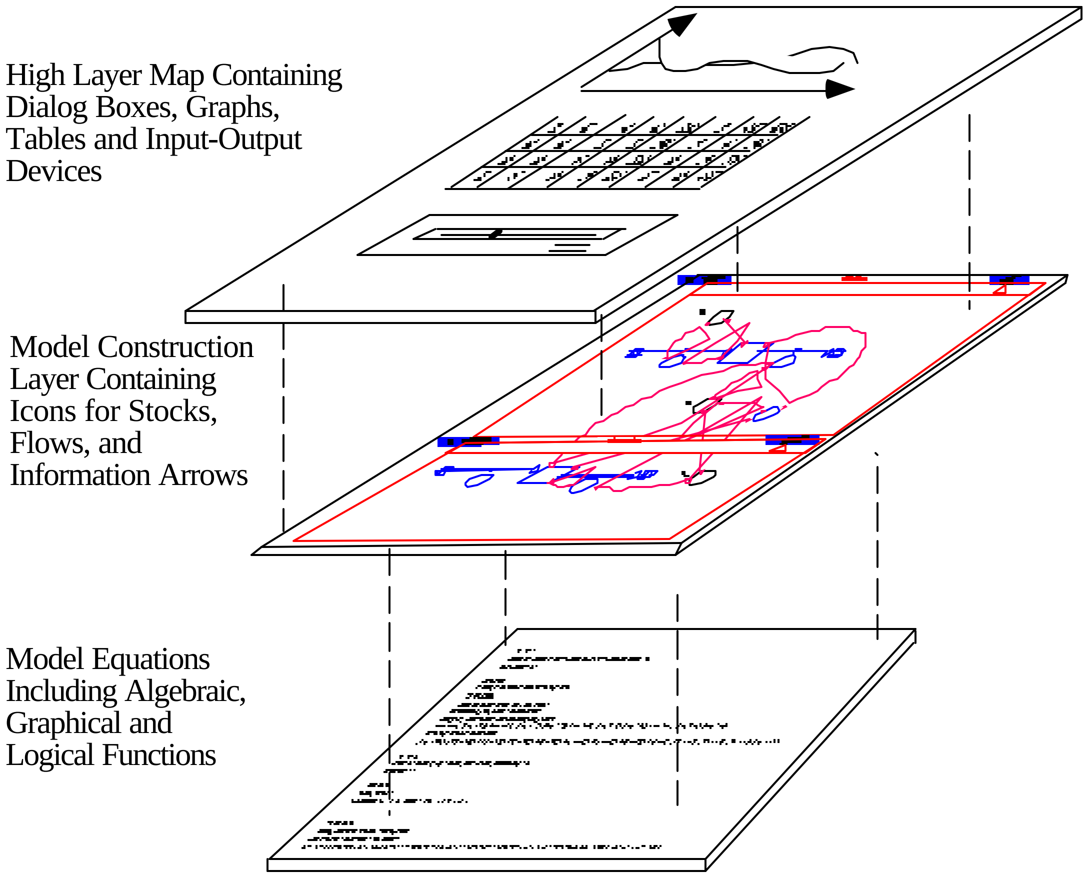
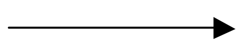


Figure 1. STELLA II Modeling Environment

Models are constructed in the next lower layer. Here, the symbols for stocks, flows and parameters are chosen and connected with each other. STELLA represents stocks, flows and parameters, respectively, with the following three symbols:

Icons can be selected and placed on the computer screen to define the main building blocks of the computer model. The structure of the model is established by connecting these symbols through "information arrows"



Once the structure of the model is laid out on the screen, initial conditions, parameter values and functional relationships can be specified by simply clicking on the respective icons. Dialog boxes appear that ask for the input of data or the specification of graphically or mathematically defined functions.

Equally easy is the generation of model output in tabular or graphical form through the choice of icons. With the use of sliders, a user can also immediately respond to the model output by choosing alternative parameter values as the model runs. Subsequent runs under alternative parameter settings and with different responses to model output can be plotted in the same graph or table to investigate the implications of alternative assumptions. Thus, the modeling approach is not only dynamic with respect to the behavior of the system itself but also with respect to the learning process that is initiated among decision makers as they observe the system's dynamics unfold. The process of learning by doing experiments on the computer rather than the real-world system gives model users the opportunity to investigate the implications of their assumptions for the system's dynamics and to assess their ability to make the "right" decision under alternative assumptions.

The lowest layer of the STELLA modeling environment contains a listing of the graphically or algebraically defined relationships among the system components together with initial conditions and parameter values. These equations are solved in STELLA with numerical techniques. The equations, initial conditions and parameter values can also be exported and compiled to conduct sophisticated statistical analyses and parameter tests (Oster 1996) and to run the model on various computing platforms (Costanza et al. 1990, Costanza and Maxwell 1993).

IV. A Three Step Modeling Process

To support decisions on environmental investments and problems, we advocate the use of a three step modeling process. The first stage is to develop a high generality, low resolution **scoping and consensus building** model involving broad representation of stakeholder groups affected by the problem. STELLA and similar software make it feasible to involve a group of relative modeling novices in the construction of relatively complex models, with a few people competent in modeling acting as facilitators. Using STELLA, and projecting the computer screen onto the wall or sharing a model via the Internet, the process of model construction can be transparent to a group of diverse stakeholders. Participants can follow the model construction process and contribute their knowledge to the process.

After the basic model structure is developed, the program requires more detailed decisions about the functional connections between variables. This process is also transparent to the group, using well-designed dialogue boxes, and the potential for graphic and algebraic input. The models that result from this process are designed to capture as much "realism" as possible and to answer preliminary questions about system dynamics, especially its main areas of sensitivity and uncertainty, and thus to guide the research agenda in the following modeling stage.

The second stage **research** models are more detailed and realistic attempts to replicate the dynamics of the particular system of interest. This stage involves collecting large amounts of historical data for calibration and testing and a detailed analysis of the areas of uncertainty in the model. It may involve traditional "experts" and is more concerned with analyzing the details of the historical development of a particular system with an eye toward developing specific scenarios or policy options in the next stage. It is still critical to maintain stakeholder involvement and interaction in this stage through the exchange of models and with regular workshops and meetings to discuss model progress and results.

While integrated models aimed at realism and precision are large, complex, and loaded with uncertainties of various kinds (Costanza et al. 1990, Groffman and Likens 1994, Bockstael et al. 1995), our abilities to understand, communicate, and deal with these uncertainties are rapidly improving. It is also important to remember that while increasing the resolution and complexity of models increases the amount we can say about a system, it also limits how accurately we can say it. Model predictability tends to fall with increasing resolution due to compounding uncertainties (Costanza and Maxwell 1993). What we are after are models that optimize their "effectiveness" (Costanza and Sklar 1985) by choosing an intermediate resolution where the product of predictability and resolution (effectiveness) is maximized. As a consequence, resolution of the research models is medium to high, depending on the results of the scoping model.

The third stage of **management** models is focused on producing scenarios and management options in this context of adaptive feedback and monitoring, and based on the earlier scoping and research models. It is also necessary to place the modeling process within the larger framework of adaptive management (Holling 1978) if management is to be effective. "Adaptive management" views regional development policy and management as "experiments," where interventions at several scales are made to achieve understanding and to identify and test policy options (Holling 1978, Walters 1986, Lee 1993, Gunderson et al. 1995). This means that models and policies based on them are not taken as the ultimate answers, but rather as guiding an adaptive experimentation process with the regional system. Emphasis is placed on monitoring and feedback to check and improve models, rather than using models to obfuscate and defend a policy which is not corresponding to reality. Continuing stakeholder involvement is essential in adaptive management.

Each of these stages in the modeling process has useful products, but the process is most beneficial and effective if followed in the order described. Too often we jump to the research or management stage of the process without first building adequate consensus about the nature of the problem and without involving the appropriate stakeholder groups. What we save on time and effort by jumping ahead is easily lost later on in attempts to forge agreement about results and generate compliance with the policies derived from the model.

V. Case Studies

In this section we briefly describe a set of case studies that embody some or all of the characteristics of the three stage modeling process outlined above. The purpose of this section is to illustrate the range of environmental issues to which scoping and consensus-building modeling can be applied, and to indicate the various degrees to which stakeholder involvement has been achieved in model development. Workshop meetings for scoping and consensus building were conducted in which a group of stakeholders convened to collectively develop models for scoping and consensus building purposes. Some of the models presented here have been followed up with more detailed research and management models.

A. Louisiana Coastal Wetlands

Applications of dynamic modeling to scoping and consensus building in industrial systems have concentrated on material and energy flows within these systems and between these systems and their environment. In contrast, the Louisiana coastal wetlands project traces the distribution of water and sediment through a landscapes.

The changing historical sequence of Mississippi River main distributaries have deposited sediments to form the current Mississippi deltaic plain marshes. This delta switching cycle lasts on average 1500 years and sets the historical context of this landscape. At present, the river is in the process of changing from the current channel to the much shorter Atchafalaya River. The US Army Corps of Engineers maintains a control structure at Old River to control the percentage of Mississippi River flow going down the Atchafalaya. Since about 1950 this percentage has been set at approximately 30%. Atchafalaya River borne sediment first filled in open water areas in the upper Atchafalaya basin, and more recently have begun to build a delta in Atchafalaya Bay (Roberts et al. 1980, Van Heerden and Roberts 1980a, 1980b). During the next few decades, a new delta is projected to form at the mouth of the river, and plant community succession will occur on the recently formed delta and in the existing marshes. At the same time, the overall Louisiana coastal zone is projected to have a net loss of approximately 100 km^2/yr due to sediment starvation and salt-water intrusion (Gagliano et al. 1981).

The leveeing of the Mississippi and Atchafalaya Rivers, along with the damming of distributaries, has virtually eliminated riverine sediment input to most Louisiana coastal marshes. This change has broken the deltaic cycle and greatly accelerated land loss. Only in the area of the Atchafalaya delta is sediment-laden water flowing into wetland areas and land gain occurring (Roberts et al. 1980, Van Heerden and Roberts 1980a, 1980b).

Primary human activities that potentially contribute to wetland loss are flood control, canals, spoil banks, land reclamation, fluids withdrawal, and highway construction. There is evidence that canals and levees are an important factor in wetland loss in coastal Louisiana, but there is much disagreement about the magnitude of the indirect loss caused by them (Craig et al 1979, Cleveland et al. 1981, Scaife et al. 1983, Deegan et al. 1984, Leibowitz 1989). Natural channels are generally not deep enough for the needs of oil recovery, navigation, pipelines, and drainage, so a vast network of canals has been built. In the Deltaic Plain of Louisiana, canals and their associated spoil banks of dredged material currently comprise 8% of the total marsh area compared to 2% in 1955. The construction of canals leads to direct loss of marsh by dredging and spoil deposition and indirect loss by changing hydrology, sedimentation, and productivity. Canals are thought to lead to more rapid salinity intrusion, causing the death of freshwater vegetation. Canal spoil banks also limit water exchange with wetlands, thereby decreasing deposition of suspended sediments.

Proposed human activities can have a dramatic impact on the distribution of water and sediments from the Atchafalaya River, and consequently on the development of the Atchafalaya landscape. For example, the Corps of Engineers was considering extending a levee along the east bank of the Atchafalaya that would restrict water and sediment flow into the Terrebonne marshes.

