Defining Sustainability

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Water is perpetually recycled on the Earth. The recycling goes back in time far beyond the dinosaurs. Through what is known as the hydrologic cycle, water on Earth is continuously replenished and redistributed through precipitation, runoff, and percolation into the soil, and evaporation, condensation, and ultimately precipitation again. The key for a water supply system is to determine how the hydrologic cycle provides water to the service area (e.g., recharge basin), in what quantities, and with what reliability.

This essay was written to initiate a discussion of some of the concepts on the implications and definitions of sustainability and their practical aspects as applied to water systems. While we all recognize the idea that:

Withdrawals = Consumption + Returns (to hydrologic cycle)

the concept is not that simple, and the concept of "sustainable water" is expressed in different terms, depending on the profession using it.

From a hydrologic perspective, the term "sustainable yield" is the amount of water that can be withdrawn from a source at rates that are less than their recharge potential and that do not deteriorate the source. For geologists, "safe yield" is oriented toward groundwater, but is the amount of water that can be withdrawn without a decrease in the long-term water levels. A definition for "sustainability" created by the American Water Works Association's Water Resource Division Trustees was:

"The planning, development and management of water resources to provide an adequate and reliable supply of water with a quality suitable to meet their economic, environmental and social needs for current and future generations."

The following question still remains regarding the completeness of the definition: *Does it address all the associated issues?*

A recent report by Murley (2006) defined sustainability as "use of resources by our generation in a manner that will not diminish the ability of future generations to meet their needs." Murley (2006) also ties "sustainability" with "prosperity" and notes that improved economic health and greater social equity result in a better quality of life for all people.

In some instances, sustainable use may be limited seasonally based on hydrologic patterns (wet-season allocation and dry-season allocation). Typically, there are a variety of uses competing for water resources, and each basin has unique characteristics. For example, in Florida many basins have the following competing interests:

- Agriculture
- Ecosystems
- Urban demands
- Industrial demands
- Cooling water

From a practical perspective, sustainability is oriented to a pool of resources/materials and their optimal extraction, the uses of these resources, and their ultimate sustainable use; therefore, all users in a basin must be considered, but how will uses be prioritized and by whom?

The uses of these resources can not be separated from the opportunity costs of the same resources, and therein lies the dilemma. While water is constantly recycled, its use in one sector may make it unusable by a competing sector. The impact of these decisions ultimately affects the basin's social, economic and ecological basis.

The Systems Concept

Sustainability is influenced by a number of different factors, such as environmental quality, financial management, and institutional capacity. If projects do not meet the demands of the users, the inputs required for their maintenance and survival will not be achieved, since there is a relationship between the responsiveness of a system and its sustainability (Virjee and Gaskin (2005).

As a result, "sustainable" and "development" appear to be mutually exclusive terms, yet the concept of sustainability must assume there will be change over time within the basin that speaks to which type of "development" may be encouraged from a profit-and-growth perspective. It must be assumed, however, that to meet the "sustainable" criterion, such development should not degrade the systems on which development depends (Newton, 2003).

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From a practical perspective, sustainable development generally means addressing the environmental, economic, and social concerns. Researchers can define a comprehensible concept of sustainability, but practitioners emphasize feasibility and limitation to sustainability of the ecosystem (Starkl and Brunner, 2004).

Identifying critical natural capital requires systematically analyzing and evaluating whether environmental functions are being used sustainably, determining the extent of any sustainability gaps, identifying economic and environmental pressures, and monitoring public policies aimed at improving the ecological system. Criteria that can be used include (Ekins, 2003):

- Maintenance of human health to avoid negative health impacts
- Avoidance of loss of ecological function
- Economic sustainability – maintenance of economic activities on a basis that does not deplete the resource

From a systems perspective, a sustainable society is one that has the institutional, social, and informational mechanisms in place to keep in check the feedback loops that cause exponential population growth and natural capital

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depletion. A sustainable world is not a rigid one, where population or productivity is held constant, yet sustainability does require rules, laws, and social constraints that are recognized and adhered to by all (Meadows, 2005).

The objective of effective resource utilization is equivalent to the goal of sustainable project design (Virjee and Gaskin, 2005). Economists were the first to tackle the subject. They define sustainability in different ways, including that sustainable economic growth means real Gross National Product per capita and social development which means that per capita utility is increasing with time, and that a set of development indicators is increasing over time.

