UNIVERSITIES COUNCIL ON WATER RESOURCES
WATER RESOURCES UPDATE, ISSUE 127, PAGES 59-67, FEBRUARY 2004

Water Resources Criteria and Indicators

Ethan Timothy Smith

Sustainable Water Resources Roundtable

In June 2003, the Sustainable Water Resources Roundtable (SWRR) held a meeting at the U.S.G.S. National Center in Reston, Virginia. One purpose of the meeting was to ascertain what kind of water resources sustainability indicators have already been developed by prior studies. The SWRR hopes in the future to develop indicators that will be widely useful, and this effort will be facilitated by taking advantage of the substantial work accomplished to date and by avoiding duplication of these studies. The content of this paper is a presentation that reviews at least some of the major existing studies and that was made at the June meeting.

It is worth noting that not all the studies focus exclusively on water resources. However, many of the roundtables, including that on Sustainable Forests, look upon water as a vital component of their core disciplines. It appears that water resources constitutes a cross-cutting subject that will be an inescapable reality for a whole range of disciplines. Water issues have been mentioned as perhaps one of the most important subjects with which the Twenty-first Century will have to deal . This view reinforces the hypothesis that so important a subject well deserves its own venue for discussion, which in fact is a role that SWRR aspires to fill, at least insofar as exchange of information is concerned.

The paper represents an interpretation of what conclusions can be drawn from the existing studies. Discussion at the SWRR meeting touched on many aspects of water indicators that are not necessarily captured here. The forthcoming proceedings of the June meeting will include a great deal more detail about the entire discussion, and the reader is referred to the SWRR website (http://water.usgs.gov/wicp/acwi/swrr/), where those materials will appear in the future. An appendix to this paper includes materials from other roundtables.

What Studies Exist about Sustainability?

The following review is based on seven existing studies that include criteria for selecting indicators as well as the indicators themselves. The links to each of these studies can be found on the SWRR website (http://water.usgs.gov/wicp/acwi/swrr/), and these studies are also cited in the references section of this paper.

Questions to be Addressed

To begin the process of examining water sustainability, the following questions should be addressed:

(1) What key questions must be answered to determine the degree to which the nation is on a sustainable course with respect to its use and management of water resources? What are the issues that involve water resources?

(2) What indicators would be most useful in addressing these questions and defining sustainability? How should sustainability be measured and monitored? For what purposes would indicators be useful?

(3) What water information and statistics are needed to develop indicators? How can this be done? What institutions should carry out these efforts?
(4) What sources of data or statistics should be considered for developing indicators of sustainable water resources in the United States? A growing compilation of possible sources is maintained on the SWRR website (http://water.usgs.gov/wicp/acwi/swrr/).
(5) If new data should be collected for these indicators, what organizations should do it and why? What are the gaps in data collection that should be filled? What options exist for filling these data gaps?

Some Technical Problems

Number: Upon even cursory consideration of these questions, some technical problems arise. For example, because of the ubiquitous nature of water, it is very easy to make a long list of possible necessary indicators. A key problem therefore is determining how many indicators are needed. The use of too many will lead to an inability both to comprehend the sustainability problem and to make necessary tradeoffs between various parts of the system to improve its functioning. Some thinking along these lines leads to another problem: it will be impossible to achieve a comprehensive picture of water resources if too few are selected. Finding a balance between these competing needs is one technical problem to be solved.

Scale: Those who have thought about sustainability have noted that there is also a problem associated with geographic scale. Sustainability at the national scale does not assure sustainability at other scales. This problem is reminiscent of classic systems analysis cases in which the sum of a set of optimal results may only accidentally yield an optimal result for the whole. In more concrete terms, this kind of problem has been described as the tragedy of the commons. Quite a bit has been written about how these problems relate to water resources conflicts between upstream and downstream users. It appears that some water indicators, like economic indicators such as employment, may be nested geographically at many scales. However, other indicators may not have this property. If it is true that water indicators are somehow connected to public policy issues, then we may have local issues with associated indicators that are relevant at the community level in many parts of the nation, yet even this feature may depend on regional variations in physical conditions(e.g., between the humid East and the arid West). When the national scale is considered, the water resources issues that seem important may be quite different, thus requiring different indicators to measure change for national decision makers.

