PROCEEDINGS

Towards upstream/ downstream hydrosolidarity

A SIWI/IWRA SEMINAR
STOCKHOLM, August 14, 1999

SIWI

IWRA AIRE AIREH

The seminar was organized by
the Stockholm International Water Institute (SIWI)

in collaboration with
International Water Resources Association (IWRA)

with financial support from
Foundation for Strategic Environmental Research (MISTRA), Sweden
Ministry for Foreign Affairs, Sweden

Published 1999
by Stockholm International Water Institute, SIWI
Sveavägen 59
113 59 STOCKHOLM, SWEDEN

Front cover: Quadrata HB

Printed by Arkpressen

ISBN 91-973359-2-4

ISSN 1103-0127

CONTENTS

AUTHORS
in alphabetical order

Agarwal, Anil	Centre for Science & Environment Director *41, Tughlakabad Institutional Area,* *New Delhi 110 062* *telephone: +91 11 699 57 78* *e-mail*: cse@cseindia.org	India
Braga, Benedito	International Water Resources Association *President of the International Water Resources Association – IWRA* *Dept. of Civil Engineering – Colorado State University – Fort Collins, CO 80523* *telephone: +1 970 491 33 81* *e-mail:* benbraga@engr.colostate.edu	USA
Falkenmark, Malin	Stockholm International Water Institute *SIWI, Sveavägen 59, SE-113 59 Stockholm* *telephone: +46 8 522 139 77* *e-mail:* malin.falkenmark@siwi.org	Sweden
Folke, Carl	Stockholm University *Professor, Natural Resource Management* *Department of Systems Ecology* *Stockholm University, S-106 91 Stockholm* *telephone: +46 8 164 217* *e-mail*: calle@system.ecology.su.se	Sweden
Garduño, Hector	*FAO International Consultant* *Mirador 63, E-11,* *Col. Fuentes de Tepepan, Tlalpan 14648,* *Mexico D.F.,* *telephone +52 55 55 96 46* *E-mail:* hgv@mail.internet.com.mx	Mexico
Gleick, Peter H	Pacific Institute for Studies and Development	USA

Director, Pacific Institute for Studies in Development Environment, and Security
654 13th Street, Oakland, California 94612
telephone: +1 510 251-1600
e-mail: pgleick@pipeline.com

Gordon, Line Stockholm University Sweden
Ph.D. Student, Natural Resource Management
Department of Systems Ecology
Stockholm University, S-106 91 Stockholm
telephone: +46-8-164215
e-mail: line@system.ecology.su.se

Lee, Michael Department of Geography and Environmental Studies USA
Ph.D., Assistant Professor
California State University, Hayward
25800 Carlos Bee Blvd.
Hayward, CA 94542-3049
telephone: +1 510 885 31 55
e-mail: mlee@csuhayward.edu

Lundqvist, Jan Linköping University Sweden
Professor
Dept. on Water and Environmental Studies
SE-581 83 LINKÖPING
telephone: +46 13 28 22 72
e-mail: janlu@tema.liu.se

Meybeck, Michel University of Pierre Et Marie Curie France
4, Place Jussieu, 75252 Paris Cedex 05
telephone: *+33 1 44 27 51 48*
e-mail: meybeck@biogeodis.jussieu.fr

Ongley, Ed WHO/UNEP (Senior Adviser) Canada
Emeritus Scientist, Environment Canada, Senior Advisor, WHO/UNEP GEMS/Water Programme, 3486 Hannibal Road, Burlington, Ontario, L7M 1Z6
telephone: *(1- 905) 335-6299*
e-mail: eongley@ibm.net

Peters, Norman (Jake) U.S. Geological Survey USA
3039 Amwiler Rd., Suite 130

Atlanta, GA, 30360-2824
telephone: +1 770 903 91 45
e-mail: nepeters@usgs.gov

Pigram, John University of New England Australia
Director, Centre for Water Policy Research
University of New England, Armidale NSW 2351
telephone: +61 2 6773 2420
e-mail: jpigram@metz.une.edu.au

Vlachos, Evan Colorado State University USA
Professor, Sociology and Civil Engineering
Colorado State University
Fort Collins, CO 80523-1784
telephone:+1 970 491-6089
e-mail: evlachos@engr.colostate.edu

Wouters, Patricia University of Dundee Scotland
Director, Water Law and Policy Programme
CEPMLP University of Dundee
Dundee, Scotland DD1 4HN, The UK
telephone: + 44 1382 34 5179
e-mail: p.k.wouters@dundee.ac.uk

TOWARDS UPSTREAM/DOWNSTREAM HYDROSOLIDARITY

Introduction
by

Prof. Malin Falkenmark och Prof. Jan Lundqvist

Everyone lives downstream - the 1999 motto

The World Water Day 1999 had the motto "everyone lives downstream", drawing attention to the conflicts of equally legitimate water-related interests between those living upstream and those living downstream. Finding models for how these interests can be reconciled is an urgent and challenging task. Not only between countries but also within countries are such problems growing in scale. The World Watch has drawn attention to the fact that the Yellow river in recent years goes dry in the downstream part seven months per year due to water consumptive use higher upstream in the river basin, creating enormous problems for the irrigated agriculture in the downstream basin. Similar river depletion problems may easily develop all over the dry climate regions as the "price" to be paid for intensified crop production to feed a rapidly growing population.

This problematique is the background against which the SIWI/IWRA Seminar "Towards upstream/downstream solidarity" is being organized. The Seminar was initiated by Professor Luis da Cunha, member of IWRA's former Committee on Strategies for the 21 Century, a committee active in the 1980's and early 1990's to raise the awareness of the looming water crisis, which went largely uncommented in the report of the World Commission on Environment and Development "Our common future. This Committee was initiated at the Brussels Congress, organized two special sessions. one on ....in Ottawa, with a statement on the WCED conceptual freshwater void, and one on ....in Rabat, with a statement on the water scarcity threat and its implications

World Water Vision

The Seminar was organized against the background of the ongoing work of World Water Council on a "World Water Vision" aiming at a consensus document. This document will be developed by sub-sectoral and regional groups, to reflect"what people really care about". A key component will be socalled "out-of-the-box"-thinking, referring to what happens in the outside world in terms of energy, biotechnology, IT, economy, etc . The Vision document will be composed of two parts, one part encompassing a set of alternative visions including the threats and opportunities, and the other part a

Framework for Action, developed within the Global Water Partnership. Both documents will be presented at the World Water Day in the Hague 22 March 2000.

The consensus approach of the Vision document suggests that it will be based on mainstream thinking. The SIWI/IWRA Seminar aimed at complementing this effort by focusing on essential but largely neglected dimensions within the "in-the-box" thinking. What is referred to are dimensions where there is a need for renewal to reach better harmony between what is happening in society and what really takes place in the landscape around us. A one day Seminar was organized immediately after the presentation of the Vision at the Stockholm Water Symposium on Tuesday 10 August 1999. The Seminar took place on Saturday 14 August 1998.

The need for renewal of "in-the-box" thinking

In the conventional approach, more stress is laid on allocation between different sectors rather than upstream/downstream interdependency and interaction. Another shortcoming in conventional conceptions is the focus on water provision with no or scant concern about what happens to water after use. The fundamental relation between water quantity/utilization and water quality is often neglected due to prevailing institutional and organizational structures of society. A third gap is the stress on "right to water" rather than on the solidarity needed between various stakeholders, including upstream and downstream water users. In practise, the notion of water rights is quite vague, partly due to the fact that there is virtually no inclusion of responsibility in connection to water rights. Water rights and reciprocal responsibility were discussed in view of the different kinds of water use(r)s: those literally consuming water, those who merely pollute it, and those who focus on the protection of crucial ecological services. In all cases, there is a noticeable upstream-downstream dimension which needs to be considered.

The idea of the seminar was to try to get out of mainstream thinking and compartmentalization. A key question was the following: what has to be entered into the decision-making and institutional and organizational structures in order to achieve a true hydrosolidarity?

The Seminar was organized by Stockholm International Water Institute (SIWI) and International Water Resources Association (IWRA).

The dynamic adaptive approach

The growing concern over the impending water crisis has helped to clarify the need for new dimensions in water policy. Escalating water scarcity has profound implications for society as well as for processes in the landscape. Adaptation to the growing scarcity is increasingly conceived of in terms of changes in society itself. Moreover, it is a continuous process where human activities have implications for the shape and fate of processes in the landscape, which, in turn, require modifications in adaptation and management. This kind of dynamic adaptive approach stands in sharp contrast to the earlier pre-occupation with society's interventions in water flows in the landscape. The notion of demand side management, for instance, implies that efforts should be devoted to modify human behavior and perceptions rather than changing water's behavior. But it is not an either-or situation. Proper management requires due attention *both* to social and landscape processes and technical interventions to achieve harmony between society and the life-support systems.

By now, there is ample evidence to show that *even if* society adopts best available technology (BAT) with due consideration to what is economically feasible, water resources are inadequate to meet aggregate demand or they are too vulnerable to neutralize impacts caused by human activities. Climatically induced shortage of water and/or a growing scarcity as a consequence of demographic and other changes in society is a harsh reality in many countries. Choices have to be made and strategies worked out which may counter anticipated challenges and which could facilitate the achievement of a desired future. Choices and strategies refer, for instance, to allocation between competing demands, how to conserve water, how to safeguard required quality, what fractions of stream-flow should be exempted from withdrawal, etc. Apart from quantitative shortages, the impending water crisis is reinforced and compounded by a serious degradation of water and, thus, environmental quality. Most of the choices have implications for upstream/downstream relationships and interactions.

Allocation and upstream/downstream considerations

Allocation of water between competing sectors and interests in society is an important issue in water policy. The debate in this regard has focussed on a few issues; it has repeatedly confirmed what is already a firmly established policy, namely, that first priority in water supply considerations must be given to basic human requirements. But it has also helped to clarify the role of water in the 'income-generation-equation'. If water is allocated to sectors or activities which generate a low-value per unit of water, and if sectors, which have a potential to generate high-value, are deprived of water, the opportunities for socioeconomic progress are thwarted.

Leaving aside the tremendous obstacles and challenges in many countries to develop activities, which generate high-value per water unit, it is of fundamental interest not only to penetrate questions of how to allocate water between competing sectors of society. Partly, the intricacy of the issue is due to the difficulties to decide what is meant by high and low-value respectively. For overall societal development, it is equally relevant to consider water requirements in an upstream-downstream dimension. Allocation choices typically neglect this dimension. These requirements do not only refer to the claims from people and interests in various segments of river basins. They also refer to regional aspects of development, the in-stream functions and, generally, the ecological implications from water use in various segments of a catchment area.

We suggest that the Seminar penetrates the issue of allocation in the context of upstream-downstream considerations. Allocation may be seen as choices that have to be made in each locality whereas the upstream-downstream refers to a much wider set of questions, i.e. safeguarding ecosystem services, regional development, coastal zone management, etc. To what extent can upstream-downstream consideration be taken care of in the prevailing management structure? What kinds of mechanisms are needed to *better coordinate the interests and reconcile the incompatible claims in various segments of a basin?*

The quality and quantity connections

Similar to the quantity problem, the degradation of water quality is a tangible reality in many parts of the world. More often, though, it may be characterized as a creeping and largely invisible threat. Wherever water shortages prevail, the risk for degradation is imminent. Causes for degradation might be multiple but a strong correlation to withdrawal ratio is plausible. With a high withdrawal ratio, or a high use-to-availability ratio, the pollution load per flow unit tends to be high while the dilution capacity of recipients is low. Consequently, there is an obvious relationship between quantity and quality, the 'Q&Q connection', in water-short areas which is surprisingly seldom contemplated in water policy.

But even in water rich countries, significant challenges with regard to threats of quality degradation remain in order to achieve harmony between society and the long-term utilization of water and land resources. Ample flow may increase dilution but it will not reduce the amount of environmentally harmful substances. Acidification and eutrophication of water courses and the build-up of pools of heavy metals and other deleterious substances in the soil illustrate that society's utilization of water, in combination with other resources, should be subject to scrutiny.

Technologies and monitoring procedures concerning how to handle point source pollution and how to reduce water consumption in these sectors/activities are, at least in principle, known. To some extent they are also successfully implemented in parts of the world. Utilization of water in non-point activities, i e agriculture, forestry and fishery, is related to other kinds of problems. Food and biomass production is synonymous with heavy consumptive use of water while fisheries require plenty of free-floating water of high quality. Non-point sources of pollution, primarily from agriculture are quite difficult to control and monitor.

We suggest that the Seminar penetratse the quality dimension of the impending water crisis. This threat is, of course, relevant to analyze in an upstream-downstream dimension, but it may be dealt with from other angles as well. For instance, to what extent can the core of the problem be traced to an omission to pay adequate attention to what happens to water after use? To what extent is water and environmental quality affected indirectly through depositions from near and far away sources? What steps and procedures can be proposed to mitigate the threats?

Cross cutting issues

The determination to tackle the impending water crisis has grown appreciably. The insight of the challenges involved has also spread to various groups in society. Water management is no longer to be conceived of as a duty for water professionals alone. Water issues are on the agenda at the highest policy making level. Basically, it is the water users themselves who have to participate in water resources management An active involvement of the users and other stakeholders, in turn, presumes that the roles of various actors are properly defined and the rules are clear and adhered to. Water rights *and* the associated responsibilities should reflect the growing scarcity and the mounting competition and also the vulnerability of water as touched upon above.

The combination of socioeconomic and environmental concerns constitutes a basic element in the contemporary, wider security thinking. If people do not have access to basic livelihood components, like water, their possibilities to lead a productive and healthy life are at stake. Increasing water stress is a source of personal and societal stress and will most likely hamper the progress and security of society. Conflicts over water are common. But it is also true that considerable effort is devoted to promote cooperation. National and international institutions have made substantial progress in the determination to promote efficient, equitable and ecologically sound utilization of water.

On the agenda for improved water resources management and in efforts to tackle the impending water crisis, water diplomacy plays a growing role. A number of arenas exist or are being established, where various stakeholders meet, where negotiations are carried out, etc. Various interests are penetrated and compared in these negotiations. It is also important that various options are scrutinized not only with regard to the various interests but also with regard to legal and administrative structures and capacities. At a more general level, water diplomacy may be seen in an inter-generational context. How can the next generation, and their interests, be adequately brought into management decisions.

Thus, the impending water crisis does not only refer to current problems. A desired future is not likely to be achieved only by handling acute problems. A systematic adoption of steps, which can be assumed to lead to goals that society aspires to reach, is called for.

We suggest that the Seminar discuses the crosscutting issues briefly identified above. What are the limitations of the water right concept in an upstream/downstream perspective and to what extent are rights and responsibilities taken care of in the prevailing regulatory system? Is PPP effective? Do we need a 'Regulatory Impact Assessment (RIA), What are the most significant security aspects related to water? What role does water diplomacy have in creating a readiness to constructively deal with incompatible and conflicting interests? What steps should be taken to achieve a desired future?

COMPETING FRESHWATER AND ECOLOGICAL SERVICES IN THE RIVER BASIN PERSPECTIVE

An expanded conceptual framework

by

Malin Falkenmark

A river basin approach with focus on upstream/downstream conflicts of interest has to involve attention not only to water itself and the services that it provides to society, but also to water-related ecosystem services, terrestrial as well as aquatic. Besides the blue water, i e liquid water flows in rivers and aquifers, attention has to be paid to the green water flows, i e the water vapour flow involved in i a plant production. What basically has to be shared between those upstream and those downstream in a river basin is the rainfall over the basin. To satisfy societal needs, humans have to manipulate various landscape elements. These manipulations - due to fundamental water functions - tend to produce side effects ("environmental impacts"). In an integrated basin approach, side effects of water-impacting land use conversions upstream on water-dependent activities and on ecosystem health downstream have to be considered. A fundamental challenge is therefore to find ways and mechanisms by which reconciliation can be developed between upstream and downstream activities.

Needed renewal of the in-the-box thinking

The world is running into more and more complex water problems but much of the debate tends to concentrate on one thing at a time: water supply, sanitation, water treatment plants, irrigation, water storage, hydropower development, sectoral pricing etc. The past approach to freshwater has been highly incomplete also with its focus on water itself, not on the services that the water provides. And many politicians continue to be "water-blind" without preparedness for the looming water crisis.

Already in the 1980's were efforts against this "water blindness" started within the IWRA Committee on Water Strategies for the 21 Century. Major contributions of that Committee were two Special Sessions at IWRA Congresses, both leading up to widely circulated IWRA Statements: the first after the Ottawa Congress in 1987 severely criticizing the Brundtland Commission for their water blindness, the second after the Rabat Congress in 1991, drawing attention to the problems of an intensifying water scarcity with its links to land use problems and deteriorating ecological fabric in the semi-arid tropics and subtropics.

A deepgoing quantity/quality dichotomy among professionals, legislation and institutions is mirrored in a widespread neglect of water pollution and its implications for future water use. It has been addressed in separation from water quantity and the dilution flow that it contributes. In the North, there is almost a paralysis to such non-technical problems as eutrophication and non-potable levels of nitrate in groundwater originating from socalled diffuse sources in traffic and agriculture - both largely unabated. In the South , water pollution is met by reliance on the inverted U-curve, implying that a society should wait for GNP to rise enough to allow the financing of pollution abatement structures. However, the monsoon climate and the lack of dilution water during the dry season that it involves, may produce societal collapses already ahead of the intended GNP rise. The consequences are moving towards a widespread *hydrocide* , i e a situation where the available freshwater cannot be used for any societal purpose (1).

The conceptual framework inherited from the past is vastly insufficient as a tool to address the increasingly complex water-related problems of tomorrow. The result can be seen in the more or less general paralysis with plenty of lip service and large redundance in the water policy debate, an overreliance on policy principles developed some 10 years ago (the socalled Dublin principles - more or less institutionalized in the instructions to the Global Water Partnership). Especially disturbing is the general laissez-faire in relation to water pollution, which is continuously reducing the use options of the available water.

One effort to try to break this apparent standstill is the world-wide efforts of the World Water Council in terms of the World Water Vision 2025. The Vision aims at broadest possible consensus and therefore has to build on the just criticised conventional "in-the-box"-thinking. What is new is the large interest paid to driving forces and socalled "out-of the-box" developments (biotechnology, IT-sector, economy, institutions). Environmental protection issues are addressed in a sectoral group on "Water for Nature", less analytical than advocacy-oriented.

Neglected water use: rainfed plant production

One fundamental problem with the dominating in-the-box thinking is the concentration on direct freshwater services to society, neglecting more indirect services such as those related to *water-driven plant production*: rainfed agriculture, pasture and forestry. The reason for this neglect is the temperate zone bias which still seems to dominate much of the general debate. Dry climate countries with warm or hot climate have however come to realize the hard way that there is a close connection between the water vapour consumed in plant production and what remains of the rain to produce groundwater and river runoff. Australia suffers from large-scale water logging as the response to deforestation, S Africa even introduced a system of reforestation permits to be applied for by foresters with reforestation or afforestation in mind. This link between vegetation and vertical transport of water vapour first attracted wider general attention in the discussions around the climate change in the humid tropics and the possible influence from clearing of tropical rainforests with their considerable vapour flows. The reason why these flows have much larger relevance in the tropics than in the temperate zone is the much larger potential evapotranspiration due to a hotter atmosphere.

A recent article by Rockström et al (2) reports on efforts to bridge ecology and hydrology in order to clarify the key roles played by water in the life support system on which humanity depends. The water cycle functions i e as the bloodstream of the biosphere. Life started in water and has through the millenia developed from basic preconditions in terms of availability of water and mineral salts. Life itself has been modified but at the same time modified the preconditions as illustrated by today's effects of deforestation, afforestation, alien vegetation, etc. As will be shown in this paper plants are not just water wicks transmitting a water flow to the atmosphere, but active in the water partitioning itself.

This insight has made it more and more evident that what has to be shared between those upstream and those downstream in a river basin is not the water currently going in the river as codified by the Convention on Non-navigational uses of International Water courses, but rather the rainfall over the river basin. As a consequence, sustainable water-dependent socio-economic development will not be possible unless an integrated perspective be taken on all water-dependent and water-impacting activities in a river basin. This paper will discuss a number of issues which have to be taken into account in order to arrive at a more credible vision of how to attain a sustainable world.

Freshwater - the bloodstream of the biosphere

Freshwater is in reality a key element in the biosphere where it transports nutrients to the cells , and waste products away from the cells. Through its physical, chemical and biological involvement, water has absolutely fundamental balancing functions in the natural landscape (3). Water dissipates the solar energy pulse in space and time through three main processor properties of water: physically through the interaction between evaporation and condensation; chemically through the interaction between crystallization and dissolution; and biologically through the interaction between cleavage of the water molecule in the photosynthesis and the reassemblage through the respiration.

These fundamental roles of freshwater makes it essential to develop a conceptual framework that pays adequate attention to all the main roles played by this substance. The neglect of the interaction between freshwater and the life support components of humanity did not become alarming until humanity had grown in scale so that the ultimate resilience of the ecological fabric started to cause concern (4). **Figure 1** is a macro-scale mental image of the freshwater circulation in the water cycle, acting as the bloodstream of the biosphere with its water-dependent and nested ecosystems. Society depends both on the freshwater services provided by the direct use of water in rivers and aquifers, and on the ecosystem services provided from the ecosystems. The latter include the earlier mentioned indirect water services provided through plant production, an enormously water-consuming process.

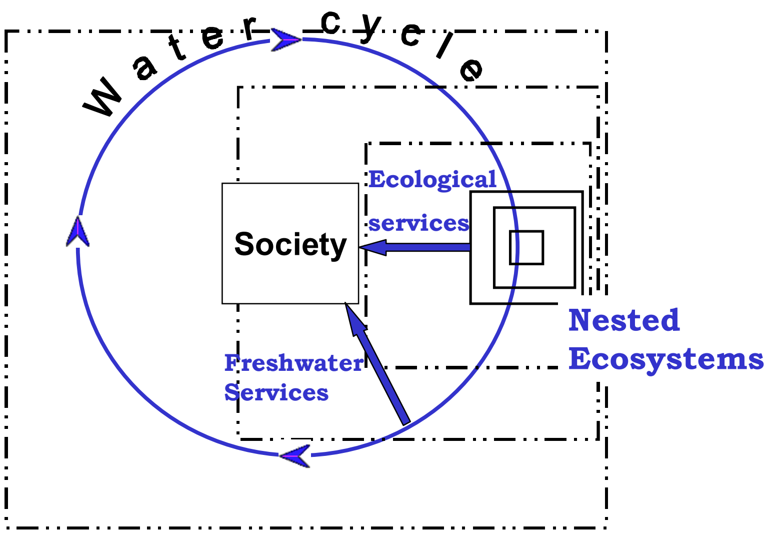

Figure 1. A macro-scale image of key relations between society, the freshwater services and the ecological services on which its activities depend. The water cycle – the bloodstream of the biosphere – provides the water withdrawn from the water cycle for the freshwater services. The ecological services originate from nested ecosystems, feeding on the same water cycle.

Complementarity and redirections of green and blue water flows

The most fundamental expansion from a conventional water resources approach is the *introduction of green water* - i e water vapour flows - besides the blue water i e liquid water flows in rivers and aquifers on which past discussions have been focused, **Figure 2**. Human livelihood security is related to safe access to household water, to water-dependent ecosystem services including food production (crops, fish), and to income generation (industrial production, cash crop production). All depend on human interventions with the green as well as the blue water flows.

Society in other words benefits directly from both branches: from the green for biomass production (food, fiber, pasture, fuelwood, timber), and from the blue for water-dependent societal water uses (water supply, industry, irrigated agriculture, hydropower). It also benefits indirectly through a multitude of ecosystem services provided by both the green and the blue branches.

The relevance of the complementarity between the green and the blue water flow branches becomes evident when addressing the need for a rapidly expanded *food production* in regions where most of the farmers are rainfed and many of them illiterate. Upgrading rainfed agriculture will call for improving both the infiltrability and water holding capacity of the soils, and the water uptake capacity of the roots by protection from dry spell-related plant damage (5). The crucial question here is to what degree the green water flow will have to increase to intensify food production in the poverty stricken dry climate countries which are those with most rapid population growth: the reason is that a green water increase is equivalent to a blue water decrease. i e a river and/or groundwater depletion.

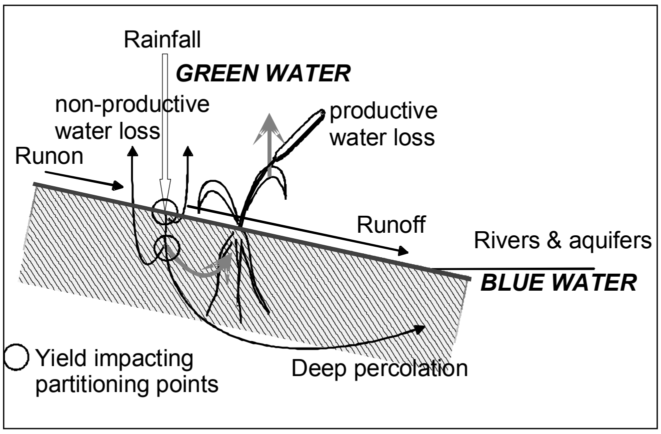

Figure 2. The rainfall, when reaching the ground, partitions into two main branches: the vertical branch of green water flow (water vapour) and the semihorisontal branch of blue water flow (liquid water) passing through aquifers and rivers.

As already indicated also *forestry* has a clear effect on blue water production in dry climate countries. Typically, deforestation on the one hand increases the runoff due to a decreased green water flow, while on the other impermeabilizes the soil, thereby reducing groundwater recharge and therefore dry season river flow (6). The consequence here is a dry season river depletion combined with wet season floods. It has been suggested that the massive river depletion reported from the Yellow river may reflect a combination of both.

Conceptualizing land-water-ecosystem interactions

Ecological services can be decomposed into elementary services, some of them physical, others chemical and biological (4).

Physical services include enhancement of soil permeability through macropore formation by the roots; soil surface protection by the vegetation cover; and sedimentation where the uplift of rapidly moving water down a river ceases.

The *chemical* services include phenomena such as oxygen production through the photosynthesis process, carbon dioxide uptake in the same process, denitrification through the action of microorganisms, and nitrogen uptake by certain plants, widely used in agriculture.

The *biological* services include phenomena such as pollination by insects - a key component in plant production, biomass production through the photosynthesis, and seed dispersal by birds.

These and other elementary ecological services tend to combine into long chains and fabrics of ecosystem components. Birds for instance depend on water-dependent terrestrial and aquatic habitats.

To satisfy societal needs for water, food, energy, goods and services, humans generally have to manipulate various landscape components (soil permeability, slope, water courses, river flows, water tables etc(7)). Due to special properties of water, these manipulations tend to produce side effects (generally spoken of as environmental effects). Side effects can occur as a result of changed water partitioning at the ground surface, influencing both the water flow down the catchment and the vapour flow to the atmosphere; and maybe even the vapour flow producing precipitation downwind. Water's function as carrier of solutes and silt contributes to the transport of substances in the landscape and affects water quality. The side effects manifest themselves in changes in water quality and quantity with higher order effects on water-dependent flora, fauna and biodiversity. Finally, water cycle continuity generates chain effects from the atmosphere - to the land and the terrestrial ecosystems - to groundwater, rivers and lakes and aquatic ecosystems - to coastal waters and ecosystems.

Due to water's many parallel functions in the natural landscape, it is in other words deeply involved in generating ecological changes in both terrestrial and aquatic systems. The mental image in **Figure 3** visualises *water-related causal chains* between key ecosystems goods (biomass harvests) and services (biodiversity) and human activities in the landscape related to food. water and energy supply, and the generation of income.

In clear wording, this means that the attention that is currently being concentrated on direct, visible changes of wetlands and other ecosystems will have to be complemented by attention also to *indirect, invisible, creeping changes* that are linked to water's movement and quality transformations as it moves through the catchment, above and below the ground surface. It goes without saying that a successful protection of a certain ecosystem such as a wetland evidently depends on enough understanding of its water-dependence and what particular threats that it has to be protected from. Similarly, to protect a certain species, the habitat of that species has to be protected against invisible, creeping changes linked to the water-dependent dimension of that habitat.

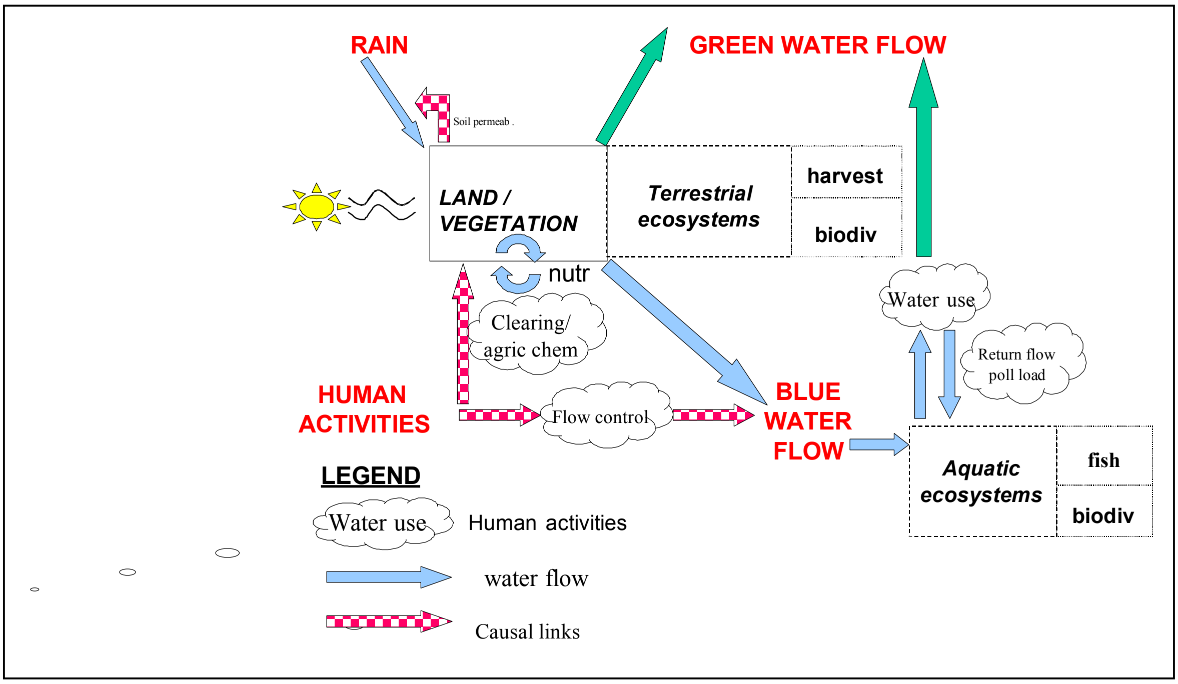

Figure 3 *visualizes water-related causal chains between key ecosystem goods (biomass harvests) and services (biodiversity), in the target end, and human activities in the landscape related to food, water and energy supply and the generation of income, in the disturbance end. Two types of landscape manipulations are important:*

- *on the one hand direct manipulations of water flows and quality (flow control, water withdrawals),*
- *on the other manipulation of land and vegetation, thereby influencing soil permeability and rainwater partitioning and consequently also water flow changes.*

Both vertical and horisontal perspectives needed

In an integrated approach covering both land use and water use, and both upstream and downstream human activities, *side effects of upstream water-impacting land use conversions* on water dependent activities and ecosystems downstream have to be carefully considered.. Land use influences both water partitioning between green and blue water flows and therefore water pathways through the landscape. It may also involve introduction of polluting agents along water pathways and therefore influence water composition.

Human activities in a river basin have to be categorized in order to clarify the main conflicts of interest (**Figure 4**).

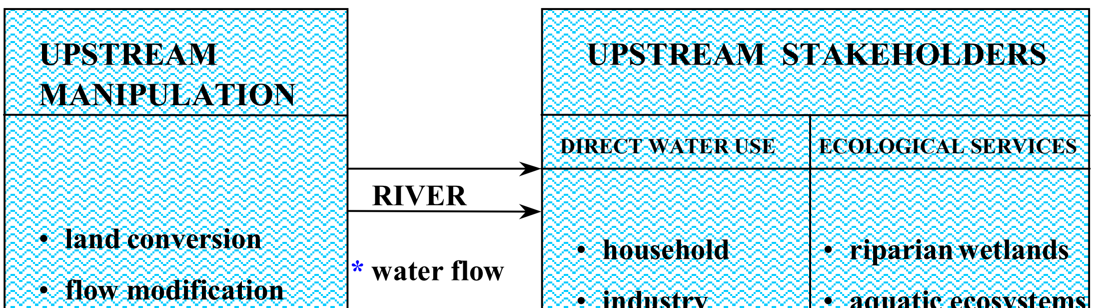

Figure 4. *Conflicting stakeholder interests in a river basin can be systematized into water-impacting activities upstream, involving water manipulations and influencing water flow and quality, and water-dependent activities and systems downstream, influenced by water flow and quality characteristics.*

First, water-impacting human manipulations may be linked both to the land use and to the water use. As already stressed, land use has links to green water flows and land use conversions may involve blue/green redirections of water flows. Typical examples relating to deforestation and reforestation have already been referred to. Such conversions are related to terrestrial ecosystems. Blue water use has to be categorized into return-flow related uses, generally including addition of a pollution load, and consumptive water use, increasing the green water flow. Second, water-dependent activities may be divided into direct blue water use (household, industry, irrigated agriculture, hydropower etc) and aquatic ecological services in riparian wetlands, fishery etc.

When blue water is used for irrigation the part consumed by the crops respresents a blue-to-green redirection of water. The evaporative losses from e g canal and conveyances that are involved in the irrigation system add to such redirections. The depletion of the Aral sea or the downstream Colorado river in USA (in both cases after correction for the effect of out-of-basin transfers) are both downstream manifestations of river depletion by blue-to-green redirections.

The traditional rice farming system in Bali was in fact based on such redirections. The river depletion was controlled by an intricate set of institutions where religion and the involvement of priests and temples played a central role (8). The task was to allocate the blue water in the water course so that there was still enough left for the most downstream rice farmer. The same thinking can be heard from many dry climate developing countries where blue water leaving to the sea is seen as a waste. Interestingly, in the Bali case, the blue water was not only used to optimize water use efficiency in the rice fields but also for ecological services like pest controls.

The widely experienced fact that forest plantations in the temperate zone have tended to lead to decreased river flow is an example of indirect blue-to-green redirection in the sense that the biomass production reduced the rainwater surplus left to form blue water.

Conversely, the large scale deforestation throughout the past millenium over the Hungarian Plain has been suggested to explain the water logging that forced the Hungarians to introduce large scale drainage systems in the 19th century in order to bring down the water table (9). The huge Working for Water project now going on in South Africa (10) is another example of this type of redirection. The goal is to take away the alien water consuming vegetation that lacks natural enemies and therefore rapidly spreads over the landscape. By this operation the Ministry of Water Affairs and Forestry expects to gain an additional 10 % of runoff, badly needed to secure safe water supply for the whole population.

Land use change and conversion may also cause consquences on downwind rainfall. If the atmosphere receives an increased input of water vapour flow, there is more water that can condensate and form rain further away in the downwind direction. This effect may be particularly relevant far away from the coast where the vapour content of evaporated marine water in the atmosphere is already exhausted and the atmospheric vapour flow contains only continentally evaporated water (11).

Compromise seeking on the way towards hydrosolidarity

Summing up the main points in this paper, a fundamental challenge towards a less unsustainable socio-economic development is to *find ways and mechanisms by which reconciliation can be developed between upstream and downstream activities.* The starting point for such an approach has to be the rainfall over the river basin. Man's dependence on water is not a merely technical issue involving water supply and irrigation but much broader since the land use is not only water-dependent but also water-impacting. Therefore, upgraded water concepts are needed as a base for the conflict analyses and discussions.

But the river basin approach has to involve attention not only to direct and indirect *freshwater services* , but also to water-related *ecosystem services*, terrestrial as well as aquatic, and direct as well as indirect. While direct terrestrial services are involved in biomass production of socio-economic importance, in particular crop production, pasture and forestry, indirect ones are related to services performed by insects and birds of importance for seed dispersal and pollination but also to biodiversity protecting the life support system against disturbances. Similarly, direct aquatic ecological services are linked to fish production and income generation among fishermen populations, while indirect ones are related to wetlands of importance for bird flyways, recreation, etc.

Ultimately, societal freshwater and ecological services will have to be seen in a river basin perspective within a new *hydrosolidarity* thinking. Upstream vegetation changes has flow consequences for downstream freshwater and ecological services. Upstream land use changes and water uses involving the introduction of pollution loads will influence the quality of the water on which downstream activities and ecosystems depend. It is therefore essential to find ways to seek balance and compromises between upstream and downstream interests and ecosystems.

Upstreamers will have to *pay adequate attention* to the ways in which their activities influence downstreamers. This is an issue of water ethics. Downstreamers have to look out for the way upstream activities may influence their water-dependent activities. This is an issue of national security.

Also downstreamers will have to practise water ethics: they will have to *adapt their expectations* to what will be realistic in terms of the constraints that those expectations will imply for upstream activities. They will also have to *provide motivation* for the upstreamers to constrain their activities, both in terms of the pollution load introduced and the water-consuming biomass production, i e activities that would otherwise pollute and/or deplete the river on which the downstreamers and their aquatic ecosystems depend.

REFERENCES

1. Lundqvist, J. (1998) Avert looming hydrocide. *Ambio* 27: 428-433

2. Rockström, J. et al (1999) Linkages between water vapor flows, food production and terrestrial ecosystem services. *Conservation Ecology*, August 1999

3. Ripl, W. (1995) Masnagement of water cycle and energy flow for ecosystem control. The energy-transport reaction (ETR) model. *Ecological Modelling,* 78: 61-76

4. Falkenmark, M., Folke, C.&Gordon, L. (2000) Water in the landscape. Functions and values. In: Lundqvist et al. *New dimensions in water security. FAO.* In press.

5. Rockström, J. & Falkenmark, M. (2000) Semi-arid crop production from a hydrological perspective. Gap between potential and actual yields. *Critical Reviews in Plant Science.*In press.

6. Sandström, K. (1995) *Forests and water - friends or foes? Hydrological implications of deforestation and land degradation in semi-arid Tanzania.* Linköping Studies in Arts and Science. No 120. Linköping University.

7. Falkenmark, M. (1997) Society's interaction with the water cycle: A conceptual framework for a more holistic approach. *Hydrological Sciences* 42: 451-466

8. Lansing, J.S. (1991) *Priests and programmes. Technologies of power on the engineered landscape of Bali.* Princeton paperbacks

9. Szesztay, K. (1994) The role of water in landscape ecology and in crop production. *Periodical Polytechnica. Ser. Civil Eng.* 38: 315-331

10. van Wilgen, B.W., Le Maitre, D.C.,&Cowling, R.M. (1998) Ecosystem services, efficiency, sustainability and equity: South Africa's Working for Water programme. *Trends in Ecology and Evolution,* 13: 378

11. Savenije, H.H.G. (1995) New definitions for moisture recycling and the relationships with land-use changes in the Sahel. *Journal of Hydrology,* **167:** 57-78

ECOHYDROLOGICAL LANDSCAPE MANAGEMENT FOR HUMAN WELL-BEING

by

L. Gordon and C. Folke

Large parts of modern society remains illiterate about ecosystem contributions to economic development and growth. This is reflected in the neglect of the environmental resource base in most models of economic growth. Ecosystem services are water-dependent. There tends to be a ”double invisibility” encompassing more or less invisible flows of water needed to produce similarly invisible ecosystem services. The paper highlights the role of freshwater in sustaining the ecological processes behind ecosystem services. A couple of examples of eco-hydrological causal chains are described where intentional as well as unintentional changes of ecological processes upstream led to loss of ecosystem services as well as severe consequences for downstream citizens. The potential trade-off between freshwater needed to produce food to a growing world population and freshwater needed to support ecosystem services is highlighted. New institutional structures are important steps towards a more integrated approach to human dependence on freshwater as the bloodstream of the biosphere.

Introduction – identifying a black box of natural resource management

Management of natural resources has suffered from managers that have a partial view (1). *Freshwater management and assessments* has focused primarily on the visible liquid water that is running through rivers and aquifers, and which is used directly by humanity in industries, households and irrigated agriculture (see e.g. UN-SEI (2), Gleick (3)). *Ecosystem managers* have for a long time focused their attention on how to optimize the flow of visible goods produced by the interactions between organisms and their surrounding environment.

Societal dependence on functional ecosystems, which e.g. generate food and timber and modify water flows, is however not fully understood. The work of ecosystems is scarcely reflected in market prices, seldom perceived by individuals, or fully taken into account by the institutions that provide the framework for human action. Large parts of modern society is illiterate about ecosystem contribution to economic development and growth, which is reflected, for example, by the neglect of the environmental resource base in most models of economic growth (4). Recently, large parts of the scientific community has, however, begun to pay attention to how to ensure the capacity of ecosystems (including biodiversity) to generate natural resources and ecosystem services through improved management of the whole ecosystems and the landscapes in which they are situated (see e.g. Daily (5), de Groot (6)). The unperceived support capacity of ecosystems has been highlighted and emphasized (7, 8).

Ecosystem services are also dependent on freshwater and we argue that this is *a black box of natural resource management.* It can also be seen as "a double invisibility" since the interaction between more or less invisible flows of freshwater which are needed to produce the "invisible" ecosystem services is a neglected area in water management. The importance of secured freshwater quality and quantity for the generation of ecosystem services in aquatic ecosystems has been given some attention in the last couple of years (9,10). It is however only recently that the importance of freshwater for ecological processes in *terrestrial* systems has been acknowledged in relation to water management (12, 13). The analyses of the relations and interdependencies between freshwater needed for direct human consumption (e.g. in households, industries and irrigated agriculture) and the indirect human dependence on freshwater for sustained ecosystem services are far from satisfactory.

In this paper we start with a short introduction to the concept of ecosystem services. We highlight the role of freshwater in sustaining the ecological processes behind ecosystem services. The next section deals with relations of water flows and ecological processes in a catchment area, and how unintentional side-effects can cascade over large temporal and spatial scales. The potential trade-off between freshwater for food to a growing world population and freshwater needed to support ecosystem services are highlighted. In the conclusions we pinpoint some key questions that will have to be addressed in integrated water management if further unintentional degradation of the life-support system is to be avoided.

Humanity depends on freshwater to generate ecosystem services

Ecosystem services have been defined as "the ecological processes and interactions that fulfill and sustain human life" (5) and the concept of ecosystem services has been used as an eye-opener to communicate the dependence of society on the work of ecosystems (14). Some examples of ecosystem services are denitrification, CO_2-sequestration and pollination (see also table 1), which all constitute a fundamental basis for socio-economic development. A distinction of ecosystem services and ecosystem goods are sometimes used. Ecosystem services are the prerequisite for the production of ecosystem goods. The actual production capacity, the ecological process behind e.g. timber production, is seen as a service while the biomass produced (e.g. wood, fish, and crop) is seen as goods.

Freshwater is involved not only in transpiration, which is needed to build up biomass, but it also performs multiple functions for ecosystem services. For example, freshwater is involved in the creation of both aerobic and anaerobic environments that are needed for *denitrification* to occur. Aerobic conditions are needed for nitrification (the first step in the denitrification process). Nitrate is then used for oxidation of organic matter under anaerobic conditions. In *pest control* freshwater can be important both directly, as the changes between dry and wet periods can facilitate pests management (15), and indirectly, as water is needed in habitats to support organisms that feed on pests (for further examples, see table 1).

Table 1. Elementary ecosystem services and the involvement of freshwater

	Elementary ecosystem services	Ecosystem processes	Examples of freshwater involvement
Chemical	Denitrification	Denitrification by microorganisms	Flooded areas provide aerobic and anaerobic environments, e.g. in wetlands.
Physical	Enhancement of infiltration through interception	Interception by vegetation, transferred into stemflow in woody vegetation.	Rainfall
	Soil permeability	Micropore creation by micro-organisms and roots in the soil.	Rainfall/Stemflow
Biological	Seed dispersal	Dispersal of seeds by e.g. birds, bats, insects, moving animals in general, and wind and water.	Direct: Transportation by surface runoff Indirect: water dependent habitats
	Pest insect control	Predation by birds, insects, other animals	Direct: interactions between dry/wet periods can control pest outbreaks Indirect: water dependent habitats
	Fish production	Primary and secondary production	Habitat
	Meat production	Herbivory and secondary production	Watering points Plant-rainfall interaction in rangelands can control distribution of palatable grass

A way to illustrate the human dependence on ecosystem support is by spatial indicators. The appropriated ecosystem area, or the ecological footprint (16), is an indicator that attempts to capture the ecosystem support that is required to generate a flow of resources and ecosystem services. It also demonstrates that human activities, which at first glance may seem separated from nature, would not function without ecosystem support. The footprint concept has been used to illustrate ecosystem support needs of different cultivation intensities in e.g. aquaculture (17, 18). City inhabitants, for example, require productive ecosystems to produce the food, the water, and the renewable resources that are consumed inside the city. They also depend on ecosystems to provide clean air and process waste (19). This kind of analyses can provide important information about ecological constraints that may otherwise be overlooked in policy decisions. The ecological footprint of the eighty-five million people that live within the Baltic Sea drainage basin has been estimated as well as the freshwater requirements to support it (11). The estimate concerns the consumption of food, including seafood, and timber, and waste assimilation of nutrients and carbon dioxide, and is represented by the area of forests, wetlands, lakes, croplands and marine systems needed to support present human lifestyles in the region. The ecological footprint as a whole corresponded to an area as large as 9 times the Baltic Sea and its drainage basin, with a per capita dependence of ecosystem support of 220,000-250,000 m^2.

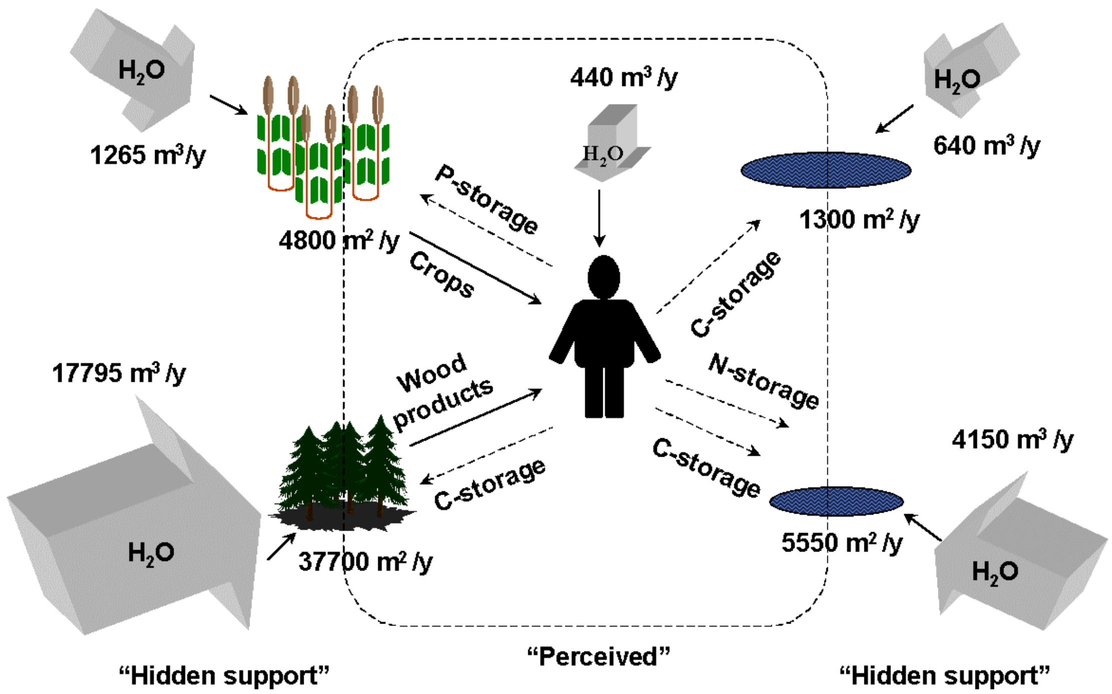

Figure 1*: The per capita appropriation of ecological footprints of forests, wetlands, agriculture and lakes by the inhabitants of the Baltic Sea drainage basin. The picture also illustrates the size of the green water flows needed for making the human appropriation of ecosystem services possible. (Source: Jansson et al. 1999 (11)).*

The amount of freshwater – the vapor water flow - which the inhabitants depend upon for their appropriation of these ecosystem services was also estimated. The vapor water demand in the forest, wetland, agriculture and lake footprints corresponded to a water flow that is more than twice the annual precipitation in the whole Baltic region, or as much as 54 times the amount of liquid runoff freshwater that is used and managed in society.

The estimate reveals that the wellbeing of people from the 14 nations in the drainage basin not only depends on indigenous ecosystems and freshwater availability, but also on the productivity of ecosystems of other nations and their freshwater resources. Hence, economies are dependent not only on imported goods from other countries but also on the support capacity of other nations' ecosystems and freshwater sources for the production of these goods and services (11). This water dependence is similar to the concept of "virtual" water, which is usually referred to as the amount of water that is needed to grow the food imported by water-scarce countries due to lack of water resources. A ton of imported food roughly corresponds to a thousand tons of virtual water. The difference is that the "virtual water" needed for the appropriated footprint area is not "imported" as a result of an intentional national strategy. It is rather a result of actions taken which are mentally separated from the life-support system and which to a large extent shows the neglect of the need of a physical resource base.

Upstream-downstream ecohydrological causal chains

To secure ecosystem services in a world with rapidly growing demands for increased freshwater withdrawal by households, industry and irrigated agriculture, and changed water allocations between different stakeholders, there is an urgent need to understand how water moves between systems and what its role is in ecological processes.

Organisms are both adapted to the prevailing hydrological conditions and at the same time they modify their environment. Due to the interdependencies of freshwater flows and ecological processes, side effects from changes in partitioning of water flows due to e.g. land-use changes or changed water availability can cascade over long distances, in what we call *ecohydrological causal chains.* There are side effects, sometimes transboundary, created in the catchments. Unintentional side effects in relation to freshwater do not always occur in the area where ecological processes are changed intentionally (e.g. land use conversion, intensification of crop production). We will exemplify two ecohydrological causal chains, illustrated by case studies from Australia and South Africa.

Land conversion that reduces water vapor flows and increases water liquid flows
In the Australian wheat belt, demand for increased production of food and fiber has led to substantial deforestation of the native scrub and woodlands. These woodlands have low rainfall (roughly 375 mm) and very low, almost none, runoff. Organisms vary in the way they capture and distribute rainfall. The woody vegetation of these woodlands is efficient in catching rainfall (by interception) and distributing it in the ecosystem. The vegetation captures and participates in the partitioning of up to 70 percent of rainfall that reaches the vegetation. This efficiency is due to four main characteristics: i) intercepted rainfall is transferred into stemflow that infiltrates close to the root system, ii) micropores are created along the tree roots which also facilitates infiltration close to the deep root system (up to 28 meters) iii) rainfall outside the tree canopy is slowed down by a dense layer of leaf litter and shrubs. The water thus has a longer time to infiltrate, and iv) the vegetation is primarily perennial and evergreen, therefore taking up moisture the whole year around (20, 7).

When the shrub and woodlands were replaced with annuals that only transpire during 4-5 months and have shallow rooting structures, an increase in runoff and thus a rise in water table were the consequence. Current estimates are that up to 25% of all cleared land can be so affected that they cannot be used for cereal production within the next 50 years (Saunders, D.A., CSIRO Wildlife and Ecology, Canberra, Australia – pers.comm.).

To improve the situation cultivation of salt tolerant plants and drainage and discard of wastewater are two solutions, but they do not deal with the source to the problem. Also, to move the salt water transfers the problems to the suggested discard areas, e.g. wetlands, with potential further loss of ecosystem services. Another solution is a "designed landscape" where thirsty salt tolerant native trees and shrubs, which change the hydrological regime, are replanted. It has been estimated that over 30 billion perennial trees and bushes will be needed in order to stop the water tables from raising (Saunders, D.A. – pers.comm.). This will require discussions about upstream-downstream *ecohydrosolidarity* as it is the land area in the valley bottoms that is worst off. But it is the farmers located upstream in the landscape that will have to give up their crop production to secure the ecosystem services of new designed ecosystems, and the sustained crop production downstream.

Consumptive water use – reducing liquid water flows and increasing water vapor flows
The fynbos in the Western Cape province in South Africa is sometimes referred to as the worlds "hottest hotspot" in terms of biodiversity. The fynbos is a hard-leafed, fire prone shrubland that grows on the highly infertile soils in a cool climate with wet winters and warm, dry summer. Several ecosystem services of importance for both the local and national economy have been identified; harvesting of wildflowers which provide livelihood to 20-30 thousand people, hiker and ecotourism which is a major growth industry, and the value of biodiversity for food, and drugs (21). Additionally, both the cities of Capetown and Port Elisabeth depend on runoff from the fynbos catchment. This region is developing quickly and with an expected increase in population there will be increasing pressure on freshwater for households and industries (22).

In contrast to the eucalyptus in Australia, the fynbos are not very efficient in capturing rainfall and they have low biomass. Alien woody vegetation (primarily Pinus and Acacia) is the largest threat to the fynbos system. When aliens invade an area, a 50-1000% increase in biomass can occur. As they are more efficient in capturing rainfall and direct it to water vapor flows this diminishes the water runoff. The actual processes are not yet clearly known, but are undoubtedly a function of both increased interception of rainfall and increased transpiration by the alien trees. If the situation would be unmanaged, there would be an estimated 30% reduction of the water supply to the Cape Town over a 100 years time (23). The sustained supply of water thus depends on maintaining a cover of fynbos vegetation. Fire management complicates the situation. Regular fires are important to secure the resilience and development of the fynbos system, but the fires also facilitate the development pathways and seed dispersal of Pinus and Acacia.

A comparison between different alternatives of how to secure water to Cape Town have shown that management of aliens provide a cost-effective alternative to more traditional solutions like waste recycling, sewage effluent exchange plant, and desalinization (22, 24). Thus the fynbos "deliver water" in the cheapest way, and they also "deliver" more water while at the same time supplying many other ecosystem services. This has started a national program called "Working For Water" where catchments today are cleared of aliens in order to secure freshwater to the cities as well as other ecosystem services.

Relations between freshwater, food production and ecosystem services – a need for intentional management

In the future reallocation of freshwater to secure food production to the growing world population will be needed. This implies that freshwater may have to be withdrawn from flows that already supports ecological, social and economic processes. Addressing future global food security requires an approach that does not neglect the essential role that ecosystems have as a basis for food production and socio-economic development. Water for food, water for people and water for ecosystem services to support human wellbeing have to be seen as integrated parts that are dependent on each other. Water as the bloodstream of the biosphere is an essential basic image of the role of water connecting all three approaches.

The per capita dependence on water vapor for food production in croplands is roughly 1,180 m^3/yr, based on a population of 5.7 billion in 1995 (12). As there in general is a more or less linear relation between biomass production and water vapor flows (25), future demand for food will involve an increased appropriation in terms of additional water vapor flow for crop production. Using the human population increase reported by the UN (2) (i.e. an increase of 2.6 billion to 8.3 billion in 2025), this would correspond to an additional water need of 3,100 km^3/yr in 2025. This is based on the assumption that the per capita dependence on water vapor from croplands will be constant. This implies a total crop water demand in 2025 of about 9,800 km^3/yr (12). The key question is how to appropriate this amount of freshwater without undermining our ecological life-support system? There are a couple of different ways to meet the future freshwater need in croplands. All of them raise questions that need urgent investigation if we want to avoid further unintentional side effects.

If the additional water will come from *irrigation* there is a need to improve our understanding of the functioning of non-linear, dynamic and complex processes in aquatic ecosystems and our dependence on these systems for fish production and other ecosystem services (10). The key questions addresses how appropriation of water for irrigation will affect elementary ecosystem services from the aquatic ecosystems that depend on this water.

If the water demand will be met through small-scale *water harvesting techniques* there is a need to understand dynamics of downstream ecosystems, terrestrial, as well as aquatic. The tiger bush in West Africa is, for example, a “natural water harvesting system” that depends on crusted surface areas for runoff, and infiltration areas for biomass production. Will changed dynamics due to decreased surface runoff threaten ecosystem services like pollination and pest management in croplands? Will there be causal chains similar to what was mentioned previously, and experienced in South Africa? These are questions seldom addressed by research aimed at increasing future food security.

A third way of securing water for future food production is through *land use conversion* of forests and woodland, as well as *drainage* of wetlands. There is thus a need to understand human dependence on these systems for essential ecosystem services. There is also a need to address and understand how effects might cascade through the catchment, causing severe impacts as in the case of southwestern Australia mentioned earlier.

There is also a possibility to increase water use efficiency (WUE) in croplands by converting soil evaporation to plant transpiration. This is especially fruitful in the rainfed croplands in the semi-arid tropics where very low WUE can be found on farmer’s fields with low nutrient contents in the soils. One way of doing this is by managing soil nutrients and water in an integrated way where small-scale supplementary irrigation can be added when the plants are in drought sensitive stages of their developments (26). An extensive amount of traditional water harvesting techniques exists that are useful for small-scale irrigation (examples from Indiga – 27).

Conclusions

As the scale of the human enterprise on the planet is growing, the freedom in ways that we can redistribute natural resources, including freshwater and ecosystem services, is decreasing. In both examples of ecohydrological causal chains in this paper (South Africa and Australia), intentional as well as unintentional changes of ecological processes upstream in the landscape led to loss of ecosystem services as well as severe side-effects for downstream citizens. To be effective, freshwater management today can not deal only with allocation of liquid runoff water, but has to include also significance and role of freshwater in ecosystems. This requires that we learn to link upstream and downstream activities to reduce the ecohydrological *illiteracy* that exist today.

Whatever the solutions will be to the need of increasing food production in some areas, there is a need to avoid the previous sectoral management which has led to unintentional and sometimes surprising welfare losses (1). There are also a couple of key questions that need an answer:

- Which are the key interactions between ecosystems and how can these become secured?
- How much rainfall needs to be captured by terrestrial ecosystems to secure ecosystem services?
- How much water has to be left in the river in order to secure key ecosystem services, and why, when and how to do it?

It is however not only an understanding of the ecohydrological processes operating in the landscape that is needed. We also have to increase the understanding of human organization in relation to natural resources. There is a need to remove institutional barriers in order to improve allocation of freshwater among human activities and the life-support system. There are several interesting nested institutional arrangements of irrigation systems in catchment areas (28, 15, 29, 30). There has also been sophisticated watershed-ecosystem based management of ancient societies (30). The new institutional structures that are developing in Australia and South Africa are important steps forward towards a more integrated understanding of human dependence on freshwater as the bloodstream of the biosphere.

REFERENCES:

1. Holling, C. S., and Meffe, G. K. (1995). "Command and control and the pathology of natural resources management." *Conservation Biology*, 10(2), 328-337.

2. UN-SEI. (1997). "*Comprehensive assessment of the freshwater resources of the world*." , WMO-SEI, Stockholm.

3. Gleick, P. H. (1993). *Water in crisis*, Oxford University Press, New York.

4. Dasgupta, P. (1997). "Economics of the environment". *Environment and Development Economics* 1:387-428.

5. Daily, G. C.(Ed) (1997). "*Nature´s Services - Human Dependence on Natural Ecosystems*." , Island Press, Washington D.C.

6. de Groot, R. S. (1992). *Functions of Nature: Evaluation of Nature in environmental Planning, Management and Decision Making*, Wolters-Noordhoff, Groningen.

7. Baskin, Y. (1997). *The Work of Nature: How the Diversity of Life Sustains Us*, Island Press, Washington D.C.

8. Limburg, K. and Folke, C. (1999). "The ecology of ecosystem services: introduction to the special issue". *Ecological Economics*, 29, 179-182.

9. Covich, A. P. (1993). "Water and ecosystems." *Water in Crisis*, P. H. Gleick, ed., Oxford University Press, New York, 40-55.

10. Postel, S., and Carpenter, C. (1997). "Freshwater ecosystem services." *Nature's Services*, G. C. Daily, ed., Island Press, Washington D.C., 195-214.

11. Jansson, Å., Folke, C., Rockström, J., and Gordon, L. (1999). "Linking freshwater flows and ecosystem services appropriated by people: The case of the Baltic Sea drainage basin." *Ecosystems*, 2, 351-366.

12. Rockström, J., Gordon, L., Folke, C., Falkenmark, M., and Engwall, M. (1999). "Linkages among water vapor flows, food production and terrestrial ecosystem services." *Conservation Ecology*, 3(2)

13. Postel, S. L., Daily, G. C., and Ehlich, P. R. (1996). "Human appropriation of renewable fresh water." *Science*, 271, 785-788.

14. Costanza, R., R. d´Arge, R. deGroot, S. Farber, M. Grasso, B. Hannon, K. Limburg, S. Naeem, R. V. O´Neill, J. Paruelo, R. G. Raskin, P. Sutton, M. van den Belt. (1997). "The value of the world's ecosystem services and natural capital". *Nature* 387:253-260.

15. Lansing, J. S. (1991). *Priests and programmers. Technologies of power in the engineered landscape of Bali*, Princeton University Press, Princeton.

16. Rees, W. E., and M. Wackernagel. (1994). "Ecological footprints and appropriate carrying capacity: measuring the natural requirements of the human economy". *Investing in Natural*

Capital A.-M. Jansson, M. Hammer, C. Folke, and R. Costanza, eds. Island Press, Washington, D.C., 362-390.

17. Folke, C. and Kautsky, N. (1989). "The role of ecosystems for sustainable development of aquaculture". *Ambio*, 18, 234-243.

18. Folke, C., Kautsky, N., Berg, H., Jansson, Å., and Troell, M. (1998). "The ecological footprint concept for sustainable seafood production: a review." *Ecological Application*, 8 (supplement)(1), S63-S71.

19. Folke, C., Jansson, Å., Larsson, J., and Costanza, R. (1997). "Ecosystem appropriation by cities." *Ambio*, 26(3), 167-172.

20. Nulsen, R. A., Bligh, K. J., Baxter, I. N., Solin, E. J., and Imrie, D. H. (1986). "The fate of rainfall in a mallee and heath vegetated catchment in southern Western Australia." *Australian Journal of Ecology*, 11, 361-371.

21. Cowling, R. M., Costanza, R., and Higgins, S. I. (1997). "Services supplied by South African fynbos ecosystem." *Nature´s Services*, G. C. Daily, ed., Island Press, Washington D.C.

22. van Wilgen, B. W., Cowling, R. M., and Burgers, C. J. (1996). "Valuation of ecosystem services: a case study from South African fynbos ecosystem." *BioScience*, 46(3), 184-189.

23. Le Maitre, D. C., van Wilgen, B. W., Chapman, R. A., and McKelly, D. H. (1996). "Invasive plants and water resources in the Western Cape Province, South Africa: modelling the consequences of a lack of management." *Journal of Applied Ecology*, 33, 161-172.

24. van Wilgen, B. W., Le Maitre, D. C., and Cowling, R. M. (1998). "Ecosystem services, efficiency, sustainability and equity: South Africa´s Working for Water programme." *TREE*, 13(9), 378.

25. Sinclair, T. R., Tanner, C. B., and Benett, J. B. (1984). "Water-use-efficiency in crop production." *BioScience*, 34, 36-40.

26. Rockström, J. (1997). "*On-farm agrohydrological analysis of the Sahelian yield crisis: Rainfall partitioning, soil nutrients and water use efficiency of pearl millet*.," Ph-D, Stockholm University, Stockholm.

27. Agarwal, A. and Narain, S. (1997). *Dying Wisdom*, Centre for Science and Environment, New Delhi.

28. Ostrom, E. (1990). *Governing the Commons: the Evolution of Institutions for Collective Action*, Cambridge University Press, Cambridge.

29. Mabry, J. B. (1996). "*Canals and communities: Small-scale Irrigation Systems*." , The University of Arizona Press, Tuscon.

30. Berkes, F., Kislagioglu, M., Folke, C., and Gadgil, M. (1998). "Exploring the basic ecological unit: Ecosystem-like concepts in traditional societies." *Ecosystems*, 1, 409-415.

THE LINKAGE BETWEEN FRESHWATER AVAILABILITYAND WATER-QUALITY DEGRADATION

Cyclical and cascading effects of human activities

by

Norman E. Peters and Michel Meybeck

Introduction

The continuing increase in global population is increasing the demand on freshwater supply. One important factor affecting freshwater availability is associated with socio-economic development, and another factor is the general lack of sanitation and waste-treatment facilities in high-population areas of developing countries. A principal cause of water scarcity is water-quality degradation, which can critically reduce the amount of freshwater available for potable, agricultural, and industrial use, particularly in semi-arid and arid areas. Thus, the quantity of available freshwater is closely linked to the quality of the water, which may limit its use.

The major water-quality issues resulting in degradation include water-borne pathogens and noxious and toxic pollutants. Despite efforts of United Nations organizations, international banks, and some national governments over the past several decades, human health is still at significant risk due to water-quality problems in many areas of the world (1). In 1990, 1.2 billion people, or 20% of the world population, did not have access to a safe supply of water, and about 50% of the world population had inadequate sanitation services (2). The continued rapid degradation of land and water resources due to water-quality degradation may result in hydrocide for future population (3).

Hydrogeological and biophysical environments are directly affected by changes in land use and socio-economic processes, which are largely controlled by human activities and resource management. A land-management decision is a water-resource decision, a fundamental concept for addressing and implementing integrated land and water resources management (4). Land alteration and associated changes in vegetation have not only changed the water balance, but typically have altered processes that control water quality. One of the most important issues for effective resource management is the recognition of cyclical and cascading effects of human activities on the water quality and quantity along hydrologic pathways, particularly in a watershed context. Hydrologic pathways are routes along which water moves from the time it is received as precipitation (e.g. rain and snow) until its delivered to the downstream most point in a watershed, the drainage area defined by the downstream point to which flow converges. The degradation of water quality in upstream parts of a watershed can have negative effects on users in downstream parts of the watershed, and because there generally is a continuum of users throughout a watershed, the degradation effects cascade through the watershed. Cyclical effects include the artificial movement of water upstream, such as ground water abstraction for irrigated agriculture. Another cyclical effect is the increased leaching of nutrients to waterways. The increase in nutrient flux increases rates of growth of aquatic and riparian vegetation, which in turn increases the flow of water vapor to the atmosphere through increased evapotranspiration. The water-quality crisis is much more immediate and may be more serious than from other phenomena, such as global climate change.

This paper provides (1) an overview of factors affecting water quality and its degradation, (2) provides a scope for water-quality problems and issues, and (3) highlights interactions and linkages between water quality and water quantity as they affect sustainable water use within a drainage basin. Inherent to the discussion is the importance of the exploitation of land and water resources, which affect the quantity and quality of water flows, particularly in an upstream/downstream context germane to any drainage basin.

Evolution of Water Quality

The quality of surface water or groundwater at any point in a watershed reflects the combined effect of many physical, chemical, and biological that affect water as it moves along hydrologic pathways over, under and through the land. The chemical composition of water varies depending on the nature of the solids, liquids and gases that are either generated internally (*in situ*) or with which the water interacts. Furthermore, the chemical composition depends on the type of interaction. At the mostly pristine part of the hydrologic cycle, precipitation quality is derived from interactions with gases, aerosols and particles in the atmosphere. Evaporation purifies water as vapor but concentrates the chemical content of the water from which it evaporated. Condensation begins the process of imparting chemical quality to atmospheric moisture by inclusion of chemical substances through the dissolution of condensation nuclei. The complexity of the water-material interaction increases as precipitation falls on the land.

The physical characteristics and mineralogical composition of soil and bedrock, topography, and biology significantly affect water quality. Most freshwater is a mixture of water derived from several hydrologic pathways. For example, streamwater may be composed of varying mixtures of shallow and deep groundwater, precipitation or snowmelt, throughfall, overland flow, and lateral flow or throughflow in the soil. Furthermore, the streamwater composition may change *in situ* due to biological reactions or due to the interactions with the streambed and adjacent riparian zone. Even the groundwater component of streamwater is a mixture of water derived from different hydrologic pathways that vary in their composition due to the residence time of the water, the length of the hydrologic pathway, biological reactions, and the nature of the materials with which the water interacts. Temperature is another important variable that affects physical characteristics (e.g. transfer of gases), state changes (vapor, water, and ice), and chemical and biological reaction rates of the water.

Water is a solvent and a medium for transfers of mass and heat. Perhaps most important, water is necessary to sustain life. As water travels along a hydrologic pathway, such as from a groundwater recharge area to a spring, a variety of interactions occur that are associated with the type of geologic media and with biota. The interaction causes some chemical elements to dissolve and precipitate and some compounds to transform, such as the oxidation of iron and the change of one nutrient species to another. Particles not only interact with the water, but can be transported by the water depending on the mass, size, and shape of the particle, the velocity, and material through or over which the water flows. Living organisms, particularly micro-organisms, such as phytoplankton and bacteria, affect water-quality genesis through several mechanisms. For example, the biota can use and release nutrients and other elements that are often specific to a particular plants and geographic regions, or generate other products, including gases. Natural water quality varies markedly and is affected by the geology, biology and hydroclimatic characteristics of an area (5). Even under natural conditions, water may be toxic or otherwise unfit for human consumption. The occurrence of high and toxic metal concentrations is not uncommon and can be attributed to weathering of naturally occurring ore deposits. Although generally non-toxic, the solute concentrations of *pure* bottled spring water can vary by several orders of magnitude worldwide. However, the concept of pollution is relative, in that it reflects a change from some reference value to a value that causes problems for human use (6). A worldwide reference value is difficult to establish because insufficient monitoring has occurred prior to changes in water-quality due to human activities. Furthermore, there is no universal reference of natural water quality because of the high variability in natural water quality (6).

Natural water-quality variations occur over a wide range of time scales (6). Long-term changes in water quality can occur over geologic time due to factors such as soil evolution, glaciation, mountain building, and mass wasting. Intermediate changes can occur due to successional changes in vegetation, forest fires, floods and droughts. Seasonal and shorter-term variations in stream and river water quality are partly explained by variations in the mixture of contributing waters (water partitioning), each of which has different composition due to transit time and the contact materials, and the growth cycle of vegetation. Rapid changes in water quality can occur over relatively short spatial distances. The ability to change water quality rapidly is an important control of water-quality deterioration, such as the mobilization of toxic substances due to a rapid change in the oxidation and reduction characteristics of groundwater discharging through contaminated streambed sediments. In contrast, these rapid changes also are an important control of water-quality improvement, such as the removal of nutrients by wetlands and other riparian zone vegetation.

Natural disasters, which accompany hurricanes, floods, tsunamis, earthquakes, volcanic eruptions, and landslides, also have major effects on water quality and water quantity. The time scale of the perturbation varies with the size of the disaster. Over the short-term, relatively more precipitation from a specific event falls directly on the surface water without passing through the soil. This contribution to the surface water has a relatively short transit time, which has more effect on catchments with a large proportion of open water (lakes and reservoirs) than on catchments dominated by groundwater. Consequently, changes in precipitation chemistry, such as decreasing pH can rapidly affect surface-water chemistry. Also, where rainfall intensities exceed soil infiltration capacities and large amounts of surface runoff occur, water quality can change due to the erosion and dissolution of substances from eroded soil particles. The time scale can vary depending on the source of the soil particles and whether or not they have been either contaminated or enriched with respect to some substance.

Human Effects on Water Quality and Quantity

Human influences have had a direct effect on the hydrologic cycle (3) by altering the land in ways that change its physical, chemical, and biological characteristics (5, 7). Physical alterations, such as urbanization, transportation, farming (irrigation), deforestation and forestation, land drainage, channelization, damming, and mining, alter hydrologic pathways and may change the water-quality characteristics by modifying the materials with which the water interacts (Figures 1 and 2). For example, the impervious surfaces created by urbanization produces overland flow and high amounts of runoff even at moderate rainfall intensities (8).

The chemical alteration associated with human activity is, in part, related to the physical alteration, but occurs mainly through the addition of wastes (gases, liquids and solids) and other substances to the land. These additions include waste disposal on the land or in waterways and the application of substances to control the environment, such as fertilizers for crop production, herbicides for weed control, and pesticides for disease control. Atmospheric transport and deposition is a major hydrologic pathway of substances directly to surface water or indirectly to groundwater by infiltration through the soil. Some human derived substances, including pesticides, micro-organic pollutants, nitric acid, and sulfuric acid from fossil fuel combustion, have been found in virtually every remote area and the occurrence and distribution of many of these is due to long-range transport in the atmosphere (9). For example, the pesticide atrazine has been found in lakes and rain in Switzerland (10) and organochlorine compounds in the Arctic (11) and the Antarctic (12). Other types of wastes may be concentrated in one area or in the case of liquid wastes, discharged to surface water from a pipe, and therefore, are referred to as point sources. In contrast, wastes distributed over larger areas, such as fertilizer application to cropland and the emission of gases and aerosols from industry, are referred to as non-point or diffuse sources. Diffuse sources also include several smaller point sources distributed over a large area, such as residential septic tank effluent from multiple dwellings and multiple building construction sites in a developing area. The erosion and transport of soils from agricultural lands during intense rainstorms can rapidly mobilize bioavailable phosphorus (13, 14), which affects the freshwater trophic status (15, 16, 17). Surface mining alters the land, which affects hydrologic pathways. Also, the water interactions with the mine tailings, and in some cases, the discarded chemicals used for ore processing can leach undesirable and toxic substances to receiving waters. The biological alterations include forest management, agriculture, and the import of exotic species.

Human requirements for water also directly affect hydrologic pathways by providing water of a specified quality for different activities to sustain human existence (e.g. agriculture, potable supplies, power generation, power plant cooling, and industry). The water-quality from urban areas is complex due to the myriad of sources and pathways (18). In urban areas, not only are there multiple sources of individual substances, but the natural hydrologic pathways are replaced with artificial drainage channels, wet and dry storage basins, sewers, and water distribution systems, all of which affect the quantity and quality of urban runoff spatially and temporally. The management of the delivery of untreated waste (point source) directly to surface water has received considerable attention in developed countries, and recently more emphasis has been placed on controlling diffuse sources (19).

Human activity is now one of the most important factors affecting hydrology and water quality. Humans use a large amount of resources to sustain various standards of living, although measures of sustainability are highly variable depending on how sustainability is defined (20). Nevertheless, the land must be altered to produce these resources. Irrigated agriculture alone is responsible for about 75% of the total water withdrawn from surface and groundwater sources, and more than 90% of this water is consumed and delivered to the atmosphere by evaporation (2). In addition to placing a demand on the quantity of water, which is diverted for food production, the quality of water flowing through a typical agricultural area is markedly degraded. Degradation depends on several factors including the climatic characteristics (amount and timing of rainfall and associated potential evapotranspiration) and the various agrochemicals applied to increase yields. