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Applying the Concept of Sustainability to Water Resources Management

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The purpose of this paper is to explore the fundamental concepts of sustainability and sustainable development and their application to water resources management. It focuses particularly on the need to improve feedbacks relevant to water resources by developing criteria and indicators based on these concepts.

Sustainability is a concept that describes a dynamic condition of complex systems, particularly the biosphere of Earth and the human socio-economic systems within it. It reflects both our fundamental values and our knowledge of the fundamental nature of life on Earth. Sustainable development is a program of action, a set of principles and ways of thinking about patterns of human activity that can be derived from the concept of sustainability and from our knowledge of how the world works. Sustainable development is also a social movement, a set of beliefs about how human activities should be conducted, that has been expanding in acceptance and applicability throughout the world for almost two decades. Sustainable development takes sustainability as an overarching long-term goal for humanity. It is clear that because water is essential to all life, water resources management, using the principles of sustainable development, will be essential for achieving sustainability.

This paper will address three questions:

- What are the key concepts?
- How will we know if we are succeeding?
- How can these concepts be applied to water resources management?

What Are the Key Concepts?

Three key concepts will be discussed:

- Sustainability,
- Sustainable development, and
- The importance of feedback in achieving sustainability.

Sustainability is an expression of people's basic values and concerns. It reflects our desires for the good life and our hopes that it will endure for future generations. It encompasses our pursuit of material well-being, our enjoyment of and connection to the environment, and recognition of the value of our relationships with each other.

Often sustainability is expressed in more conceptual terms taken from various sciences. A fundamental basis for the concept is the recognition in biology and ecology that sustainability is a result of the underlying organization of life in Earth's biosphere which has endured for over 3 billion years. Sustainability is the most miraculous and awe inspiring achievement of life. The processes through which sustainability has occurred should be our primary source of understanding about its nature. Fritjof Capra has described many of these fundamental concepts in his book *The Hidden Connection*: life is comprised of complex, self-organizing networks of chemical processes, cells and organisms in which each part adjusts its structure and its behavior in response to feedback from its interactions with other parts. The essence of life is the ability to learn and do what works, to adapt, to evolve, to endure (Capra 2002).

Ecology has also provided a concept of sustainability that is somewhat more applicable to the human situation—the notion of carrying capacity. The population of a given species must of necessity "live within the carrying capacity" afforded it by the ecosystem of which it is a part. That carrying capacity results from the flows of food, water, light, and shelter needed by the individuals of the species. These flows are provided by processes that are cyclical and renewable.

When the population exceeds the carrying capacity of its environment in some way, the resulting degradation in the flows of food, water or shelter will eventually cause sufficient declines in the population to bring it back within the limits of the environment's carrying capacity. A population thus keeps its use of food, water, light and shelter within the renewable flows made possible by its environment. The carrying capacity concept makes us mindful that every species experiences limits in its relationship with its environment.

Economics also provides a concept of sustainability that we can draw upon, namely, the "don't spend principal." This concept was first fully developed by Hicks who defined income as the amount that can be spent for consumption without decreasing the productive capacity of the capital assets from which the income is derived (Hicks 1946). If the capacity to produce income is to be maintained, the depreciation of capital must be offset by investment in its replacement. Thus, sustainability requires that consumption not cause the liquidation or decline of capital.

Economics at its most fundamental level deals with the scarcity of resources and thus reflects recognition of the limits of human energy, economic capital, and the environment. The push for economic growth, however, places great emphasis on the substitutability of resources and goods as well as on technological development as ways to push back the limits of scarcity. Many uses of technology substitute human-made capital for natural capital. For some, this seems to be an effort to ignore or repeal the carrying capacity concept. As we shall see, these issues stem from problems in deciding what counts and what to count in keeping track of capital.

In these examples, sustainability is a dynamic condition to be maintained through appropriate processes. It is rather like the goal of a juggler who wants to amaze us by keeping six balls in the air while twirling a hula hoop around his waist and standing on one leg on a tight rope. (Yes, it might be that difficult and it certainly is that amazing.) It is achieved through movements, through constant adjustments of many actions each to the others.