This situation represented both a unique opportunity to study landscape dynamics and a unique opportunity to build consensus about how the system works and how to manage it. The Atchafalaya landscape is changing rapidly enough to provide time-series observations that can be used to test basic hypotheses about how coastal landscapes develop. In addition to short-term observations, there is a uniquely long and detailed history of field and remotely sensed data available on the study area (Bahr et al. 1983, Costanza et al. 1983). Solutions to the land loss problem in Louisiana all have far-reaching implications. They depend on which combination of solutions is undertaken and when and where they are undertaken. Outside forces (such as rates of sea level rise) also influence the effectiveness of any proposed solution. In the past, suggested solutions have been evaluated independently of each other and in an *ad hoc* manner, and without adequate dialogue and consensus among affected parties.

In order to address this problem in a more comprehensive way, a project was started in 1986 to apply the three-stage modeling approach described above. The first stage of scoping and consensus building involved mainly representatives of the Corps of Engineers, the US Fish and Wildlife service, local landowners and environmentalists, and several disciplines within the academic community. This stage involved a series of workshops aimed at developing a "unit model", using STELLA, of the basic processes occurring at any point in the landscape, and at coming to agreement about how to model the entire landscape in the later stages. This stage took about a year.

In the second (research) stage an integrated spatial simulation modeling approach was developed (Costanza et al. 1988, Sklar et al. 1985, Sklar et al. 1989, Costanza et al. 1990) that replicated the unit model developed in stage 1 over the coastal landscape and added horizontal flows of water, nutrients, and sediments, along with successional algorithms to model changes in the distribution pattern of habitats on the landscape. Using this approach, the ability was demonstrated to simulate the past behavior of the system in a fairly realistic way (Costanza et al. 1990). This part of the process took about 3 years.

In the third (management) stage of the dynamic modeling process a range of projected future conditions was laid out as a function of various management alternatives and natural changes, both individually and in various combinations. The research and management model simulates both the dynamic and spatial behavior of the system, and it keeps track of several of the important landscape level variables in the system, such as ecosystem type, water level and flow, sediment levels and sedimentation, subsidence, salinity, primary production, nutrient levels, and elevation.

The research and management model was called the Coastal Ecological Landscape Spatial Simulation (CELSS) model. It consists of 2,479 1 km^2 spatial cells to simulate a rapidly changing section of the Louisiana coast and predict long term (50 to 100 year) spatially articulated changes in this landscape as a function of various management alternatives and natural and human-influenced climate variations.

The model was run on a CRAY supercomputer from initial conditions in 1956 through 1978 and 1983 (years for which additional data were available for calibration and validation) and on to the year 2033 with a maximum of weekly time steps. It accounted for 89.6% of the spatial variation in the 1978 calibration data and 79% of the variation in the 1983 verification data. Various future and past scenarios were analyzed with the model, including the future impacts of various Atchafalaya River levee extension proposals, freshwater diversion plans, marsh damage mitigation plans, future global sea level rise and the historical impacts of past human activities and past climate patterns.

The model results were used by the Corps of Engineers and the Fish and Wildlife service in making decisions about these management options. Because they were involved directly as participants in the process through all three stages, the model results were much easier to both communicate and implement. The participants also had a much more sophisticated understanding of the underlying assumptions, uncertainties, and limitations of the model, along with its strengths, and could use it effectively as a management tool.

B. South African Fynbos Ecosystems

A scoping and consensus building project was initiated in South Africa to address issues of water supply, exotic species invasion, and species diversity. The area of study is the Cape Floristic Region—

one of the world's smallest and, for its size, the richest floral kingdom. This tiny area, occupying a mere 90,000 km^2, supports 8,500 plant species of which 68% are endemic, 193 endemic genera and six endemic families (Bond and Goldblatt, 1984). Because of the many threats to this region's spectacular flora, it has earned the distinction of being the world's "hottest" hot-spot of biodiversity (Myers 1990).

The predominant vegetation in the Cape Floristic Region is fynbos, a hard-leafed and fire-prone shrubland that grows on the highly infertile soils associated with the ancient, quartzitic mountains (mountain fynbos) and the wind-blown sands of the coastal margin (lowland fynbos) (Cowling 1992). Owing to the prevalent climate of cool, wet winters and warm, dry summers, fynbos is superficially similar to California chaparral and other Mediterranean climate shrublands of the world (Hobbs et al. 1995). Fynbos landscapes are extremely rich in plant species (the Cape Peninsula has 2 554 species in 470 km^2) and narrow endemism ranks amongst the highest in the world (Cowling et al. 1992).

In order to adequately manage these ecosystems several questions had to be answered, including, what services do these species-rich fynbos ecosystems provide and what are their value to society? A two-week workshop was held at the University of Cape Town (UCT) with a group of faculty and students from different disciplines along with parks managers, business people, and environmentalists. The primary goal of the workshop was to produce a series of consensus-based research papers which critically assessed the practical and theoretical issues surrounding ecosystem valuation as well as assessing the value of services derived by local and regional communities from fynbos systems.

To achieve the goals, an 'atelier' approach was used to form multidisciplinary, multicultural teams, breaking down traditional hierarchical approach to problem-solving. Open space (Rao, 1994) techniques were used to identify critical questions and allow participants to form working groups to tackle those questions. Open space meetings are loosely organized affairs, which give all participants an opportunity to raise issues and participate in finding solutions.

The working groups of this workshop met several times during the first week of the course and almost continuously during the second week. The groups convened together periodically to hear updates of group projects and to offer feedback to other groups. Some group members floated to other groups at times to offer specific knowledge or technical advice.

Despite some initial misgivings on the part of the group, the loose structure of the course was remarkably successful, and by the end of the two weeks, seven working groups had worked feverishly to draft papers. One group focused on producing an initial scoping model of the fynbos. This modeling group produced perhaps the most developed and implementable product from the workshop: a general dynamic model integrating ecological and economic processes in fynbos ecosystems (Higgins et al. 1996). The model was developed in STELLA and designed to assess potential values of ecosystem services given ecosystem controls, management options, and feedbacks within and between the ecosystem and human sectors. The model helps to address questions about how the ecosystem services provided by the fynbos ecosystem at both a local and international scale are influenced by alien invasion and management strategies. The model comprises five interactive sub-models, namely hydrological, fire, plant, management and economic valuation. Parameter estimates for each sub-model were either derived from the published literature or established by workshop participants and consultants (they are described in detail in Higgins *et al.* 1996). The plant sub-model included both native and alien plants. Simulation provided a realistic description of alien plant invasions and their impacts on river flow and runoff.

This model drew in part on the findings of the other working groups, and incorporates a broad range of research by workshop participants. Benefits and costs of management scenarios are addressed by estimating values for harvested products, tourism, water yield and biodiversity. Costs include direct management costs and indirect costs. The model shows that the ecosystem services derived from the Western Cape mountains are far more valuable when vegetated by fynbos than by alien trees (a result consistent with other studies in North America and the Canary Islands). The difference in water production alone was sufficient to favor spending significant amounts of money to maintain fynbos in mountain catchments.

The model is designed to be user-friendly and interactive, allowing the user to set such features as area of alien clearing, fire management strategy, levels of wildflower harvesting, and park visitation rates. The model has proven to be a valuable tool in demonstrating to decision makers the benefits of investing now in tackling the alien plant problem, since delays have serious cost implications. A research and management modeling exercise may ultimately follow from this initial phase.

C. Patuxent River and Gwynns Falls Watersheds, Maryland

The case studies described above concentrated on the ecological impacts of human activities in a complex ecosystem. In contrast, the following case study includes both the ecological and economic aspects of the system endogenously.

The Maryland Patuxent River Watershed, which includes portions of Anne Arundel, Calvert, Charles, Howard, Montgomery, Prince George's, and St. Mary's counties, has been experiencing rapid urban development and changes in agricultural practices, resulting in adverse impacts on both terrestrial and aquatic ecosystems. Significant water quality deterioration had begun in the 1960's and concern peaked when the Patuxent estuary began to experience rapid degradation of water quality and disappearance of sea grass beds in the 1970's. Since then the Patuxent has been a focus of scientific study and political action in efforts to conserve environmental resources. It is also a model of the larger Chesapeake Bay watershed and serves as an example and test bed for many ideas about managing the entire Bay watershed (Costanza and Greer 1995).

As part of this effort a three stage modeling project was begun in 1992. This ongoing project is another outgrowth of the initial work with the CELSS model in Louisiana. It uses: (1) workshops involving the full range of scientific, government and citizen stakeholder groups to develop initial scoping models, to communicate results, and to refine and adapt the research agenda; and (2) integrating ongoing and new scientific studies over a range of scales from small microcosms to the Patuxent watershed as a whole. The project is aimed at developing integrated knowledge and new tools to enhance predictive understanding of watershed ecosystems (including processes and mechanisms that govern the interconnected dynamics of water, nutrients, toxins, and biotic components) and their linkage to human factors affecting water and watersheds. The goal is effective sustainable ecosystem management at the watershed scale. Major research questions include: (1) What are the quantitative, spatially explicit and dynamic linkages between land use and terrestrial and aquatic ecosystem structure and function; (2) What are the quantitative effects of various combinations of natural and anthropogenic stressors on watershed ecosystems and how do these effects change with scale; and (3) What are useful ways to measure changes in the total value of the landscape including both marketed and non-marketed (natural system) components, and how effective are alternative mitigation approaches, management strategies, and policy options toward increasing this value.

The overall model consists of interrelated ecological and economic submodels that employ a landscape perspective, for this perspective captures the spatial and temporal distributions of the services and functions of the natural system and human-related phenomena such as surrounding land-use patterns and population distributions (Bockstael et al. 1995). Configuration and reconfiguration of the landscape occurs as a result of ecological and economic factors, and these factors are closely intertwined.

The ecological part of the model is based on the Patuxent Landscape Model (PLM), one of a series of landscape-level spatial simulation models as discussed above (Costanza et al. 1995). The PLM is capable of simulating the succession of complex ecological systems using a landscape perspective. Economic submodels are being developed to reflect human behavior and economic influences. The effects of human intervention result directly from the conversion of land from one use to another (e.g., wetlands conversion, residential development, power plant siting) or from changes in the practices that take place within specific land uses (e.g., adoption of agricultural best management practices, intensification of congestion and automobile emissions, change in urban water and sewer use, and storm run-off).

Economic submodels will characterize land use and agricultural decisions, and capture the effects on these decisions of institutional influences such as environmental, zoning, transportation, and agricultural policies. The integration of the two models provides a framework for regulatory analysis in the context of risk assessment, non-point source pollution control, wetlands mitigation/restoration, etc. Figure 2 show the relationship of the various model components.