As another option, economic production involves transforming raw materials into finished goods, and the success of economic enterprises is tied to some degree to the cost and availability of the raw materials. Such economic indicators provide useful information about the structure of an economy, the changes to it, economic gains and losses, and gains and losses to a particular sector or individual.

Even among economists, however, these indicators are generally misunderstood. The measures should reflect the scale of the activity and the scale of the net financial changes to the region, not specific benefits or non-benefits to a particular activity, industry, or individual. To do so would ignore the value of the ecosystem, and the potential value that may be understood only in the future that the ecosystem may derive.

Implicit in evaluating these sustainability concepts is the uncertainty and reversibility of natural resources and their substitutes. Sustainability should consider what is being sustained and whether it is inclusive enough to account for multiple objectives, less money or resources being wasted in competition between objectives. (Popp, et al, 2001).

One concept that provides uncertainty is the biodiversity of the ecosystem. Biodiversity may be described in terms of genes, species, and ecosystems, corresponding to three fundamental and hierarchical levels of biological organization. Species diversity has economic value to the concept of sustainability, but the economic value of biodiversity may be difficult to measure without understanding the mix and makeup of the ecosystem (Pearce and Moran, 1993).

For example, in many regions, it is apparent that the loss of forest lands leads directly to water-quality degradation (Barten and Ernst, 2004). A natural resource stock (such as forests) generates forms of desired human services (such as lumber and recreation (Popp, et al, 2001). Forests contribute to the livelihood of 90 percent of those living in poverty (Haigh, et al, 2004). As a result, forest cover has been adopted by the United Nations as a key environmental stability indicator.

The environment is vulnerable to the impacts of development and other human activities, which generally have adverse impacts on ecosystems. The most significant are climate changes that may arise from increasing concentrations of carbon dioxide in the atmosphere and non-point water pollution from increased fixation of nitrogen through the production of industrial fertilizer, along with the loss and/or fragmentation of wildlife habitats from man-induced landscape changes (Prato, 2005). Distortions of natural cycles of water resources are also a problem in the water resource sustainability question (Beck, 2005).

Depleted ecological stocks can not be sustained, and conserving natural capital does not always imply absolute protection against depletion. Compensatory mitigation is one replacement strategy that has been tried – pursued mostly in an attempt to mitigate impacts to ecological systems (NRC, 1994). The question, therefore, is this: Should resources should be sustained as they currently exist, or should the services they provide be sustained?

The current local economic situation of many areas indicates how specific analyses undertaken years ago have wrought unexpected impacts, most of which appear negative to the capacity of sustaining the system. An example: In the Klamath River Basin in Oregon, the historical $4.5 billion/year salmon fishery has been reduced to $50 million per year as a result of agricultural diversions that produce a gross revenue of $200 million per year. Irrigation diversions during a drought wiped out salmon runs in 2000 and 2001. The result will be that salmon can not return to the stream during those intervals (4-6 years from birth), meaning salmon runs are potentially damaged for many years. At the same time, it should be noted that recreational opportunities mostly concerned with fishing and bird watching in large wildlife sanctuaries is the fastest-growing economy in the area – grossing $800 million/year and growing at up to $50 million/year. If salmon were a reliable fishing opportunity, the potential for this sector dwarfs all other sectors (GAO, 2004).

Sustainability in Water Resources

Sustainability of water resources incorporates the concept of inputting socioeconomic constraints in exploiting water resources (Adrians, et al, 2003). The Dublin Water Principles claimed that water is an economic good within the European Union setting, despite its recognition as an economic good for centuries before that time (Rogers, et al, 2001). The production and delivery of drinking water and the treatment of wastewater are recognized as vital functions of society, and securing them for future generations is important for sustainable development.

Sustainable development indicators for water bodies include the withdrawal of freshwater and releases of nitrogen and phosphorous (Palme, et al, 2004), but based on the current water quality management practices employed worldwide, the situation is far from satisfactory as a result of pressures from increasing population and economic development. Tools to help assess sustainability concerns include risk assessment tools, data availability and reliability, modeling system complexity, water quality modeling, water quality monitoring, and policy integration (Huang and Xia, 2001).

In sustainable water management, water systems should be treated as holistic entities, incorporating supply or input, use, and disposal (output). Sustainable water management requires a holistic approach to water planning, integrating and the recognition on interconnections between systems, differing levels of scale, and the dynamic nature of the complex ecosystem to meet its goals (Tippet, 2003). The recognition of regenerated supplies and their water-quality impacts are important.