Duration: The concept of sustainability clearly has a temporal dimension.. What time span defines a sustainable system? We note that whole civilizations come and go over time spans of hundreds or thousands of years. Those time spans seem to be connected to the longevity of institutions, like governments, that can maintain some degree of management over their water resources sufficient to be self-sustaining. On this time scale, water resources seems to be a topic embedded within even larger considerations that have to do with how nations maintain their existence. We should recognize this fact, although these larger concerns are beyond the scope of this paper. However, time remains an important factor to be considered.

Prioritization: Given these thoughts and daunted perhaps by the possibility of unreasonably long lists of water indicators, we might think about how to prioritize indicators. Possibly, we do not have to consider them all simultaneously. This possibility of course implies that we are somehow prioritizing the issues associated with the indicators either by topic or geography. Thus far, our system of government has not developed any single way to deal with this problem. Indeed, public policy issues sometimes seem to have life cycles of their own. Sometimes they spring from a seminal book, like *Silent Spring*; other times they are brought forward by some charismatic political leader. We can think of issues that have seemed to rise and fall only to be replaced by some other issue. Unlike organisms, however, issues can rise again and sometimes in a poorly understood evolutionary way. Perhaps, the indicators associated with the public policy issues are arranged in a similar hierarchy. If this is the case, we might think that indicators of point source water pollution have a lesser priority than those for non-point source pollution and that traditional indicators of water quality, like dissolved oxygen, have a lesser priority than indicators about endocrine disruptors or pharmaceuticals. We should emphasize that these conclusions are not stated as undisputed facts but to illustrate the complexity of the problem.

Assuming that issues and their associated indicators come and go in some Darwinian fashion, the current practice (in which agencies and others develop indicators from almost any set of statistics) may actually embody a useful process. By throwing out this large collection of so-called indicators, the sorting process of history would determine which is used at any given time. This natural selection of indicators would depend on the current popularity of a given issue, which might well vary enormously. If this process is true, it probably makes our job more difficult. If we do not know with any certainty which issues, indicators, and statistics will be needed, it will be very difficult to maintain adequate data collection programs.

Professional Literature: Clearly, one of the cardinal sins of the researcher is to assume that no one has worked on the subject before. Thus, we should recognize at the outset that water indicators have been developed by a wide variety of organizations, perhaps not overtly linked with the notion of sustainability. How can indicators that others have developed be used and improved? What are the relationships among such water indicators? Among the many indicators that have been noted on the SWRR website are those developed by the U.S. Environmental Protection Agency, the U.S. Geological Survey, and the Heinz Center. Many scientists have worked on these and other studies. By tapping this professional literature, we hope to foster the development of water sustainability indicators.

A Systems Approach to Sustainability

Systems analysis offers some clues about the nature of sustainability. By reasoning about how systems behave under a variety of conditions, we can perhaps better understand the properties of a sustainable water resources system.

Rate of Change: When examining a system, we should ask how quickly it can change? Systems are very sensitive to rate of change, especially the rate of change of inputs. Too great a change in too short a time leads to undesirable or unstable system behavior. Examples show that a sudden spike or step function will lead to unexpected results. This holds true for changes in both directions. A sudden upswing or drop in prices can be undesirable in either case. We may call the results inflation or depression, but these terms are just ways of naming a set of unwanted effects.

Static vs. Dynamic Systems: It was once assumed that our human and natural systems could reach a state of equilibrium. Models have been built around ideas like comparative statics that depict how elements exist in balance. This research implies that some kind of steady state is the norm. More recently, however, it appears that human systems embody a set of conditions that may seek equilibrium in a dynamic sense but never reach it. This may be the case because the forces that impact the system are changing faster than the system can adjust, thus making it impossible to reach equilibrium.

Buffering: It is important to realize that the buffering capacity of a system has limits. This capacity also determines the amount of "wiggle room" that we have to carry out policies that provide benefits without real damage to other parts of the system. The system is not so tightly determined that no changes can be made, nor is it so flexible that infinite action will make no difference. The balance lies somewhere between. Possibly a good example of this situation is national debt, which can continue for perhaps very long periods but which ultimately lead to serious system degradation.

Deterministic vs. Stochastic Systems: In days gone by, human relationships with the physical world have been defined in deterministic terms (i.e., a change in x must have an effect on y). However, now it appears that our systems are more stochastic. A change in x thus will change y but only with some probability. Multiple causes lead to multiple effects with probabilities mediating each link in the system. Needless to say, such systems are much harder to model. The nature of the system makes it difficult to intervene in a way that is highly likely to produce only positive results. It is almost certain that the so-called law of unintended consequences is rooted in this system property, even assuming that all parts of the system are well known, which is not usually the case.

A corollary of this stochastic property involves the nature of sustainability. When we deal with such systems, all the variables exist in a probabilistic context. Each one can be represented by some mean

Table 1. The Role of Various Institutions in Measuring and Implementing Water Resources Sustainability.

	Federal, State, & Local Government	Business Community	Professional Associations	Public Interest Groups	Academia	Congress & Legislatures
Data Collection	X					X
Archiving	X					
Develop Statistics	X					
Decide on Indicators	X	X	X	X	X	
Report & Outreach	X		X		X	
Develop Policy	X					X
Evaluate Performance	X	X	X	X	X	
Determine Improvements	X	X			X	X

value, but in truth has its own probability distribution function. This means that the very nature of system sustainability is probabilistic and can only be stated in terms, for example, of minimum and maximum values. Needless to say, we are far from being able to do this now in any reasonable way.

Wild Cards and Tipping Points: Large-scale patterns seem to suggest that long-term trends may continue for long periods without much change, even though the results may be harmful to the system that represents civilization. The structure becomes increasingly unstable. If a wild card event occurs with some probability, this can cause rapid unexpected change in the system, in the same way that a input step function might. This kind of tipping point is hard to anticipate or prepare for. It might well be forecast, but prevailing forces tend to discount it as an unlikely event compared to daily occurrences. An example of this behavior might be the recurrent tendency to build in flood plains, in which the demonstrated benefits of the location are thought to outweigh the small chance that a flood will occur.

Here it may be useful to connect these ideas with the concept of duration discussed above. The time frame of an individual is greatly different than that of the system (i.e., civilization) within which he exists. Rational decisions on an individual basis may, especially in the aggregate, lead to the gradual degradation of the system as a whole. Depending on the factors noted in the preceding paragraph, various outcomes can occur. Gradual and irreversible negative changes in the whole system may occur; such changes may in fact be reversible, but only at a cost considered exorbitant by those then living. Alternatively, the negative changes that originally happened gradually may be stopped or reversed, but only by measures that must be carried out in a short time. This would be like sending a step function through the system, which is usually a destabilizing action. All these effects lead to outcomes for the whole system, which can well make it unsustainable. History offers some interesting examples that look very much like exactly this process. In parts of the Middle East we can detect from satellite the remains of irrigation canals that were constructed by successive civilizations, which occupied the same region. There are repeated cycles of canal building, followed by increasing soil salination, followed later by the collapse of the central government. We cannot push this example too far, since there are clearly many other things besides water that can contribute to this kind of change. But it certainly would appear that a progressive inability to maintain an agricultural food supply, in an arid region, would not promote the stability of the government then in existence.

A Mosaic of Institutions

Faced with this daunting set of problems, it is no wonder that a generally accepted set of water sustainability indicators has not yet appeared. The job now is to organize the effort, recognizing that there is ample work to go around. In this spirit this issue contains thoughts about various aspects of water indicators, but this is just the beginning. The illustration included in this paper is a first attempt to develop a set of tasks that should be pursued as well as organizations needed to address these tasks. Some choices are noted in the cells of the matrix, but the reader is invited to think carefully about all aspects of the matrix. There are quite likely many ways in which it can be improved, and we are looking for those ideas.

While considering this set of ideas, it is well to remember that in our experience no single organization that works on an issue can maintain its focus for more than perhaps five years. Organizations also evolve over time; there are reorganizations, budget problems, and partners that may influence the organization change or disappear. Clearly, our organizations, which are the primary tools for our efforts, must also be subject to change. For this reason we suggest that a diversified portfolio of organizations (several in each category) work simultaneously.

What do we need to learn?

By examining these studies, we hope to draw on knowledge that will help the SWRR address such important questions as:

What criteria do others use to select good indicators?
How can these criteria be adapted for SWRR's use?
What do others define as an indicator?
How can these indicators be used by SWRR?
What indicators might be added or deleted?
What is the SWRR rationale for these choices?