From these concepts, we can see that sustainability is a dynamic condition of the biosphere and its various systems, focusing particularly on human social and economic systems and their interactions with the non-human elements of the biosphere, the environment. (For a discussion of systems concepts related to sustainability, see Kranz et al. in this volume.) Many dynamic elements are interacting with each other in ways that allow each element to adjust while the whole endures.

Sustainable development is a program of action that has emerged from peoples' basic values, from concerns about the consequences of past development, and from scientific concepts of sustainability. The most widely accepted statement of sustainable development was set forth by the Brundtland Commission in 1987: "Sustainable development is development that meets the needs of the current generation without compromising the opportunities of future generations to meet their needs" (World Commission on Environment and Development 1987). The term has come to encompass the economic, environmental and social realms, focusing particularly on the unintended or undesirable environmental and social consequences of economic development. The concept of sustainable development has focused policy, management, and design efforts on the search for ways to increase economic output while reversing the degradation of environmental resources and making the distribution of economic and environmental outcomes more equitable.

Much effort has been devoted to identifying and promoting actions that are consistent with the principles of sustainable development. This effort is as important for water resources management as it is for any other sector. However, while such efforts are clearly needed, a long-run commitment to achieving sustainability must also recognize the possibility that our early ideas about how best to proceed may not be the most effective. In fact, the example set for humanity by the biosphere's achievement of sustainability shows us that it is a condition achieved through an ongoing process of

adaptation and evolution. Thus, to achieve sustainability over the long run, we need to strengthen our capacity for making continual improvements in human activities, adapting them to fit the biosphere as it changes. We need to be able to identify what is working and what is not so that we can repeat and extend our successes and solve the problems revealed by our failures.

The key is effective feedback and the capacity to respond with appropriate changes in human social and economic activities.

The importance of feedback can be illustrated by a comparison of smart and dumb bombs. Dumb bombs are ballistic. They are aimed and launched. Whether or not they will hit their target can be neither predicted nor affected by human agents once they are launched. Smart bombs, on the other hand, have a built-in capacity for continual adjustment of their flight path. They have a subsystem that allows their direction to be changed slightly from time to time in response to information about the relationship between their path and the target. It is the capacity to create, receive, and respond to feedback that makes smart bombs smart and increases their accuracy in hitting targets.

Feedbacks are clearly an important element in the sustainability of the biosphere. They also contribute substantially to the success of democratic systems of government, the effectiveness of market-based economic systems, and the power of science. A key feature that has made these three institutions effective is their capacities for systematic feedback. Governments receive feedback through elections and statistics. Individuals, businesses, and governments receive economic feedbacks through systems of accounting for their transactions. The process of science relies on feedback from repeated testing of scientific hypotheses. The effectiveness of feedback in human activities should not be surprising in light of its importance in helping life to endure for 4 billion years.

Unfortunately, the powerful feedbacks inherent in these systems have weaknesses. Market transactions do not provide feedback on costs that arise in elements of the environment that no one owns because there are no transactions to be counted. Democratic systems of government get disproportionately more feedback from individuals with more resources and almost no feedback from people outside the engaged citizenry. Science does not provide feedback on problems too difficult to merit research or processes that do not fit existing disciplinary boundaries. We need to address such weaknesses in our feedback systems if we are to achieve sustainability over the long run.

How Will We Know Whether We Are Succeeding?

What sorts of feedback are needed to help us evolve policies, management practices, technologies, and lifestyles that promote sustainability? This brings us to the main point of this paper: how can we determine the extent to which the patterns of interaction among human social and economic systems and the environment are contributing to sustainability? To answer this question, substantial efforts are being made to develop the means to measure sustainability, particularly through the use of statistical indicators. To identify appropriate indicators, we need to translate the general concepts of sustainability into categories of measurable phenomena.

Many different approaches have been suggested for measuring sustainability. For a useful survey, see *Measuring Sustainable Development* (Atkinson et al. 1997). The approach that seems most consistent with the concepts summarized above is called the capital maintenance approach. (For an overall application of this approach, see US Interagency Working Group on Sustainable Development Indicators 1998) It recognizes that in addition to the human-made capital in our economic systems, there are also forms of natural capital in the environment (Prugh et al. 1995) and social capital in our cultures, institutions, and systems of governance (The World Bank 1997).

The development of criteria and indicators for assessing sustainability has been undertaken for forest management by countries participating in the Montreal Process following the 1992 UN Conference on Environment and Development in Rio de Janerio. Although not explicitly based on the concept of capital maintenance, the seven criteria agreed to by the countries signing the Santiago Agreement are consistent with the concept (Sustaining 1995). Sixty-seven indicators are grouped under the seven criteria. Similar criteria and indicators are being developed for assessing rangelands and mineral and energy resources.

In this use of the term "capital," we include resources, assets, and other durable productive capacities in all three realms. Capital includes both renewable natural resource systems and non-renewable resources. It includes the capacities of the environment to absorb and disperse wastes and the capacity of the biosphere and its various subsystems to adapt and evolve. In addition, it includes the capacities for undertaking coordinated and cooperative activity made possible by traditions, relationships, knowledge, and institutions.

All three types of capital, appropriately used, can provide an enduring flow of matter and energy in the various forms that can be transformed into goods, services, and experiences that meet human needs. While current generations draw upon all three forms of capital to meet current needs, they also pass them along to future generations in degraded or enhanced condition. The capital being passed along to future generations is the primary source of the opportunities they will have to meet their needs. Thus, by maintaining capital we can avoid compromising those opportunities as the Brundtland statement requires.

The capital maintenance approach is also consistent with the ecological and economic concepts of sustainability. In broad terms, the three types of capital provide the carrying capacity that supports the human population. We can live within that carrying capacity by maintaining or enhancing our capital rather than degrading it. From the economic perspective, the three types of capital constitute a wider principal that we must not consume if its benefits are to endure. Maintaining capital is precisely the requirement embodied by Hicks' principle.

How Can These Concepts Be Applied to Water Resources Management?

Water is essential to life and the life processes of all living things. It is thus a primary basis for sustaining life on Earth.

Water is essential for meeting human needs and wants. It is used directly for drinking, sanitation, and food production, and only slightly less directly for economic production across a very broad range of sectors. It is thus a primary basis for sustaining human well-being for generations to come.

The global water cycle and the factors that affect the flow of water on and within the Earth's crust provide a natural capacity to supply water. The availability of water varies in time and space. In many places, human populations have tapped the available water to such an extent that there are times when there is not enough for all the competing human uses, much less for supporting the functioning of aquatic and terrestrial ecosystems. There are also times when there is far too much water in some places, and its interaction with humans and their artifacts is costly to humans. The natural capital of water resources systems includes both assets and liabilities.

For centuries, water resources management has involved the alteration of the flows of water to the benefit of humans. Humans have built infrastructure to store, treat, and deliver water; to control its flow in rivers for flood control and navigation; and to generate electrical power. Humans have augmented natural capital with human-made capital in order to make water available for human uses.

Unfortunately, many of our most powerful and extensive alterations of the flows of water have had long-run consequences that are unintended, unanticipated, and undesirable. The gains in some uses have been accompanied by losses in other uses, particularly as the natural capital supporting those uses was replaced or degraded.

Developing and using a set of criteria and indicators based on the concept of capital maintenance can improve the feedback available to water resources policy makers, managers, and the public. In particular, it can help us overcome the weaknesses in existing feedback systems that report very effectively on some aspects of water resources availability and use and less effectively on other aspects. The criteria and indicators identified using this approach can also be used to systematize the evaluation of policies, investment decisions and management practices.

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Notes

[1] The views expressed in this paper are the personal views of the author and not necessarily those of the White House Council on Environmental Quality or the U.S. Government.

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