With regard to surface waters, development has substantially impacted the fluxes, timing, and quality of water that recharges aquifers and discharges to streams, rivers, and wetlands (Adrians, et al, 2003). Planning for sustainability is an emerging role in the context of river catchment management.

Within groundwater systems, sustainability is usually measured where the total amount of water entering, leaving, and being stored must be conserved for sustainability of the resources, hence all inputs and outputs must be accounted for in the water budget (USGS, 1999). The concept of safe yield may be a flawed concept, however. To insure sustainability, it is imperative that water withdrawal limits be established based on hydrologic principles of mass balance (Sophocleous, 2000).

Rising expectations concerning levels of services, protection of the environment, and enhanced sustainability are increasing demands on the urban wastewater system (Butler and Schutze, 2005). To achieve sustainable development, the principles for designing wastewater treatment system alternatives, in conjunction with urban water and wastewater policy limitations, must be developed (Berndtsson and Hyvonen, 2002). To be sustainable, wastewater technology assessment should include community participation within the decision-making process and an environmental education component with all alternative wastewater treatment systems (Burkhard, et al, 2000).

Huang and Xia (2001) state that humanity has the ability to make development sustainable, to ensure that it meets the needs of the present without compromising the ability

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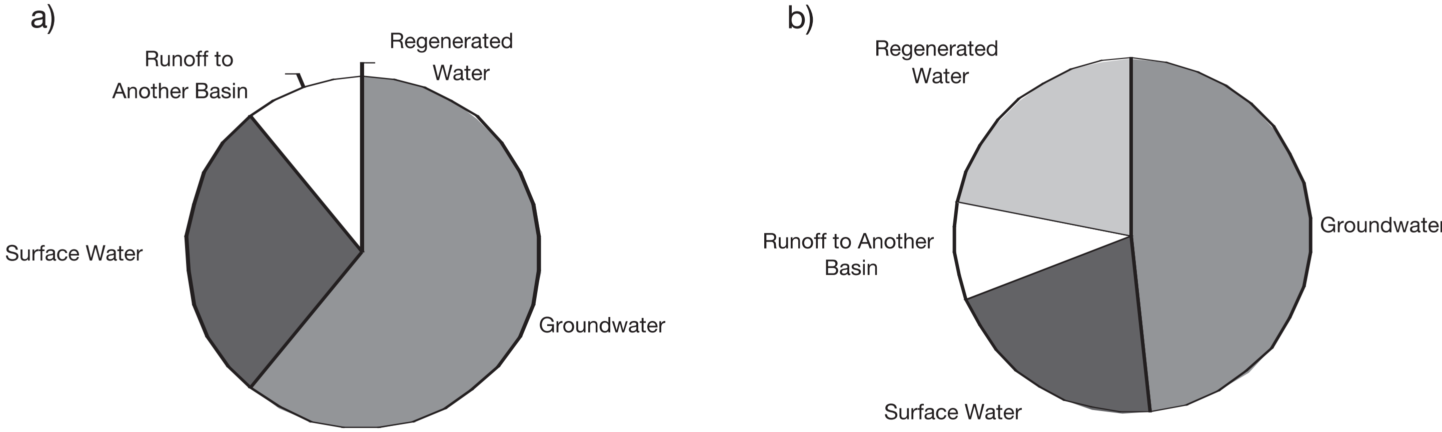

Figure 1a – An example of surface water and groundwater supplies. Figure 1b – Expansion of regenerated supplies in the basin leads to additional supplies (the area of the groundwater and surface water wedges are the same as Figure 1a)

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of future generations to meet their own needs. To achieve such sustainable practices such as water supply, groundwater recharge, environmental mitigation, wastewater disposal, and stormwater discharge requires a series of decision-making processes that involved controlling environmental, institutional, planning, and regulatory constraints (Ellis, et al, 2004).

Developing sustainable solutions involves:

- Problem Identification
- Data collection and analysis
- Development of goals and objectives
- Diagnosis of problems and issues
- Identification of alternatives
- Evaluation and recommendation on actions
- Implementation of action
- Monitoring

Comprehensive planning (diverse interests) is typically applied to basins to identify priorities and resolve conflicts. Functional planning looks only at one issue, such as:

- Water conservation versus demands
- Impaired water quality impacts on ecosystems
- Withdrawals < demands?
- Legal restrictions/allocations

Human needs (development, agriculture, transport, industry, etc.) compete with natural systems for clean air, clean water, materials, and waste disposal. Scarcity of the resource makes choices unavoidable. Economics, defined as the study of how scarce resources are allocated, applies easily to water-resources decisions on the surface, but lessens in clarity as unknown ecosystem, tourism, or other economic sectors that are not currently established may be grossly underestimated. While water economics is prescriptive, it should not be the only criterion for evaluating sustainability.