Criteria for Selecting Indicators

First, we can look in the professional literature to see *what kind of criteria* are proposed for selecting good indicators. One such source lists the following criteria (Moffatt et al. 2001):

The indicator or the information from which it is calculated should be:

-readily available,
-relatively easy to understand,
-about something that can be measured,
-something believed to be important in its own right,
-based on information that can be used to compare different geographical areas,
-internationally comparable, and
-there should only be a short lag time between the state of affairs referred to and the indicator becoming available.

Summary: Criteria for Indicators Used in Studies.

If we look at the seven studies, we see that the definitions of criteria for selecting indicators are quite varied. For example, here are how the different studies conceive of criteria.

Roundtable on Sustainable Forests:
Stated as goals.
Sustainable Rangeland Roundtable:
Stated as goals.
Sustainable Minerals Roundtable:
Goals supplemented by indicator properties.
Sustainable Development in the US:
Six technical indicator properties. These are similar to those used in the professional literature, as cited above.
State of the Nation's Ecosystems:
Goals plus some indicator properties.
EPA Report:
Quality, coverage, and suitability categories with details about indicator properties.
USGS Circular 1223:
Mix of indicator technical properties plus geographical and process requirements.

Summary: Water Indicators Used in Studies

Now, it is possible to summarize the very large number of water indicators used in the seven studies. Recall that the specific indicators for each study are in the appendix.

Roundtable on Sustainable Forests:
    Area, flow, biological diversity, quality.
Sustainable Rangeland Roundtable:
    Area, flow, erosion, biota, quality, channels, ground water change, wetlands, riparian extent and condition
Sustainable Minerals Roundtable:
    Quality compliance, problem sites withdrawal and ground water, use, consumption, discharge, recycling, reinjection, evaporation.
Sustainable Development in the US:
    Quality, supply vs. withdrawal
State of the Nation's Ecosystems:
    Area, length, chemical & physical conditions, biota, withdrawal, ground water level, disease, recreation
EPA Report:
    Area, length, use standards, withdrawal, ecosystems, riparian land cover, atmospheric deposition, runoff, sedimentation, toxic releases, nutrients, wetlands, coastal waters, eutrophication, drinking water quality, recreation, seafood consumption.
USGS Circular 1223:
    Surface & ground water availability (flow, storage); withdrawal, consumption, losses; water cycle (inflow, outflow, storage).

Conclusions

Although there are a few indicators that appear repeatedly, the seven studies examined show a great variety. The purposes of each study are different, so the indicators tend to be tailored to a particular purpose. For example, the Sustainable Minerals Roundtable is concerned with the problems associated with extractive mineral sites, and for that reason, there tends to be a concentration on water quality and compliance measures at individual sites. In some of the studies, water is just a part of the focus, which tends to preclude going into detail if a limited number of total indicators is an objective. Clearly, it will be much harder to grasp an overall picture if one must deal with a very large number of indicators.

Some types of indicators tend to recur. For example, some measures of water quantity are measured in flow, area, water use, or availability. The terminology may differ. Also, one will find measures of water quality in chemical and/or biological terms. Interestingly, it's much harder to find indicators of extreme hydrologic conditions, such as floods and droughts. There may be an assumption of "business as usual" underlying many of these studies.

Future selection of indicators for the SWRR may thus depend on how one defines water resources sustainability. If sustainability implies some form of long-term balance among environmental, economic, and cultural elements, then water indicators must be connected not only with other parts of the environment but also with the economy and culture. Substantial research problems exist in developing just how this might be done. It is likely that working on these problems will be part of the future work of the Water Roundtable, and perhaps finally lead to water indicators of sustainability that can be used by a wide variety of organizations throughout the nation.

Author Information

Dr. Ethan Timothy Smith was with the federal government for more than 30 years. He was with the Water Resources Division of the U.S. Geological Survey, and before that with the Environmental Protection Agency and its antecedent agencies. He has worked in hydrology, planning, conflict management, and other fields. He is currently retired from the USGS, and working as a volunteer to coordinate the Sustainable Water Resources Roundtable. He holds a doctorate in planning and policy development, a master's in city and regional planning, and a BS in physics.

References

Environmental Protection Agency. 2003. Draft Report on the Environment. Washington, DC. [Online]. Available at http://www.epa.gov/indicators/roe/html/roeWaterW.htm.