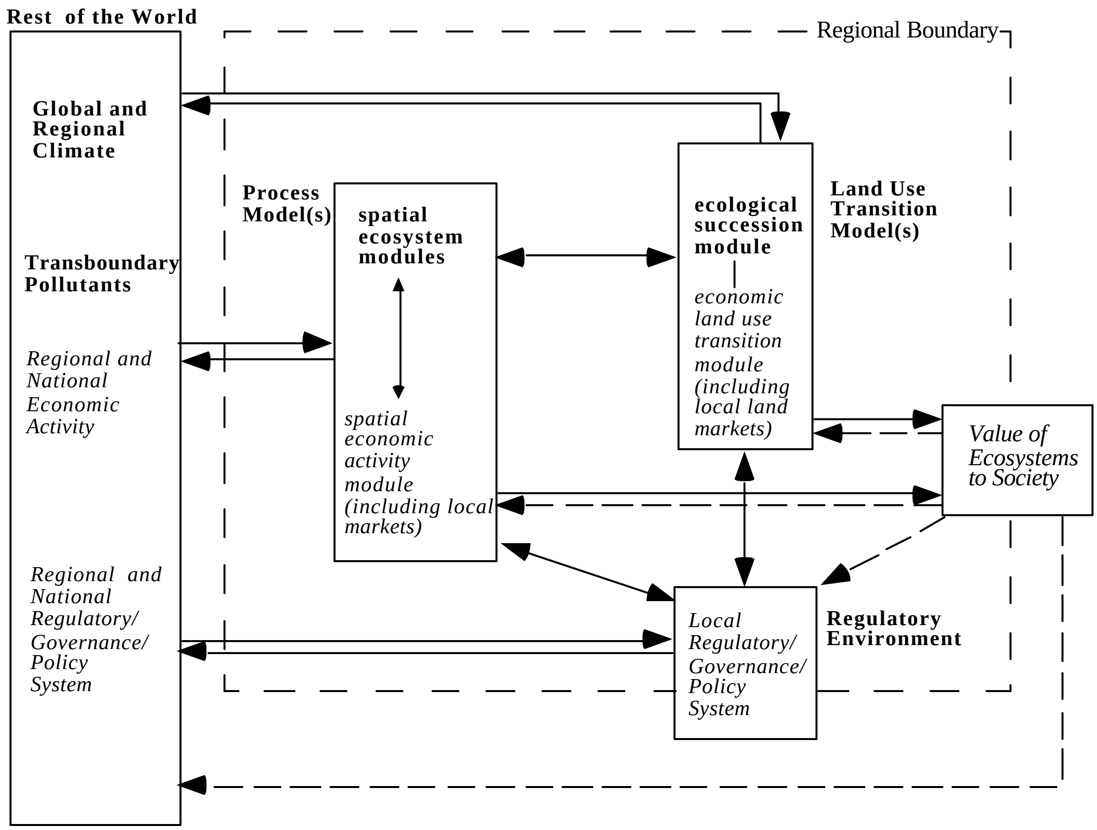


Figure 2. Integrated ecological economic modeling and valuation framework (from Bockstael et. al. 1995).

The integrated model will allow stakeholders to evaluate the indirect effects over long time horizons of current policy options. These effects are almost always ignored in partial analyses, although they may be very significant and may reverse many long-held assumptions and policy predictions. It will also allow us to directly address the functional value of ecosystem services by looking at the long term, spatial and dynamic linkages between ecosystems and economic systems. Some additional details about the structure and status of the PLM and a new application of the framework in the Gwynns Falls watershed in urban Baltimore are given below.

VI. Structure of the Patuxent Landscape Model (PLM)

The Patuxent Landscape Model (PLM) is designed to serve as a tool in a systematic analysis of the interactions among physical, biological and socioeconomic dynamics of the watershed. (For a complete description of the model and its current status, see our web site: http://kabir.cbl.umces.edu/PLM). In the ecological component of this spatially explicit model, the important processes that shape plant communities are simulated within the varying habitats distributed throughout the landscape. The principal dynamics within the model are: plant growth in response to available sunlight, temperature, nutrients, and water; flow of water plus dissolved nutrients in three dimensions; and succession in the plant community in response to the historical environment. Using a mass balance approach to incorporate process-based data of a reasonably high resolution within the entire watershed, changing spatial patterns and processes can be analyzed within the context of altered management strategies such as the use of Best Management Practices (BMPs). By incorporating high spatial, temporal, and complexity resolution, the model can realistically address large-scale management issues within the heterogeneous system of the Patuxent watershed.

For the PLM, the modeled landscape is partitioned into a spatial grid of nearly 2,500 square unit cells (Costanza, DeBellevue, et al., 1993). The model is hierarchical in structure, incorporating an ecosystem-level "unit" model that is replicated in each of the unit cells representing the landscape (Figure 2). The unit model (Fitz et al., 1996) itself is divided into a set of model sectors that simulate the important ecological dynamics at a daily time step.

The model includes sectors for hydrology, nutrient movement and cycling, terrestrial and estuarine primary productivity, and aggregated consumer dynamics. The hydrology sector of the unit model is a fundamental driving force, simulating water flow vertically within the cell. Phosphorus and nitrogen are cycled through plant uptake and organic matter decomposition, with the latter simulated in another sector that describes the sediment/soil dynamics. The sector for macrophytes includes processes such as growth response to various environmental constraints (including water and nutrient availability), changes in leaf canopy structure (influencing water transpiration), mortality, and other basic plant dynamics. As may be evident from the above linkages, feedbacks among the biological, chemical and physical model components are important structural attributes of the model. While the unit model simulates ecological processes within a unit cell, horizontal fluxes across the landscape occur within the domain of the broader spatial implementation of the unit model to form the PLM. Such fluxes are driven by cell-cell head differences of surface water and of ground water in saturated storage. Within this spatial context, the water fluxes between cells carry dissolved and suspended materials, determining water quality in the landscape.

The same generic unit model structure is run in each cell and there is a database of parameters that serves as input to the model to represent the different habitat types within the landscape. The vegetation communities in the cells respond to changing hydrologic and nutrient regimes via successional algorithms. Thus, when run within the spatial framework of the overall PLM, the landscape evolves to reflect changing hydrology, water quality, and material flows between adjacent cells.

The ecological model is linked to an economic model which predicts a spatial distribution of the probability of land use change within the seven counties of the Patuxent watershed (Bockstael, 1996). Human decisions to develop land are modeled as a function of both economic and ecological spatial variables. The land value (derived from tax assessment data) is used as the dependent variable in the first stage regression model and spatial variation in land prices is explained by an extensive array of features of the location: distance to employment centers, access to public infrastructure (roads, recreational facilities, shopping centers, sewer and water services), and proximity to desirable (e.g. waterfront) and undesirable (e.g. waste dumps) land uses to name a few. Also included are explanatory variables based on spatial pattern of land use that describe the land uses surrounding a parcel. A second stage model predicts the probabilities of land conversion based on the land values in residential land use generated by the first stage model and the costs of conversion. The model generates the relative likelihood of conversion of cells and when used in combination with information about growth pressures, allows maps of predicted new residential development to be developed.

The linked model allows the effects of both direct land use change through human actions and indirect effects through ecological change to be evaluated. Preliminary models of land prices and land use conversion explain the factors that have the most effect on land values in different uses and therefore the factors that affect pressures for land conversion. The physical location of the parcel as well as the spatial pattern of regulations affect the value of a parcel in different uses and therefore the likelihood that a parcel will be developed or kept in a natural state or used in agriculture. The following factors have been investigated for affects on land use pattern: Transportation network (Bell 1997); Public utilities provision (Bell and Bockstael 1997); Competing county zoning and agricultural preservation (Bockstael and Bell 1997).

VII. PLM Status

The unit ecological model has undergone rigorous testing using newly-developed calibration software, which calculates a comprehensive Model Performance Index (MPI). The index integrates an array of variable-specific tests into a single score, which expresses the overall fit with data and hypotheses (Figure 2). Each test considers a different aspect of the model's output, e.g. fit to data, known patterns of autocorrelation, meaningful boundary values, or steady states. For example, calibration data used in the analysis included 10-day maxima of the Normalized Difference Vegetation Index (NDVI), which were supplemented with data on stand characteristics from the Forest Inventory Analysis (FIA) database. The MPI structure is inspired by multi-criteria decision analysis as well as statistical estimation theory and is defined as a weighted average of variables' partial scores, each weighted according to the importance of the variable for the model's goals or to the quality of the reference data. MPI values range from 0 to 1, with 1 indicating maximum agreement between the model output and calibration criteria.

An adaptive directed search algorithm was developed to automatically search the parameter space for points yielding the highest MPI values. The combination of the automated search cycles and the formal analysis of the results has allowed us to identify satisfactory parameter combinations which would have otherwise been impossible to find. The unit model was calibrated for two years at a daily timestep and MPI values have reached 0.53 in experiments to date (Figure 3). Documentation on the MPI is available on the Internet at the URL http://kabir.cbl.umces.edu/~villa/svp/svp.html.

Unit model calibrations were carried out to test the general model performance for typical forest and agricultural land uses of the Patuxent watershed. Within the macrophyte sector, calculated forest and crop biomass remained within acceptable bounds established from literature, field data, and EPIC model output. The model captures important seasonal dynamics in plant growth. Data from the Patuxent watershed sites provided boundary conditions for biomass, but data on seasonal dynamics to track forest nutrients and primary productivity were not readily available. Data from Coweeta LTER proved useful for comparing general dynamics. Data being developed from satellite imagery (e.g. NDVI) have been used both for calibrating NPP and standing crop biomass in the unit model and the spatial model.

Calibration of the spatial hydrology model at several spatial and complexity scales has improved model robustness and overall performance. The hydrology portion of the landscape model, which serves as the major vector for movement across the landscape, has been calibrated at several spatial extents and the full ecosystem model has been implemented and tested for general conformity to expected variable ranges for the entire Patuxent subwatershed. The hydrology model shows good agreement with measured streamflow data for an initial 2-year testing period in 1980-82. Fig. 4. shows a portion of this comparison. Several nested subwatersheds were used to test model behavior at a range of spatial extents (from 58,905 to 566 cells and resolutions (200x200 m and 1x1 km). The model performs well in describing overall surface and ground water flow at all spatial extents with model predictions generally falling within 10% of daily values, although some large flood peaks deviate to a larger extent. We have run several scenario analyses to investigate the effects of land use changes and other perturbations on various hydrologic variables (Fig.5). (For further details of the model structure and calibration, see: http://kabir.cbl.umces.edu/PLM).

The full ecosystem model is running spatially and displays expected orders of magnitude in ecosystem stock variables, and appropriate seasonal dynamics in plant growth and nutrient cycling. Spatial calibration data include: annual increment to forest biomass (using species-specific tree ring records and spatial distributions in the Patuxent watershed), seasonal and longitudinal dynamic records for phosphorus and nitrogen concentrations in the river, and 10-day maximum NDVI data at the 1 km^2 spatial resolution derived from AVHRR satellite images.

VIII. GFLM Status

The Gwynns Falls Landscape Model (GFLM) is an application and extension of the PLM to a largely urban watershed in Baltimore, as part of the Baltimore LTER project (http://baltimore.umbc.edu/lter/). This will involve both the collection of the relevant data base for the new watershed, and expansion of the "human" component of the model. During year 1 of the LTER project (1998), we have been working with other project participants to apply the basic framework of the PLM model to the Gwynns Falls watershed. This includes discussions about basic data requirements and sampling strategies, and assembly of the relevant existing data bases (see the PLM web site for a more complete description of the model and its data requirements: http://kabir.cbl.umces.edu/PLM/). By the end of year one (1998) we should have assembled most of the data sets necessary to run the PLM model for the Gwynns Falls site. We will also add a human dynamics component to the GEM unit model, including human populations, built infrastructure, and institutions. This will allow the GEM model to represent the full range of habitats, from “natural” ecosystems with little human influence, to “agroecosystems” with intermediate levels of human influence, to “urban ecosystems” with high levels of human influence. By the end of 1998, we expect to have a running model with preliminary calibrations to several sites within the study area.

IX. Conclusions

The complexities that surround environmental problems require that nonlinearities and spatial and temporal lags be adequately reflected in the models used for decision support. Dynamic modeling is designed to address these system features. Dynamic modeling can also be used to scope environmental problems and build consensus and it has been used in this way in a number of case studies.

In the case studies described above, the three stage modeling process enabled us to provide a set of detailed conclusions regarding the management of the respective system. These conclusions were built on models that embodied the input and expert judgment of a broad range of stakeholders. The modeling process also offered unique insight into our ability to anticipate a system’s dynamics in the light of nonlinearities, and spatial and temporal lags. Our ability to anticipate those dynamics on the basis of available data and knowledge, and to develop consensus about those dynamics, is an essential prerequisite for the successful management of complex ecological-economic systems. We anticipate that future modeling efforts will increasingly make use of the software tools and the three-step modeling process with stakeholder involvement described in this paper.

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Discussant Comments for

"Using Integrated Dynamic Modeling to Scope Environmental Problems and Build Consensus," by Robert Costanza, 9/6/99

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This paper presents a thoughtful discussion of the roles of science, research, and stakeholders in the management of environmental systems. A "three step" modeling process is advocated in which the first step engages stakeholders in the formulation and initial modeling of the environmental system, aimed largely at building consensus; the second step focuses on developing more detailed dynamic models that are calibrated with historical data; and the third step is focused on producing policy scenarios that predict the system dynamics under alternative management regimes. The second part of the paper presents several case studies in which one or more of these three modeling steps were used to guide the research process.

From a philosophical perspective, the paper is appealing since it challenges the more conventional approach to research and urges that research and model building seek involvement from stakeholders and policymakers from the outset. Although somewhat vague about exactly how stakeholders should contribute to an understanding of a system's dynamics, the paper presents important and useful ideas about how to develop optimal policy models to guide ecosystem management.

From a modeling perspective, the author does a good job in making some important points about the nature of integrated economic-ecologic models, but the paper is less satisfying in the clarity and details given to discussing these models. In formulating my comments about the paper's specifics in this regard, I focus mainly on questions relating to the integrated modeling, with an emphasis on the economic component of these models. I recognize that this paper was written more from the perspective of developing ecological models and offer these comments in the spirit of how the paper could be broadened to include a fuller discussion of economic models and integrated modeling.

An important goal of integrated economic-ecologic modeling is to understand the choices that humans make that impact the environment, how these actions alter ecosystem functioning, and how subsequent ecological changes impact human welfare and ecosystem health. As is pointed out in the paper, to do so requires a spatially explicit modeling approach in which the linkages between human actions and ecosystem changes can be evaluated at a sufficiently fine level of spatial disaggregation. In discussing the various case studies, the author provides some explanation of the spatially explicit landscape models that are used to model the ecological processes both within and across cells. However, the paper lacks a full discussion of spatially explicit economic models and of the challenges involved in "linking" outputs from economic and ecological models.

The question of how economic and ecological models trade outputs is not a trivial issue. For example, the relevant temporal and spatial scales of ecosystems and economic systems (i.e. markets) are very different. Ecologists tend to employ high-resolution time models (e.g. with hourly or daily time steps), but are also interested in very long time horizons. This is largely because they are primarily concerned with the cumulative effects of human actions on ecosystem change, which may require tens or hundreds of years to fully manifest themselves. Alternatively, economists typically concern themselves with lower time resolution models (e.g. annual or quarter time steps), but are loathe to predict changes in economic systems over the very long run. They believe that future perturbations that are relevant to economic systems (e.g. changes in technology) are essentially impossible to predict. Reconciling these two different temporal scales is not straightforward.

Other modeling challenges include the fact that ecological models are naturally defined by ecosystem boundaries (e.g. watershed boundaries), whereas economists rely on the extent of the economic market to define the geographic boundary of their models. Another issue concerns the choice of state variables – the variables that are important for one model may not be relevant or useful in the other. For example, ecologists may treat all developed land as one category – e.g. urban. But for economists, the distinction between whether the land is in a residential, commercial, or industrial use is paramount to explaining human behavior. In discussing "linked" models, the paper fails to explicitly address issues such as these.

A second limitation of the paper is the lack of discussion and detail devoted to the economic modeling of landscape change. References are made to models of the "human component," but the paper lacks much specific detail. The only detail that is provided is a brief summary of some of the work by Bockstael and others in modeling land use conversion, but this is a limited account. The limitations of the paper in this regard are understandable, however, since the development of spatially explicit economic models of land use change is a relatively new endeavor in economics.

Traditional economic models of land use conversion offer descriptions of the spatial pattern that depend on equilibrium conditions, even though the spatial process of land use change may often be better characterized as one that is fundamentally out of equilibrium. In addition, traditional models have ignored the types of spatial heterogeneity in the landscape that are central to the science questions. As such, the traditional approach is largely inapplicable to analyzing the spatially disaggregate consequences of the types of policies and environmental management strategies that are of interest in economic-ecologic modeling.

Economists have begun to develop spatially explicit and disaggregate models of land use conversion in which the transition probabilities associated with a parcel of land are estimated using discrete choice models based on behavioral models of agents' land use decisions. In addition to the Bockstael (1996) work referenced by the paper, Landis (1995) and Landis and Zhang (1997) have developed an urban simulation model (called the California Urban Futures Model) for the San Francisco Bay and Sacramento areas. Both public land use policies and private development decisions are incorporated into the model. Landis and Zhang use econometric models to predict future household and employment projections by jurisdictions and a multinomial logit model to estimate the probability of land use change as a function of a variety of site and community characteristics. The resulting parameters are used to calculate land use transition probabilities for all cells that are "developable" and development is then allocated based on the highest probabilities or "bids" for development.

Irwin and Bockstael (1999) have used a similar approach to studying the spatial and temporal dynamics of land use change. A model of the individual agent's land use conversion decision is developed in which the conversion decision is treated as a function of both exogenous landscape features (e.g. roads, public services) and a temporally lagged spillover effect generated by neighboring development. Because the spillover effect is generated from neighboring agents' land use decisions, this introduces an endogenous component into the evolution of land use pattern. Econometric results identify the spillover as a negative effect, suggesting that congestion externalities among neighboring residential areas contribute to a scattered pattern of development. A spatial simulation model using the estimated parameters demonstrates that this model predicts the evolution of a pattern that is qualitatively similar to the scattered development observed in recent residential development.

Some evidence of the impact of ecological changes on economic systems has been provided in the literature. For example, Brucaro, Murdoch, and Thayer (1990) estimate the economic benefits of improvements in air quality by measuring both the improvements to health and aesthetic effects and the change in housing prices generated by a reduction in air pollution. Bockstael and Leggett (1999) use hedonic techniques to show that water quality has a significant effect on property values along the Chesapeake Bay and use these results to calculate the potential benefits from a water quality improvement.

Despite these advances, much work remains, particularly in terms of integrating economic models with ecological models. A central question is whether fully integrated models should be developed, in which a simultaneous model of the economic and ecologic systems are built, or whether the economic and ecologic models can be built somewhat separately. In the later case, it is necessary that each model recognize the spatial and temporal scale and the state variables used in the other model so that the two models can be linked interactively. A fuller discussion of these issues would improve the paper.

Finally, while the paper discusses the importance of evaluating the benefits and costs of alternative landscapes that result under different policy scenarios, there is no discussion of how the non-market benefits of the various ecosystem configurations can be evaluated. The author suggests at one point that the relevant parameters can be pulled from the exiting literature, which is an invalid approach from an economics perspective. While this may be appropriate for parameters from a model of a physical process, it is inappropriate for an economic model of valuation, in which the parameter estimates are functions of individuals' income levels and local and regional markets. The question of how to value changes in ecosystems is a complex one. Evaluating the costs and benefits of various landscape configurations is certainly a desirable goal, but not as straightforward as is suggested in this paper.

As an aside note, I found the paper to be somewhat sloppily written. For example, there are several references to figures that aren't included. In addition, outdated language is used in some places, e.g. preliminary results from the Gwynn Falls landscape model are said to be expected by the end of 1998.

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The Economics of Preserving Environmentally and Ecologically Valuable Lands

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Abstract

Preservation of environmentally and ecologically valuable lands is attracting fresh attention amid growing concerns with urban sprawl. I outline an economic perspective for understanding the issues, conflicts, private and social costs and valuation mechanisms involved in preserving land. The economics of preservation is addressed from the point of view of a society, which respects private property rights. The role of private property ownership and how it comes into conflict with public claims is the starting point of the discussion and provides a basis for the proposed preservation strategy. In a market-based economy, preservation would succeed and be most defensible, if preservationists can properly value and buy the lands that they wish to preserve. I discuss some of the fundamental difficulties and complexities associated with this approach and how they can be circumvented. I close with a brief discussion of strategies on both sides of the debate: government policies such as growth boundaries under which land is taken without compensation, versus more recent policies focused on buying the land to preserve it. Next, I discuss zoning and development taxes as alternatives to fee simple ownership of land targeted for preservation. Respect for private property requires that unanticipated losses in land value that result from zoning, development taxes and from infrastructure provision should be compensated by taxing the gains that are reaped by others. The planning and management of metropolitan water resource systems is a case in point where public actions have spatially complex effects on the entire metropolitan economy. Design of policy in this context would benefit from the development of economic-ecological models capable of calculating the consequences of water resources policy actions.

Key words
Land economics, land preservation, environmental protection

1. Introduction

Although this paper is presented at a conference on water resources, the focus of the paper is much more general. I am not an expert on water resources. As an urban economist, I am interested in how land markets function efficiently and in the consequences of public policy on land market efficiency and on the distribution of resources. In section eight, I explain how the development of metropolitan economic-ecological models would allow application of the principles discussed in this paper to metropolitan water resources planning.

The perspective of efficiently functioning land markets should play a central role in how we, as a society, formulate policies which bear on environmental preservation. More than ten years ago I authored two papers in which I attempted to introduce this perspective into environmental economics by bridging it with land economics.[1] I now take a fresh look at the problem of environmental preservation of land within the context of efficiently functioning land markets. The same principles apply whether the reasons for preservation are hydrological resources lying on the surface (such as wetlands), underground or adjacent to the land, or the survival of plant and animal populations (bio-diversity), or the conservation of a unique aquatic natural amenity.

I approach the problem by introducing the concept of property rights. We live in a society in which privately held property rights are of central importance. I argue that policies for the preservation of land should respect the fundamental principle of private ownership. I attempt to delineate the extent to which this principle can be respected, where we run into difficulties in implementation and how we can circumvent these difficulties.

The most proactive strategy for preservation uses the market itself as the arena for insuring preservation. *Buying land to preserve it* is the most defensible strategy. [2] This entails the related questions of *"how much to buy and where?" "who should pay?"* and *"how much to pay?"* and *"how to buy it?"* These are questions that require complex responses. But these are not as complex or as unpleasant as the consequences of alternative strategies rejecting or opposing market-based approaches. There is room for innovation and institutional change to realize the promise of market-based solutions to the problem of preservation. At the same time there are serious difficulties which ultimately call for the involvement of the public sector albeit in ways which are much more amenable to economic efficiency than currently existing legislation allows.

2. Private property rights and public claims

It is sometimes best to illustrate a point by reciting anecdotal evidence. I will borrow from the June 1999 issue of *Reason* in which the author (DeLong, 1999) refers to an April 1,1999 article which appeared in the Washington Post [3] It is an excellent example of the clash between private rights to property and public claims on that property. The article refers to a 79-year old retired contractor, John Taylor. His 74 year old wife is confined to a wheelchair. Taylor wants to relocate his family from their multistory house to a single story home he plans to build on an adjacent lot he owns. But because a bald eagle has built a nest on nearby land, the U.S. Fish & Wildlife Service, acting under the Endangered Species Act, has declared a 750-foot no-build buffer zone around the nest, even though ten houses already exist within that zone. The service is willing to let Mr. Taylor build the new home if he pays $3,500 to a fish restoration program in the Potomac River designed at increasing the food supply for eagles. According to the article, Mr. Taylor's response is: *"I'm not going to bribe my government to let me build on my own land."*

In this case, society has not clearly recognized Mr. Taylor's private right to his property. On the one hand, under normal circumstances, his right to build on his lot is undisputed. On the other hand, such right ceases to exist the moment that a bald eagle chooses to build a nest nearby. In that case, the *de facto* "owner" of the vacant lot becomes society. Mr. Taylor is recognized to have merely a conditional right: he must buy back his right to use the land by paying $ 3,500.

It is incredible that such an absurdly complicated solution has been worked out to what in essence is a simple problem. I am not an ornithologist and have no expertise on the nesting patterns of bald eagles. But I am willing to bet that, in this particular instance, the welfare of the bald eagle can be vastly improved by relocating the nest to surroundings far superior to those of urban Washington, D.C. We as a society should have an interest in the preservation of bald eagle habitats. We should all derive some satisfaction from knowing that their extinction is prevented or forestalled. But the extra satisfaction we would derive from knowing that a bald eagle and his family are coping to make it in urban Washington, D.C. rather than in a location far better suited to their species is surely negative not positive. There is also, I would presume, not an iota of evidence that increasing the number of houses within 750 feet of the nest by one, from ten to eleven, in any way degrades the welfare of the bald eagle.

Apparently, the Endangered Species Act makes no provision for the welfare of the Taylors: they would benefit substantially from their new home, probably to the tune of thousands of dollars. They are prevented from enjoying these benefits, even at the social benefit of simultaneously improving the welfare of the bald eagle and they are asked to pay to get the chance to reclaim those benefits. Clearly, if Mr. Taylor has the right to his property (that is if he has an unconditional right) it is society that must compensate him for taking his land. If his lot is worth say $ 30,000 that is at least the price the public must pay him to compensate him for not using it. I would argue the price should be higher to compensate Mr. and Mrs. Taylor for the inconvenience they are enduring or to cover the cost of moving them elsewhere where they could enjoy the benefits of living in a one-story home.

Consider, furthermore, the bad example and – more importantly – the distorted incentive structure created by the policy in question. If the environmentalists knew that they would have to buy Mr. Taylor's lot to in effect purchase nesting rights for our bald eagle, they would have to come up with the hypothetical $ 30,000 +. If this were the policy, the environmentalists would quickly realize that moving the bald eagle to more favorable surroundings would be cheaper for them and thus they would be drawn inexorably to the policy which is socially efficient. Alternatively, they might try to raise the required capital from those citizens of Washington, D.C. and elsewhere who value bald eagles in their town or in cities, and value them enough so as to pay for the purchase of Mr. Taylor's land.

If environmentalists lobbied them for the funds, most people would see the benefits of relocating the eagle away from urban pollution and cement structures to more pastoral settings. This "*saves* two birds with one stone": it improves the welfare of the bald eagle and its ability to prosper and multiply, while also benefiting the Taylors by letting them do with their property as they wished. It is clear in this case that the cheapest solution is the most efficient, entailing the least waste of resources, as it is also the most equitable. The challenge is to set up a mechanism which naturally leads all parties involved not only to the discovery of the cheapest solution but also to its implementation to the mutual benefit of all.

Restricting the Taylors' rights to property is not such a mechanism. To the contrary, this policy breeds irresponsibility and even lawlessness. Instead of lobbying the people to raise funds for a good cause, the preservationists lobby the politicians to set up restrictions on peoples' property rights. If the law says that I have to pay to gain back the right to use my land, the preservationist does not have to work to convince people that bald eagles must be preserved. Under current law, it is the property owner who must pay to repopulate the fish in nearby rivers (the solution rejected by the Taylors) and the people who most value bald eagles take a free ride: they do not have to pay anything at all while getting the benefit. Meanwhile the property owner, seeing an affront to his rights, has become intransigent: he does not build because he is insulted to pay the required fee even if he may be financially better off paying it than not paying it.

The result is a bitter standoff. The owner cannot enjoy his property, the preservationists allocate their efforts unproductively and end up lobbying the wrong people, those who love bald eagles take a free ride, while the bald eagle remains in inferior surroundings. It could be worse: an irate property owner – we are happy that the Taylors are not such people, but less admirable folk have been known to do harm for less – could damage the bald eagle nest. Should society assign police to guard urban bald eagle nests? You do not have to be a genius to see that the solution under present law is an abject failure. It gives all the wrong incentives to *all* the parties involved. Its moral basis is highly questionable.

3. The benefits of preservation and the land market

We can let the owners of land have an unconditional right to the use of their land. Preserving that land for the future should entail purchasing the land *or special development rights to the land* from the current owner by the entity, whether governmental or private, which wishes to do the preserving.

Suppose that a private entity owns a piece of land with unique resources on it or under it. Suppose that development of the land in an urban or other use is so threatening to the resource that it would cause its permanent destruction and society would incur serious unrecoverable losses.[4] The correct solution here is to first value the benefits to society of preserving that land by forestalling the planned development on it. The second step is to raise the funds necessary to purchase that land from the owner and thus keep it out of the reach of development for a while or forever. But this second step should not be taken if the value of the land in development is higher than the value of the land in preservation.

No smart preservationist should want to pay more for a piece of land than that land is worth to preservation interests. Those extra dollars would be better spent preserving other land where the preservation value exceeds the development value. Preservationists who waste money by paying too much for preservation should be treated with the same harshness accorded to financial officers of companies who waste resources on bad investments.

The point I am trying to get across is that preserving land is an economic activity. The activity is worth undertaking if by undertaking it more value is created than would be by undertaking alternative competing actions. The preservationist entities could be private individuals, groups of individuals, businesses, or local, state or federal agencies. In each case we can and should expect these agents to compete with the other potential users of land in the land market. An adage of the land economist is that *land goes to the highest bidder*. It is common to think of the bidders for land to include speculators, farmers or commercial or residential real estate developers. There is no inconsistency in broadening our understanding to include among such bidders those entities that want to buy the land in order to preserve it.

As a society we are very far from the point in time when preservationists must compete for land. That is because our society has not yet developed the institutions and broadly held values which support a market-oriented approach to land preservation. This is despite the efforts of the Nature Conservancy and other similar organizations. Historically, most preservationists have sought the support of the government to help them *take* what, in their judgment, *must be preserved*. They are not trained to *buy what must be preserved*.

Part of the reason for this is that they are not trained to see the preservation activity as a form of investment – as it should be – but rather view it as a form of policing action as it most definitely should not be.

Market discipline requires vigilance. Suppose I am holding land I wish to preserve by keeping it out of development forever. Like any investor, I should keep an open mind to the possibility that circumstances may change. I need to regularly recalculate the present value of the benefits I am creating by preserving that land. If, at some point in time, someone walks up to me and bids more for my land than the benefits I am creating, I should seriously consider selling. That land might be developed, but I may be able to use the funds to buy and preserve other land elsewhere, the development of which would be more detrimental. All in all, by selling the land I was holding and by re-deploying the funds I should have improved the stream of benefits created by my overall preservationist activity. Indeed, to be successful in a market environment preservationists should learn some portfolio management.

4. Difficulties with the market-based approach

So far I have been trying to weave a story free of wrinkles. But there are a number of aspects that make the economics of land preservation considerably more complex than the economics of farming or commercial land development. Studying these complexities should guide how we, as a society, should conceive, design and support our preservationist entities. But, it does not, in my judgment, change the conclusion that these entities should be subjected to market discipline as much as possible.

The first difficulty with preserving land is the *difficulty in estimating the benefits from preservation.* Consider a piece of land that is currently wild. It is a big area of shallow wetlands. There are two investors bidding on it. One would like to cover it with earth or drain the water and put it into farming barley. The other would like to buy it and keep it out of development. Doing so would preserve a unique species of microscopic aquatic life. The same aquatic life can be found in some other places around the country but not many are left. The barley farmer has a relatively easy job. He can with little effort estimate the net profit from barley farming, taking into account the historical evolution in the price of barley relative to inflation. While there are many sources of uncertainty in these calculations, some benchmark numbers, reliable in the short run at least, are not difficult to pin down. Using an appropriate interest rate, our barley farmer arrives at a present value for the land and he is not willing to pay the current owner more than that.

Our preservation minded investor faces a much more difficult job. While he strongly believes in the value of the genetic information to be ultimately extracted from the rare aquatic species, he is nowhere near certain about when that will be possible or how much it will be worth. After all, with all of the advances in gene decoding, equally useful genetic information might emerge out of a species of butterflies which are not in danger of extinction or, for all we know, out of microorganisms we might someday find on Europa, a moon of Jupiter.[5] Perhaps, the land has some recreational value and a fairly reliable income can be extracted by charging wetland buffs to visit the land and engage in various recreational activities on it. But it is difficult to believe that the ultimate annualized stream of net revenues from the preservationist use of the land can be calculated with the same degree of confidence as can the stream of net revenues from farming it. Under these circumstances, how much is the preservationist willing to pay? That is why the element of faith should play a big role in preservation. Faith *does* count in the marketplace. One should be prepared to pay for one's faith by coming up with the bucks to outbid the barley farmer.

A second area of difficulty comes from knowing *how much is best to preserve.* We may all value the bald eagle and can derive a sense of pride and satisfaction just form knowing that there are enough bald eagles roaming the skies. But how many is enough?[6] And do we care if they are in Colorado or in

Washington, D.C.? Would we be satisfied if every zoo had ten bald eagles in good health? How much more is it worth to have them in the wild? Should they be sustained everywhere where they can possibly survive or just in some places? From these questions try to work back to the question of how much land must be preserved in what contiguous chunks to serve as viable bald eagle habitats and you see the complexity of the problem. The result is that we know damn little about how much preservation is enough. Especially when the resource is not renewable, there could be a tendency to preserve too much.

A third area of handicap arises from the question of *"who pays and who should pay?"* which takes us into the *free rider problem*. We already saw that Mr. Taylor should not have to pay for the bald eagle's food supply. That burden should fall on those who care and value bald eagle survival in Washington, D.C. Perhaps, that is everyone in D.C. including the Taylors but it cannot be disproportionately the Taylors. Just like those who pay for the barley crop of the previously wetland areas are those who consume barley, those who pay for the preservation of the bald eagle habitat (or the aquatic habitat) should be those who will benefit from it.

It can be argued easily that species preserved should be treated like public goods because we all benefit or will benefit from them (though to vastly different degrees). But once we enter the slippery realm of public goods, we are faced with the free rider problem. That is if the Bald Eagle Preservation Society were to attempt to raise funds to buy habitats suitable for bald eagle preservation, many potential beneficiaries would not come forward. For example, I certainly would not come forward if I heard that the Society had convinced Bill Gates to give them a few of his billions. Many potential beneficiaries cannot come forward because they are now children or as yet unborn. Their proclivities for enjoying bald eagles are as yet unknown or may be unreliable. The Society would thus probably raise fewer funds than the sum total of the value attributed to this issue by all those who will benefit. It may be able to solve the intergenerational problem in the capital markets: it could borrow and count on future fundraising to pay back the loan. It may be hard to find a private sector sponsor for such a loan, so the government may have to guarantee it. Perhaps, things would go a step further and the government would pay for the land, selling bonds for the purpose. That is still far better than the government taking the land without compensation or selectively forcing some to pay for eagle food in order to gain back their land rights.

The free rider problem works at many levels. It operates at the level of volunteering to join the preservation society. If you know that your neighbors will contribute, you may figure that the problem will be solved without your contribution. If the residents of the state of New York learn that the state of Colorado just bought a big piece of land and put it into a bald eagle preservation trust, they may decide they will vote to have their taxes pay for other needs. They may be satisfied to know that bald eagles exist in Colorado. The extra benefit of having them closer at home in New York may not be worth the extra cost given that they have been preserved in Colorado. Thus New Yorkers benefit from Colorado bald eagles without having to pay for them, while folk in Colorado assume the extra burden of sustaining the bald eagles for the whole country. It becomes all too tempting to say that the federal government should do the preservation: ergo the Endangered Species Act , twisted as its logic might be. But even if the federal government does the preservation, there is still free riding. The present generation takes a free ride on the future generations by passing the burden on to them. One way in which this is done is by doing nothing about the problem on the belief that sufficient numbers of bald eagles will survive anyway and our kids or grandchildren will pay for their preservation in the future. Indeed, free riding can cause extinction under these circumstances. Finally, there is also free riding among alternative preservationists. For example, if the bald eagle habitat is also a site for river recreation, those who wish it preserved as a bald eagle habitat may not contribute if they learn that it will be preserved as a water recreation area, figuring that this insures the preservation of the bald eagles.

Formidable as it is, the free riding problem does not shake me out my position. It is still better for the federal government to tax people at large to raise the money to buy land into preservation than to try to take land without compensation. It is virtually impossible to tax different people for what they are truly willing to pay. But it is much easier to find a reasonable tax most people would agree to pay.

This brings me to a fourth problem: the *holdout problem*. Suppose that someone refuses to sell land he owns at any price. The land has some unique characteristics that cannot be preserved by buying land elsewhere. Assume also that the current use of the land is dangerously degrading those unique characteristics. The owner holds out in the hope of extracting an even higher price than the preservation society is willing to pay, or he is holding out because of sheer irrationality or because holding out is making him or her famous. In this situation, it is reasonable for society to legally force a sale by paying the person an arbitrated fair price for his land. I believe the price should be equal to the true value the land would generate in preservation, but it should at least be equal to the value it generates in its current use. If the former were lower than the latter, society should not want to buy the land anyway. The other side of the coin is that a preservation-oriented owner of land can also hold out, refusing to return land to a commercial use, even though that land is now worth less in preservation. If the commercial benefits are indeed critical, the arbitration principle should also apply in this case.

A fifth problem I will examine is the *land assembly problem.* Suppose that several different owners own separate pieces of the land that must be preserved as a whole to achieve a preservation purpose effectively. The problem faced by the preservationists in this case is to engage in a potentially complex process of assembling the land by negotiating separately with each owner. This can lead to various forms of strategic behavior whereby each owner attempts to extract a higher price than he or she could if all owners truly competed with each other. Depending on how many owners there are, collusive holding out among them is a possibility as is also holding out by one or more owners independently. In this situation, a possible outcome is that society would be unable to assemble the quantity of land needed for effective preservation.

If the preservation activity is of critical importance, it would be important to devise a mechanism which would make it possible for the preservationist agency to successfully assemble all the land. First, the collectivity of owners can be defined as a common interest group, like the shareholders of a company holding different quantities of its stock. The rationale for this is that they jointly own land which, when viewed from the point of view of preservationist use, is indivisible. Then, the preservationist agency can buy them out by offering the same price to all of them. To avoid holdout problems, the rule may require that if a required proportion agree to the offer price, then all must sell at that price. While this sort of an arrangement appears preferable to having to negotiate with each owner separately, it may not work well if the owners are few in number because then they can easily collude regardless of how the offer is made. It may also fail, if the rule requires unanimity or a very large majority for the takeover to go through.

Economies of coordination are also important in land preservation. As we have already noted several times, people in a nation may care about land preservation for a variety of reasons. But for many purposes they may care only about the aggregate quantity of land preserved. Uncoordinated actions among different counties, different states or different private groups can result in too much land preserved in the aggregate. In this case the preservationist entities fail to free ride on each other because they cannot coordinate their actions. That is why deciding at a high level on aggregate quantities to be preserved and on what needs to be preserved for some purposes does have some advantages. This can keep the economy from preserving too much land in too many places. As an example, once a critical mass of bald eagles is achieved in several places, then it should no longer be necessary to engage in more land preservation for this purpose. But if no one monitors the aggregate performance, too much land would be preserved for this purpose and there would be too many bald eagles around. Those extra preservation resources are better spent preserving another species or buying other land for other preservation purposes.

In summary, although the various impediments discussed here are real and invite non-market responses to the problem of preservation, the solution *"if you want to preserve it, buy it do not take it,"* is still very appealing. How the buying happens is a complex problem. In many situations, the bidding entity should represent a coalition of interests jointly interested in land preservation. These interests include commercial ones because the land being preserved can lend itself to certain types of limited commercial use such as recreation, helping to defray the purchase price. Other interests include those of future generations represented by currently existing interest groups. Such groups for example, would favor using higher taxes on current generations, as they would not want future generations to overpay. More importantly, entities such as biotechnology and pharmaceutical companies or a foundation built by them, should be interested in paying to preserve in order to sustain biological diversity. And there is room for those who would pay just to preserve for the sake of preserving or for the sake of beauty or as a reaffirmation of our love for Nature and God. In preservation, it is all of these interests which must pull together and come up with the payment.

5. **Buying land to preserve it: Is there a new trend?**

As noted earlier, some private organizations such as The Nature Conservancy have been involved in buying land to preserve it. Large chunks of land such as national forests and parks are traditionally owned and protected by the public sector. The public sector has also been known to sell land when its development value increases, although it has difficulty exercising proper market discipline and is prone to succumb to political pressure in doing so.

Recently, we have seen some new examples of the public sector purchasing land to preserve it. About two weeks ago, President Clinton announced a plan to buy land adjacent to Yellowstone National Park. Many state governments have acted similarly, buying land for open space preservation. For example, an article in the New York Times (Preston, 1998) referred to a variety of states and how they are raising money to buy land for open space preservation. In New Jersey, Governor Christine Todd Whitman has proposed using a gasoline tax to buy and preserve half of the state's two million remaining undeveloped acres over ten years. In Georgia a real estate transfer tax has been proposed. Connecticut and Minnesota have proposed bond programs. Many local and county governments across the country have similar initiatives. Other states like Maryland have proposed smart growth plans targeting infrastructure subsidies to areas that are already developed in an effort to discourage development of remaining open areas.[7] All of these legislative developments are occurring in the midst of apparently growing dissatisfaction with urban sprawl.

These proposals and programs have much in their favor. It makes a lot more sense to buy land to preserve it rather than to take it without compensation or to restrict its use unreasonably. The proposals discussed in the previous paragraphs may be compared to the growth boundary policies of the state of Oregon. [8] These policies restrict development on land beyond a certain distance from the center of a city. By restricting the supply of land that can be developed, such policies function as a subsidy on the owners of land within the boundary (who realize windfall gains) and as a tax on those who rent or buy land within the boundary after the policy is announced. [9] These restrictions mean that owners of the land outside the boundary cannot realize the full value of their land because no compensation is given to them. The government in fact takes their property rights away.

A better growth boundary policy would involve buying the land beyond the boundary to keep it out of development. Since the growth boundary increases the wealth of those holding land inside the boundary, it is they who should be taxed to raise the funds to buy the land outside the growth boundary. But Oregon policy is a *take-the-land-policy* not a *buy-the-land-policy*. The purpose of Oregon policy is not land preservation per se but the creation of compact cities based on a belief, supported by no evidence to my knowledge, that living in high densities is socially better than living in low densities. [10] To the extent that specific land inside or outside urban areas is environmentally and ecologically valuable, the state government or private preservation interests or a coalition of these interests could selectively buy such land. But such a policy, which we are advocating in this paper, is far different from indiscriminately putting a boundary around each city in the state, regardless of the preservation value of the surrounding land

6. Alternatives to buying the land: zoning and development taxes

Because of the difficulties discussed in section four, a coalition of diverse interests all of whom benefit from preservation is difficult to put together and that difficulty is the Achilles' heel of preservation. This gives rise to the use of other public-sector instruments for preserving land without exercising fee-simple ownership. I now discuss these alternatives. But these alternatives do not mean that the principle of respect for private property should be dispensed with.

There are two frequently cited alternatives to buying the land to preserve it. One of these is for the public sector to use *zoning* that restricts certain uses of privately owned land. The other is to levy a *development tax* on certain kinds of development that could occur on the land with the intention of limiting, preventing or forestalling those types of development. I will now consider these two instruments, explaining how each of them amounts to a taking of private property rights. If these instruments are used properly, they should be accompanied with compensation of the land value lost. That in effect is equivalent to buying rights to the land.

Zoning restricts the land's use while leaving it in private ownership. This is, in fact, what happened to the Taylors. A zoning action that reduces the value of a parcel of land amounts to a taking. Zoning should not be used to preserve land or control its use unless such action generates positive net benefits. The zoning action would presumably raise the value of other parcels and would generate other benefits that are not capitalized into land, for consumers, businesses and government. It should be possible then, to tax the gainers and use a part of the proceeds to compensate the owners of the land that lost value because of the zoning. Such re-distributive taxation preserves private rights to property by compensating landowners for the value loss that they suffered from the zoning.

A development tax on the land is to be paid only if the land is developed in a particular way, thus preventing or greatly delaying its development in less desirable ways. This tax would reduce the property value of the land on which it is levied but would presumably generate benefits elsewhere in the economy. For example, adjacent land that might benefit from the preservation would increase in value because it abuts on the positive amenity on the preserved land. As in the case of zoning, if the tax – properly calculated – did not generate positive net benefits, then preservation would not be worth pursuing in the first place and the tax should not be levied. If net benefits are positive, as they should be, the negative effects can be remedied by taxing beneficiaries and compensating the landowners whose land lost value.

Under zoning and under the development-tax, the compensation principle offsets the taking effect. By compensating for the lost value, the public sector reaffirms the principle that rights to land's use should be purchased not taken. Can *zoning* and *development taxes* be used improperly? It is all too easy to over-zone or under-zone or to over-tax or under-tax so that the net benefits of these actions are not positive. In that case, because net benefits are not positive, re-distributive taxation cannot offset losses in land values without hurting some other economic agents. It is, of course, also true that it is possible to overpay for land to be purchased for preservation. The tendency to overpay is probably stronger if governments are doing the purchase and they act with little market discipline because their pockets are deep. It is therefore important to devise mechanisms for keeping such purchase actions transparent and accountable to the taxpayer by appropriately monitoring those government agencies that preserve land.