Scarcity occurs when there is more demand than supply, even when there is no cost. An example is for a salmon run where there are many demands for a finite resource:

- Commercial fishing
- Recreational fishing
- Tribal demands
- Return of the run to the stream for the future

Some demands can be met, but meeting all the demands can not happen. And which one is the priority? The economic demands may conflict with the ecological demands – agriculture versus ecosystem versus economics. The market does not value everything with respect to money, either. Legal agreements or treaties may distort the picture. And what is the value of wilderness? Options may include factors such as:

- Timber?
- Recreation?
- Fish?
- Biotic diversity?
- Watershed protection?
- Bequest to future generations?

In such cases, the value of the best alternative may not be provided. For example, if a wilderness area is timbered, will it cease to be a productive fishery? Is this a net positive or negative to the sustainability of the basin? The opportunity cost of the timber alternative equals the value of the fishery lost. Or, if you chose to build a hydropower plant as opposed to a coal-fired plant, the avoided cost is the cost to provide the pollution equipment to clean the air. There is a net positive to the project.

Defining Sustainability

Defining Sustainability includes:

- Understanding the water supply for a given basin.
- Understanding the water budget as currently allocated.
- Defining a hierarchy of uses based on water quality, timing and demand periods.
- Water quantity and water quality.
- Basin-based impacts of water allocations.
- Understanding the base condition, including the ecosystem.
- Understanding the current condition.
- Understanding the impact of changes from the base condition on the hydrologic cycle and ecosystem.
- Defining future needs and land-use changes.
- Defining current legal or regulatory issues.
- Understand hydrologic changes and the impact of each component to facilitate understanding of the impact of changes in the hydrologic cycle on the basin, including climatic changes.

To this end, information must be gathered to:

- Identify the current conditions.
- Create a model of your watershed.
- Calibrate the model.
- Identify the initial condition.
- Identify ecological features.
- Model initial condition and identify/quantify the changes from land-use changes.
- Identify changing land-use patterns.
- Model future watershed condition and identify/quantify the impact of changes.
- Identify ecosystem condition (good, fair, poor) versus disturbance (high, low, none).
- Identify options for water-supply needs.
- Develop alternative analysis.
- Model recommended alternatives.
- Identify political/social issues.
- Revise options to minimize adverse impacts in all sectors.
- Identify sentinel species to monitor.
- Identify additional options to mitigate adverse impacts to sentinel species/recovery plan.

For example, the "basin" defined as the

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South Florida Water Management District includes the Everglades. A water budget for the surficial aquifer for the basin can be developed from long-term rainfall data. The variability in that data can also be developed. These have been incorporated into district models (Note: The same can not be said at this time for the deeper aquifers that have no recharge area in the district). Likewise, defining the total water, both surface and groundwater needs to be generated (see Figure 1a).

To a degree, these factors have been incorporated into current models. A key factor is defining the water-quality limitations of these waters.

The ecosystem in Florida requires much higher quality water than agricultural use. Urban users require water quality somewhere between the two, depending on how much treatment is provided. The reuse of stormwater, wastewater, and agricultural runoff by other users with lower water-quality demands (irrigation) can expand the "pie" (see Figure 1b). Regenerated supplies that fail to meet water-quality requirements of other users fail to add to the "pie."

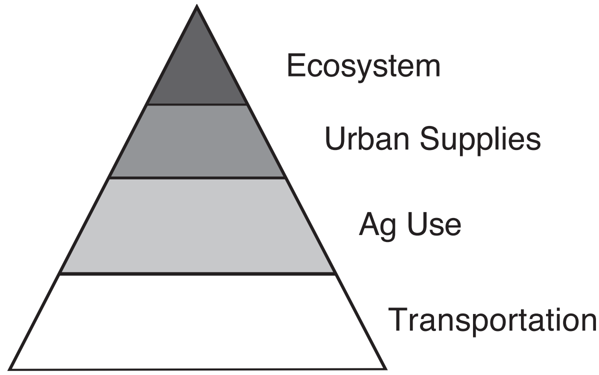

Figure 2 – Hierarchy of water quality needs?