H. John Heinz III Center for Science, Economics and the Environment. 2003. Designing a Report on the State of the Nation's Ecosystems. Washington, DC, 119pp. [Online]. Available at http://www.heinzctr.org/ecosystems/intro/toc.shtmll.

Moffatt, Ian, Nick Hanley, and Mike D. Wilson. 2001. *Measuring and Modelling Sustainable Development.* New York: Parthenon Publishing.

Roundtable on Sustainable Forests. 2003. Criterion 4: Conservation and Maintenance of Soil and Water Resources. [Online]. Available at http://www.sustainableforests.net/C&I_workshops/ci_index.htmll.

Sustainable Minerals Roundtable. 2003. Ambient Environmental Indicators. [Online]. Available at http://www.unr.edu/mines/smrr.

Sustainable Rangelands Roundtable. 2003. Criteria and Indicators for Sustainable Rangelands. [Online]. Available at http://SustainableRangelands.cnr.colostate.edu.

U.S. Geological Survey. 2002. Concepts for National Assessment of Water Availability and Use. Report to Congress. Circular 1223. Reston, Virginia, 34pp. [Online]. Available at http://pubs.water.usgs.gov/circ1223/.

U.S. Interagency Working Group on Sustainable Development Indicators. 1998. *Sustainable Development in the United States, An Experimental Set of Indicators*. Washington, DC, [Online]. Available at http://www.sdi.gov/.

Appendix: Indicators for Each of the Seven Studies in Detail

Roundtable on Sustainable Forests

I. Area and percent of forestland managed primarily for protective functions, e.g., watersheds, flood protection, avalanche protection, riparian zones.
II. Percent of stream kilometers in forested catchments in which stream flow and timing has significantly deviated from the historic range of variation.
III. Percent of water bodies in forest areas (e.g., stream kilometers, lake hectares) with significant variance of biological diversity from the historic range of variability.
IV. Percent of water bodies in forest areas (as above) with significant variation from the historic range of variability in pH, dissolved oxygen, levels of chemicals (electrical conductivity), sedimentation, or temperature change.
V. Area and percent of forest land experiencing an accumulation of persistent toxic substances.

Sustainable Rangelands Roundtable

I. Area & percent of rangeland with accelerated soil erosion by water or wind.
II. Percent of water bodies in rangeland areas with significant changes in natural biotic assemblage composition.
III. Percent of surface water on rangeland areas with significant deterioration of their chemical, physical, and biological properties from acceptable levels.
IV. Changes in ground water systems.
V. Changes in the frequency and duration of surface no-flow periods in rangeland streams.
VI. Percentage of stream length in rangeland catchments in which stream channel geometry significantly deviates from the natural channel geometry.
VII. Number and extent of wetlands.
VIII. Extent and condition of riparian systems.

Sustainable Minerals Roundtable

I. Ambient Environmental Indicators
- A. Compliance status of mines and oil and gas with respect to water quality, under Clean Water Act or delegated state/tribal program, by 5th code hydrological unit watersheds; Number of 5th code hydrological unit watersheds with mines and oil and gas.
- B. Number of permitted extraction or processing sites where water withdrawal causes environmental problems, relative to total number of permitted sites.
- C. Ambient environmental quality: Number of permitted extraction sites where ground water is contaminated / total number of permitted sites.

II. Management of Extraction and Processing
- A. Water use, recycling & discharge: Water use efficiency. Sectoral water use, consumption, discharge, loss to evaporation, reinjection.

Sustainable Development in the U.S., IWGSDI

The study uses two national composite indicators, each made up of several statistics:

I. Surface Water Quality:
- A. Line graph showing trends for dissolved oxygen, fecal coliform bacteria, total dissolved lead, and total phosphorus.
- B. Pie charts showing percent of assessed
  - (1) rivers and streams;
  - (2) lakes, ponds, and reservoirs; and
  - (3) estuaries that support designated uses at a point in time.

II. Ratio of Renewable Water Supply to Withdrawals:
A. Line graph of trend in the ratio over time.
B. Bar chart of fresh ground and surface water withdrawals in the U.S., over time.

State of the Nation's Ecosystems, Heinz Center

I. System Dimensions
A. Extent: area and length
B. Alteration: extent of change

II. Chemical and Physical Conditions
A. Phosphorus in lakes, reservoirs, & large rivers
B. Nutrients: nitrogen & phosphorus in streams and ground water
C. Chemical contamination: pesticides, PCBs, heavy metals (streams, sediment, ground water, fish)
D. Changing stream flows
E . Water clarity (no data reported)

III. Biological Components
A. At-risk native species: number
B. Non-native animal species: number
C. Animal deaths and deformities: number
D. Status of freshwater animal communities (no data reported)
E. At-risk wetland & riparian plant communities: number
F. Stream habitat quality (no data reported)

IV. Human Uses
A. Water withdrawals: quantity, use
B. Ground water levels: rate of change (no data reported)
C. Waterborne human disease outbreaks: frequency
D. Freshwater recreational activities (no data reported)

EPA Report on the Environment

I. Water and Watersheds
A. What is the national condition of waters & watersheds?
(1) Miles/acres of rivers & lakes meeting water quality designated use standards.
(2) Water withdrawals (Heinz).
(3) Altered fresh water ecosystems (Heinz).
(4) Trophic status (NRC).
(5) Harmful algal blooms (Heinz).
B. What are the pressures on water quality?
(1) Percent urban land cover in riparian areas.
(2) Atmospheric deposition of nitrogen and mercury.
(3) Sediment and pesticide runoff.
(4) Contaminated sediment.
(5)Water withdrawal (Heinz).
(6)Toxic releases to water (TRI).
(7)Nutrient runoff (NRC).

II. Wetlands
A. What is the extent and condition of wetlands?
(1) Freshwater wetland extent and change.
(2) Coastal wetland extent and change.

III. Coastal Waters
A. What is the condition of coastal waters?
(1) Water clarity.
(2) Dissolved oxygen.
(3)Sea surface temperature (Heinz).

B. What are the pressures on estuarine waters?
(1) Atmospheric deposition of nitrogen.
(2) Nitrogen runoff.
(3) Toxic releases (TRI).
(4) Coastal eutrophication.
(5) Watershed export of nitrogen.

IV. Drinking Water
A. What is the quality of drinking water?
(1) Trends in population served by water systems meeting all health standards.
(2)Percent of assessed surface waters meeting designated drinking water standards.
B. What are the causes of drinking water contamination?
To be developed.
C. What are the health effects of consuming contaminated drinking water?
See Human Health Chapter.

V. Recreation In and On the Water
A. What is the condition of surface waters that support recreational use?
Number of beach-days that beaches are open.
B. What are the sources of recreational water pollution?

To be developed.

C. What are the health effects associated with recreation in contaminated water?

See Human Health Chapter.

VI. Consumption of Fish & Shellfish

A. What is the condition of surface waters that support fish & shellfish consumption?

(1)Fish tissue in coastal waters.

(2)River miles and lake acres with fish advisories.

(3) Waters meeting designated use for fish consumption.

(4) Shellfish bed closures.

(5) Watersheds exceeding water quality criteria for mercury, PCBs.

B. What are the contaminants in fish and shellfish and where do they originate?

To be developed.

C. What are the health effects of consuming contaminated fish and shellfish?

See Human Health Chapter.

USGS Circular 1223

Indicators of water availability include:

Surface-water indicators:

- Streamflow: annual, periodic, and long-term trends.
- Reservoir storage, construction, sedimentation, removal.
- Storage in large lakes, perennial snowfields, glaciers.

Ground-water indicators:

- Ground-water level indices re hydrogeologic environment and land-use setting.
- Changes in ground-water storage re withdrawal, saltwater intrusion, mine dewatering, land drainage.
- Number and capacity of supply wells and artificial recharge facilities.

Indicators of water use include:

- Total withdrawals by source (surface and ground water) and sector (public supply, domestic, commercial, irrigation, livestock, industrial, mining, thermoelectric power and hydropower).
- Reclaimed wastewater.
- Conveyance losses.
- Consumptive uses.

Water-Cycle Characterization:

Water budget for a geographical area is (Water inflow)-(Water Outflow)=(Change in Water Storage).

- Water Inflow: Precipitation, Surface-and-ground water inflow, Imported water.
- Water Outflow: Evaporation, Evapotranspiration, Surface-and-ground water outflow, Exported water.
- Change in Water Storage: Snowpack, Unsaturated Soil Zone, Streams, Rivers, Reservoirs, Aquifers.