Zoning and levying development taxes, with appropriate re-distributive taxation are equivalent to fee simple ownership in that the principle of private ownership is respected. Another frequently used line of argument is that the government supplies infrastructure that ends up enhancing the value of some land. Hence, the argument goes the government is entitled to share in the ownership of the land. Indeed, I see nothing wrong with the government taxing the increase in land value caused by the new infrastructure as long as the government also compensates the owners of land who lost value. That is, in fact as we saw, a necessary part of the re-distributive taxation principle that should accompany zoning and development taxes. It also applies to investing in infrastructure. There are a variety of instruments available for the purpose of taxing landowners to pay for infrastructure. Impact fees on developers, value increment taxes and special assessments are all reasonable instruments for this purpose. This is how infrastructure should be financed while the pecuniary changes it imparts on land values should be remedied by re-distributive taxation.

A serious difficulty exists in measuring how much infrastructure investments impact land values. The land market tends to anticipate at least some of the infrastructure investments that are likely to be made in the future. Hence, when market agents buy land they have already paid for the benefit of some of the future investments in infrastructure because those benefits have been capitalized into land value. What is at issue, therefore, is to be able to assess unanticipated changes in land prices that result from government actions. We will see in section eight that that is not easy to do without the use of sophisticated economic models.

7. Preservation of metropolitan hydrological resources

The hydrological resources of a region or metropolitan area comprise a complex system. There are surface resources like rivers, lakes, wetlands and groundwater resources. These serve as amenities for recreation of various forms. They can also supply the metropolitan area as well as other areas with water for various uses. Hydrological resources are largely renewable but their quality is degradable by pollution generated by economic activity. Quality is positively affected by the degree of wastewater treatment and industrial pollution abatement. Improper preservation of the quality and quantity of hydrological resources is costly. If local water resources are depleted or polluted to a high degree, water may have to be transported in from other places at high cost and local recreational amenities are reduced and must be substituted with similar amenities farther away.

To maintain adequate quantities of metropolitan hydrological resources, the marginal cost pricing of water becomes important when its supply has become relatively scarce. At the same time, the quality of water is best preserved by a system of effluent taxes levied on polluters. A special feature of hydrological resources is that pollution at an upstream source has damaging effects at many points downstream. Effluent fees at the source must take into account the geographical complexities of the watershed. This makes the calculation of these fees difficult.

What is the relationship between hydrological resources and the land? Clearly, how land is developed does influence how much pollution impacts surface and groundwater resources while the quality and quantity of water resources can have effects on land's value and ultimately its use. For example, storm and sanitary sewer systems must have adequate capacity to prevent excessive pollution of lakes and rivers into which these systems discharge. The capacity of these sewer systems in turn depends on the extent and density of the metropolitan land use. Impact fees on developers and effluent charges on polluters can all be designed so that the level of pollution is optimized or does not exceed a given standard. Ownership of land is not normally a critical part of preserving hydrological resource quality and quantity within metropolitan areas except when the land itself is a critical component for preservation.

Purchase of metropolitan land parcels for preservation would be justified when there are aquatic habitats on the land such as wetlands. Aquatic amenities adjacent to the land such as a lakeshore or riverbank with recreation potential also provide reasons why such land may be purchased to insure preservation. Frequently, development of such land as a public amenity or for recreational purposes is desirable. Consider, for example, a private owner who holds unique land on the lakeshore. The highest bidding use may be apartment buildings that would have views of the lake. Preservation can purchase the private owner's rights to build such apartments. If a zoning ordinance is passed to prevent such construction, the owner should be compensated for the loss in value. Equivalently, the preservation agency can simply purchase the land and put it into an appropriate commercial recreational use.

Limiting the quantity of land that can be developed in a metropolitan area is not necessary for maintaining the quantity and quality of the hydrological resource base. The impact fees and effluent charges should do the job if these are properly calculated and monitored. When these become sufficiently high as local water becomes scarce, economic agents in the area would prefer to import cheaper water rather than use expensive local water and the revenues from these fees would be sufficiently high to permit the construction of pipelines to import such water. When fees for the recreational use of local water resources become sufficiently high, travel to other areas for recreation becomes a viable substitute.

8. The role of metropolitan models in preservation strategies

The last two sections serve as prologue for understanding the role of integrated economic models of metropolitan areas to identify economically efficient plans for charting out broad strategies for managing the preservation of natural resources at the metropolitan level. While such models to date do not incorporate economic-ecological interactions, it is possible to extend them in these directions in future years.

Models of the metropolitan economies and the land market are designed to examine a variety of factors including how zoning, investment in infrastructure and the pricing and financing of infrastructure affect metropolitan development. Such models are the only tools available for estimating how these actions will reverberate throughout the metropolitan economy. Models would determine those who would benefit and those who would lose from a particular set of actions. A model that I developed is focused on the relationship between personal transportation systems and the metropolitan economy. It determines how changes in the level of service of highway and public transit systems affects the value of commercial and residential land throughout a metropolitan area and how additional benefits are reaped by the users of these transportation systems. [11] At least in principle, the model is capable of identifying how much the beneficiaries of transport improvements should be taxed and how much compensation the landowners who lose value are entitled to under the compensation principle.

Metropolitan hydrological systems and transportation systems have important similarities. Both are networks connecting disparate locations within the metropolitan area. Effluents at some locations travel in the hydrological network affecting environmental quality at many other locations. Controls on land use, effluent charges and impact fees levied at some places will have repercussions at other locations. Because of this high degree of the spatial interdependence of hydrological resources, locally confined public actions will have effects that are highly non-local. Models which can estimate these effects and how they affect the economy including the land markets are the only means available, however imperfect, for doing logically consistent decision making for water resources.

Appropriate models would be able to help us optimize metropolitan water resources policy. Such models could also be used to calculate the social costs of adhering to unreasonable water quality standards. The models would tell us how much good policy is worth and also tell us how much bad policy would cost. As an example of the former, a well-designed model would calculate the total economic surplus that can be generated by following a particular water resources policy. As an example of the latter, the same model would be able to calculate the economic cost of maintaining a stringent water quality standard. It would be able to also calculate the resources that would be saved were this stringent standard to be relaxed. In both cases, the model should be able to determine the spatial distribution of the effects of each policy: which land parcels would increase in value, which would decrease and by how much? Which consumers would benefit and which wouldn't and by how much? How would the budgets of local governments be affected and by how much? Finally, the model would be able to calculate how the economy would be impacted if the surplus resulting from a particular policy were to be redistributed according to the compensation principle.

9. Conclusions

We have observed conflicting aspects of public policy regarding the treatment of land for preservation purposes. On the one hand, public policy takes the property rights of private landowners without compensating them, as was the case with Mr. and Mrs. Taylor. This is costly, inefficient and gives all the wrong incentives to all the parties involved. On the other hand, many governmental entities at all levels, the state of Oregon notwithstanding, have recently come to accept the advantages of buying land to preserve it as we saw in the last section. Such actions, in part driven by overreactions to urban sprawl, can result in buying too much land making developed land more expensive than is economically efficient. But at least, buying the land forces the preservationists to accept market reality and to put their money where their mouths are. This should ultimately make preservation a more effective activity.

One lesson of this paper is that preservation interests need to learn to view preservation as an investment activity. They need to submit to market discipline and come up with the funds needed to achieve their aims just like all other market agents must do. To succeed in this mission, they need to learn how to smartly put together coalitions of private and public entities interested in investing in land for preservation purposes by outbidding other uses of the land which conflict with its preservation. This is a far cry from where we are today but there is some evidence that a move in the right direction may be underway.

We also addressed alternative instruments to fee simple ownership such as zoning and development taxes. While these instruments are appropriate when preservation entities cannot come up with the price to pay for land, it should be remembered that they cause reductions in the value of the land that is preserved and are, in effect, forms of taking or partial taking of property rights. In these circumstances, the principle of compensating for reduced property values is the natural remedy. Spatial shifts in land values and in user benefits also occur when the government invests or makes management changes in infrastructure systems including water resources systems. Because such public action can have spatially interdependent effects that extend throughout a metropolitan area, we need to develop models of economic-ecological interactions designed to calculate the spatial distribution of the benefits and costs of these actions. Such models can also calculate how the compensation principle should be applied.

Footnotes

1. See Anas (1984, 1988)
2. Such efforts by some private groups are nothing new. The Nature Conservancy (www.tnc.org) serves as a good example.
3. See James V. DeLong (1999). What follows is a virtually identical recitation of the incident.
4. For example, a unique habitat would be destroyed causing the extinction of some species about which people care or which contain or might contain unique and irreplaceable genetic information. Or, the quantity of water, open space or other resources available to the immediate area would become greatly diminished.
5. I do not mean to make light of the potential importance of genetic information. I am well aware of the rapid loss of bio-diversity in places like the Amazon forest which is systematically torched by speculator-arsonists.
6. Note that to preserve genetic information, all we need to do is sustain generations of single male-female pairs, perhaps with some extra ones for safety. When positive genetic value is confirmed these can be multiplied to the desired degree to enable commercial exploitation of the required genetic materials if such cannot be artificially engineered. Using this logic only a small number of bald eagles need to be preserved in highly controlled environments. But, of course, genetic information is not the only reason for preserving the bald eagle.
7. The American Planning Association (1997) endorses a variety of such policies.
8. I have written about these policies elsewhere. See Anas (1999). Also see Knaap (1985).
9. See National Association of Home Builders (1997), Anas (1999).
10. Oregon land use restrictions have unintended effects. While land available for development is rendered scarce and expensive which does cause higher densities within the boundary, those who cannot bear that price move to other towns with lower land prices within and beyond Oregon. They include commuters from rural towns who relocated out of Portland to avoid the higher rents there. See Anas (1999).
11. See Federal Transit Administration (1993). The use of integrated transportation-land use models to evaluate the consequences of metropolitan transportation investments is a basic standard strongly recommended for compliance with the Clean Air Act and the Inter-modal Surface Transportation Efficiency Act. The improper use of such modeling has even sparked lawsuits. See Garett and Wachs (1996).

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Buying the "Right" Amount of the "Right" Lands
Comments on
"The Economics of Preserving Environmentally and Ecologically Valuable Lands"
by Professor Alex Anas

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It is a privilege and a pleasure to be able to comment on Professor Alex Anas' paper, "The Economics of Preserving Environmentally and Ecologically Valuable Lands". Privilege, because I have long admired Alex's intellectual and empirical work, as well as the efforts he takes to make tough material understandable to the broadest possible audience. Alex is not only a good economist; he is also a good writer. It's a pleasure, because I find myself agreeing with almost everything Alex writes in this paper: Buying environmentally valuable property *is* the best, most efficient, and fairest way to preserve it. It is also most permanent method. Regulation may seem cheaper and thus more cost-effective; but because political and judicial regimes frequently change, over the long run, preservation-through-purchase is clearly the way to go.

So for those of you who were hoping for a knock-down, drag-out argument, I'm afraid my comments today may seem a trifle tame. Instead of taking issue with Alex, as I was tasked to do, let me try to extend his argument further, and in some new directions. Specifically, I want to talk about how to figure out how much land of what types and in what locations to buy, and how to organize to pay for it.

I. Criteria for Identifying Potential Acquisition Sites

Like Alex, I assume that funds for land preservation are quite dear; and that any land acquisition fund, no matter how well-endowed, will not have sufficient resources to preserve all the lands it is called upon to save. This is exactly the dilemma facing the Packard Foundation in California. Established in 1998 with an initial endowment of $200 million, the Packard Foundation's California Landscape Program took upon themselves the task of working with local conservancies to preserve large chunks of California's natural and heritage landscapes. They quickly found themselves overwhelmed with requests for financial assistance. To help them, and you find a way out of this dilemma, let me propose five simple criteria for identifying and prioritizing potential acquisition lands. Starting from my California roots, I'll start in terms of *public* preservation of lands for reasons of biodiversity. I will later extend the analysis to wetlands, watersheds, and aquifer recharge areas; as well as to initiatives undertaken by locally-based conservancies.

1. First and most important, lands identified for permanent purchase/acquisition (by public entities) should be important or unique for reasons of biodiversity and/or because they are habitat lands for endangered, threatened, or unique species; and/or they should be of high aesthetic or amenity

value to local and regional populations; and/or they should be designated as signature or heritage lands; and/or, they should be designated as important and valued resource lands (e.g., forest, wetland, riparian areas, farmland). In one way or another, potential acquisition sites should be both rare and irreplaceable. It is not enough that they be undeveloped or near large populations.

2. Second, lands identified for permanent purchase acquisition should be otherwise threatened by land imminent urban land conversion or large-scale harvesting or resource extraction. We may perhaps disagree on what time frame to attach to the term "imminent," but I think we can all agree that paying top-dollar for lands not threatened with loss or land conversion would be wasteful. Acquiring land under this criteria is bound to be expensive, since, by definition land's value rises when it is desired for a developed or harvested use.

3. Third, lands slated for permanent purchase-acquisition should not be otherwise protectable by less expensive means, principally local land use and environmental regulation. Master plans, general plans, zoning ordinances, and subdivision regulations all work very well for short-term preservation, provided there is political agreement, and they tend to be far less expensive than purchase-acquisition. They also work very well when appropriately combined with purchase-acquisition. At the same time, as Alex has so rightly pointed out, regulatory approaches tend to be prone both to over-use and to misuse. Over time and all too often, land use regulators find themselves on a slippery slope, casually deriving legitimate property owners of their rights all the while conferring on the "public," rights they do not legitimately have.

4. Fourth, lands protected by purchase -acquisition should be capable of being preserved in sufficient size and shape to insure that the underlying resource remains sustainable. Preserving the most visible and obvious pieces of a watershed, viewshed, range habitat, is always the most popular thing to do. Regrettably, in terms of long-term environmental quality, sometimes that's all it is.

5. Lastly, any organized effort at land acquisition should take what has come to be known as a "portfolio approach." This means that the efficacy of a land conservation effort should be judged not on its success at preserving any single site, but on its ability to acquire a range of complementary and substitutable sites. Just as a desirable financial portfolio should included investments that "hedge" one another, so too should a desirable land conservation portfolio include sites that substitute and replicate the environmental characteristics of other sites. While this concept of a portfolio approach may seem obvious at one level, recognize that it is squarely at odds with much of physical science which tends to view sites in terms of their intrinsic uniqueness.

II. Details, Details

As with every issue in which science, economics, rights, and public policy intersect, the devil is in the details. At this point, it is easier to pose questions than provide comprehensive answers. How does one go about identifying the most biologically diverse lands, or the most sensitive habitat, or the most important forestland, or the most critical watersheds? Is it really possible to identify those sites which are most threatened by man, either through over-harvesting or development? Is it possible to optimally match particular land conservation approaches (including regulation) with particular sites and contexts? How does one identify minimum site thresholds sizes and shapes? And how exactly does one go about constructing a land portfolio?

With respect to the first question, how best to identify sensitive lands, considerable progress has been made in recent years in mapping land cover and habitat, and in spatially modeling of watersheds and waterflows. Indeed, it is quite feasible in many parts of the country, to begin to rate undeveloped lands along one or more dimensions of environmental sensitivity.

Considerable progress has also been made regarding the second issue: how to identify sites most threatened by development and over-harvesting. By coupling spatial and census data, new techniques of spatial analysis, and discrete change analysis using logit and other non-linear estimators, it is now possible to calibrate (and use) reasonably robust statistical models of urban land use change. We have constructed one such model in California, known as the California Urban and Biodiversity Analysis Model, or CURBA. CURBA is intended to be used to test the usefulness of multiple policy approaches, including purchase, for protecting sensitive habitat from incipient urbanization. There is no reason CURBA-like models could not be developed elsewhere to deal with issues of watershed preservation.

As Alex has so ably argued, purchase-acquisition is the preferred, or as economists say, "first-best" tool for preserving environmentally valuable lands. It is not the only such tool. There may be some circumstances in which other, less expensive approaches work almost as well. For more than 25 years, local governments in and around Portland, Oregon have used an urban growth boundary (UGB) to successfully protect agricultural lands at the urban fringe. (On the downside, Portland's UGBs has also contributed to a rapid run-up in local housing prices.) In California, a combination of regional coastal plans and local zoning ordinances have done a simply amazing job at protecting the state's coast from over-development, while, in most cases, not robbing landowners of their private property rights. There are other success stories as well. And failure stories. The point I'm making is that we lack a systematic understanding of which of these "second-best" approaches works best in which locations and under what circumstances. And which work well together with purchase-acquisition. This is a promising area for policy research.

An important area for scientific research is to figure out minimum required preservation area shapes and sizes. This is extremely difficult to do. What, for example, is the right minimum site shape and size for bat habitat, or for condor habitat, or for salmon habitat? Are two large-but-distant preserve areas adequate? They probably are for mountain lions, but not, for example for elk. Is a large preserved upland watershed, with no downslope protection a better configuration than a preserve that buffers most local streams? How much if any development or harvesting should be allowed within such buffers. These are difficult questions, and there are answers that are appropriate for certain types of landscapes but not for others.

III. A "Federalist" Approach

In the absence of good information, Alex worries about acquiring too much land. Maybe its my California bent (and the fact that we still have original landscapes left in California) but I worry more about not acquiring enough land, or acquiring the wrong lands. Acquiring the right lands requires going beyond just doing more and better scientific research. It also requires re-thinking how local political structures should organize themselves to do land conservation. Here again, Alex is on to something. In the initial absence of good information, the establishment of property rights and markets serves to promote the creation of better information about environmental values as well as about willingness-to-pay.

Assuming that we move toward a purchase-acquisition model of land preservation, as Alex recommends. Which entities should take the lead? The federal government? Local governments? Non-profits organizations? Private philanthropies and advocacy organizations? An obvious answer is that they all need to work together, so as to acquire the maximum amount of appropriate land for the minimum price. Without some system of coordination, the wrong lands are likely to be acquired, probably at higher-than-necessary prices. Moreover, full purchase may not be necessary. Purchase of development rights – wherein a public or non-profit entity purchases some or all rights to development, but where title and land ownership remains in private hands –may be both a more effective and less expensive approach.

One way to think about such a coordination system is in federalist terms; that is, in terms of partitioned and complementary resources and responsibilities. The role of *state and/or regional* government entities in such a system should be to use tax revenues or other public monies to purchase those lands (or their development rights), the protection of which will generate the greatest benefit to *all the* residents of a particular state or region. In economic terms, the function of large governmental entities should be to purchase those sites characterized by the greatest total willingness-to-pay over the largest possible area. The role of local governments would be to use local own-source revenues to purchase lands *within their municipal boundaries* that benefit a majority (or better yet, super-majority) of municipal residents. The function of private, non-profit entities (such as land conservancies) should be to raise funds to purchase more specialized or localized sites in line with the wishes of their memberships. In keeping with the federalist model, individual local governments may wish to voluntarily contribute more to regional preservation efforts and/or to create incentives (such as matching grants) to promote greater private and non-profit land conservation.

The advantages of this federalist system are several-fold. It maximizes total willingness-to-pay, and therefore maximizes the total resource base available for land protection. It encourages residents or persons who realize the greatest benefit or consumer surplus to contribute the most. For individuals, it more fully equalizes the marginal costs of conservation with the marginal benefits. It minimizes (while not completely eliminating) problems of free-ridership. It would also make it more difficult for holdout landowners to charge monopoly prices.

Theory is fine, but how might such a system work in practice? I'll start with the case of preserving habitat. A consortium of government and university researchers would begin by mapping all sites according to their contributions to statewide habitat quality and the estimated degree of threat. Sites with large concentrations of threatened and/or endangered species and which are most sensitive to development or resource depletion would be ranked highest, and earmarked for purchase by the state. Sites with concentrations of threatened and/or endangered species but which are somewhat less sensitive to development might be earmarked for state purchase-of-development rights; as might sites which are rich in biodiversity, but which are not inhabited by threatened or endangered species. Sites which serve as regional open space or regional wildlife corridors would be ranked one level lower, and earmarked for preservation by regional and/or county government entities. Sites which serve as municipal open space, greenbelts and greenways, or recreation lands would be ranked one level lower still. As above, the protection mechanism – be it outright purchase, purchase of development rights, or perhaps long-term development regulation – would have to be tailored to the specifics of the site and jurisdiction. The lowest ranked sites would be those which serve as private or neighborhood open space, or which are used as development buffers. Because non-governmental entities typically lack the authority to regulate land uses, the principal mechanism for preserving these locally-important lands would be through outright purchase or the purchase of development rights. Note that this is where zoning most frequently gets into trouble: when it is used to the benefit of relatively few at the expense of individual property rights.

All of this is easier said then done. Inevitably, there would disagreements about the rating or ranking or particular sites. Nonetheless, it could be done. And the disagreements would be about sites, rather than about approaches.

Extending this approach into the realm of water resources planning seems to me – and like Alex, I am not a water resources person – to be much more difficult. Depending on the area, water resources may be used for drinking and bathing; for irrigation; for recreation; and to maintain local, metropolitan, and in some cases regional, habitat quality. Moreover, as a non-water-resources-person, it is not immediately clear to me that urban development is the principal threat to water-quality. Erosion, fertilizer and chemical runoff, toxic discharges, over-drafting, and even long-term climatological cycles may play a far bigger role in affecting both runoff and groundwater quality than the amount and type of urbanization. Regulating the quality and impacts of development is probably more important than regulating the amount and type of development. Mitigation and clean-up technologies also have a large role – something that is rarely true in the case of habitat preservation. Whereas habitat models are data-driven once we have an inventory of vegetation types and species populations, we can start rating land in terms of its habitat quality water resource models are much more process and flow-driven. Temporal variations also play a much greater role. Does this mean that the type of land prioritization exercise I suggested above can not be done? Not at all. It just needs to be done by people more knowledgeable than me.

So let me conclude by saying how much appreciate being asked to be here today, and to comment on what really is a through-provoking and excellent paper. As a spatial modeler with the black heart of an economist – some might say no heart – we really are living in an exciting time. Recent advances in spatial and behavioral modeling and large-scale data integration and synthesis have made it possible for us to constructively address these problems on a large scale. At the same time, what I hope is a new-found respect for the value of private property rights in a free society, now forces us to try to more carefully and productively balance social benefits with individual costs.