Figure 2 is an example of the hierarchy that might be generated for water-quality uses. For a sustainable basin, the water needed by the ecosystem should be the highest quality water, which is what has been recognized by regulatory agencies in South Florida. Then, are urban or agricultural users the next priority? Who has first access to the water? Is this an appropriate policy? What are the downsides to that access?

Decisions must be made as to the long-term sustainability of a basin. The problem is determining what to measure. Figure 3 shows how economists can find an optimal solution, using only economics. But much is not valued or undervalued. As an example for South Florida:

1. What is agriculture's role in the long-term sustainability of water supplies for South Florida?
2. How is future development to be implemented in South Florida to achieve sustainability?
3. What impact will that have on the long-term sustainability of the basin?
4. How can we value South Florida ecosystems (recreational as well as societal)?
5. What is the economic value of the Biscayne and other surficial aquifer systems?
6. Have weather patterns impacted water supplies, coastal conditions, and/or reefs?

Few of these types of questions have easily defined values, and many other questions are unasked here. All too often, water-supply studies focus on the short-term or narrow needs of the agency, not the sustainability of the basin. Changes in the hydrologic cycle, wet/dry conditions, etc., may bring unexpected changes in the future. Care must be exercised to insure that these issues are acknowledged.

Conclusions

Sustainability implies a process which can be continued indefinitely—a course of action that does not include within itself the seeds of its own end or defeat. In 1987 the World Commission on Environment and Development created the following as a definition of sustainability:

"*…a sustainable society is one that meets the needs to the present without compromising the ability of future generations to meet their own needs.*"

The report goes on the state that the World Bank:

"*…is committed to promoting sustainable development and the proposition that economic growth, the alleviation of poverty and sound environmental management are in many cases mutually consistent objectives (Pezzey, 1992).*"

The focus on sustainable development and the interdependence of the economy and the basin environment are increasingly important concepts. Issues inherent to answering questions about sustainability include (Pezzey, 1992):

- Is sustainable development a process or a state?
- Does sustainable resource use require that every resource stock must not decline?
- What is the relevance of natural resource accounting?
- Is a sustainable resource a means or an end?
- What distinguishes economic growth and environmental improvements as mutually consistent objectives?
- How much sustainable development can be furthered by simply enforcing property rights or environmental laws?
- How can investment be attracted in the long-term?

Sustainability in this context requires that human use of the world does not detract from the seventh generation's ability to derive the same benefits from similar activities 200 years from now (Newton, 2003)

Most experts identify the biggest detriments to the sustainability of water supplies as a failure to fully understand the ramifications of the concept and the inability of elected officials and administrators to make difficult decisions, such as limiting land-use changes and development, without viewing the long-term consequences of such actions.

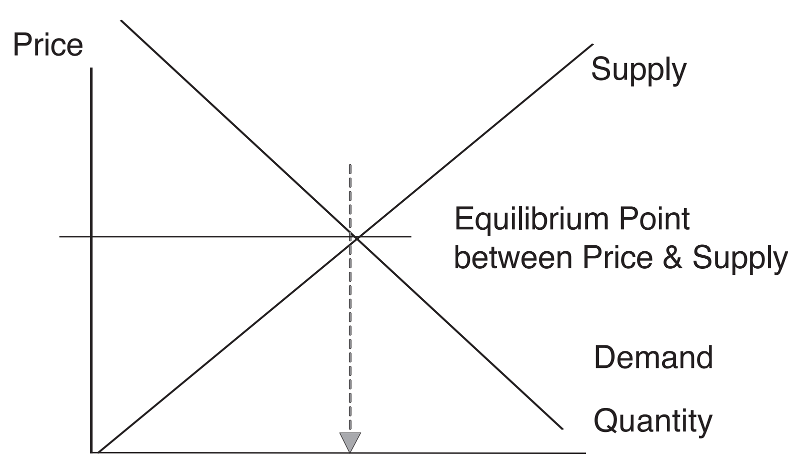

Figure 3 – Finding the optimal solution?

The concept is best stated by the following ancient proverb:

"Treat the Earth well. It was not given to you by your parents; it was loaned to you by your children." (indigenouspeople.net, 2006)

References

- *Adriaens, P.; Goovaerts, P.; Skerlos, S.; Edwards, E.; and Egli, T. (2003), "Intelligent Infrastructure for Sustainable Potable water: a roundtable for emerging transnational research and technology development needs," Biotechnology Advances, Vol. 22, pp 119-134.*
- *Barten, P.K. and Ernst, C. E. (2004), "Land Conservation and Watershed Management for Source Protection," JAWWA, Vol. 96, No. 4, p. 121-135.*
- *Beck, M.B. (2005), "Vulnerability of Water Quality in Intensively Developing Urban Watersheds," Environmental Modeling and Software, Vol. 20, pp. 381-400.*
- *Berndtsson, J.C. and Hyvonen, I. (2002), "Are there Sustainable Alternatives to Water-based sanitation system - Practical Illustrations and Policy Issues," Water Policy, Vol. 4, pp 515-530,*
- *Burkhard, R.; Deletic, A.; and Craig, A. (2000), "Techniques for Water and Wastewater Management: A review of Techniques and Their integration in Planning," Urban Water, Vol. 2, pp 197-221.*
- *Butler, D. and Schultze, M. (2005), "Integrating Simulation Models with a View to Optimal Control of Urban Wastewater Systems," Environmental Modeling and Software, Vol. 20 pp. 415-426.*
- *Elkins, P. (2003), "Identifying Critical Natural Capital-Conclusions about Critical Natural Capital," Ecological Economics, Vol. 44, pp. 277-292.*
- *Ellis, J.B.; Deautsch, J-C.; Mouchel, J-M.; Scholes, L.; and Revitt, M.D. (2004), "Multi-criteria Decision Approaches to Support Sustainable Drainage Options for the Treatment of Highway and Urban Runoff," Science of the Total Environment, Vol. 334-335, pp. 251-260.*
- *Haigh, M.J.; Jansky, L.; and Hellin, J. (2004), "Headwater Deforestation: A challenge for Environmental Management," Global Environmental Change, Vol. 14, pp. 51-61.*
- *http://www.indigenouspeople.net/quotes.htm*
- *Huang, G.H. and Xia, J (2000), "Barriers to Sustainable Water Quality Management," Journal of Environmental Management, Vol. 61, pp. 1-23.*
- *Meadows, D.; Meadows, D.; and Randers, J. (2004), Limits to Growth: The 30 year Update, Chelsea Green Publishing Co., White River Junction, VT.*
- *Murley, J. (2006), Charting the Course, Where is South Florida Heading, Florida Atlantic University, Boca Raton, FL.*
- *National Research Council (NRC – 2004), Assigning Economic Value to Natural Resources, National Academy Press, Washington, DC.*
- *Newton, L (2003), Ethics and Sustainability, Sustainable Development and the Moral Life, Prentice Hall, Upper Saddle River, NJ.*
- *Palme, U., Lundin, M.; Tillman, A.M.; and Molander, S. (2005) Sustainable Development Indicators for Wastewater Systems – Researches and Indicator Uses in a Cooperative Case Study," Resources, Conservation and Recycling, Vol. 43, pp 293-311.*
- *Pearce, D., and Moran, D. (1994), The Economic Value of Diversity, IUCN, Earthscan Publications Ltd, London, UK.*
- *Popp, J.; Hoag, D.; and Hyatt, D.E., (2001), "Sustainabiilty Indices with Multiple Objectives," Ecological Indicators, Vol. 1, pp. 37-47.*
- *Prato, T. (2005), "A Fuzzy logic approach for evaluating ecosystem sustainability," Ecological Modeling, (article in press).*
- *Pezzey, H.J. (1992), Sustainable Development Concepts, An Economic Analysis, World Bank , New York, NY*
- *Rogers, P.; de Silva, R.; and Bhatia, R. (2002), "Water is an Economic Good: How to use Prices to Promote equity, efficiency and sustainability," Water Policy, Vol. 4, pp. 1-17.*
- *Sophoeleous, M (2000), "From Safe Yield to Sustainable Development of Water Resources, - the Kansas Experience," Journal of Hydrology, Vol. 235, pp. 27-43.*
- *Starkl, M. and Brunner, N. (2004), "Feasibility versus Sustainability in Urban Water Management," Journal of Environmental Management, Vol. 71, pp, 245-260.*
- *Tippett, J. (2005), "The Value of Combining a systems view of Sustainability with Participatory Protocol for Ecologically Informed Design in River Basins," Environmental Modeling and Software, Vol. 20, pp 119-139.*
- *USGS (2005), Sustainable Water Resources Roundtable – Preliminary Report, USGS, Washington, DC.*
- *Virjee, K. and Gaskin, S. (2005), "Fuzzy Cost Recovery in Planning for Sustainable Water Supply Systems in Developing Countries," Energy, Vol. 30, pp, 1329-1341.*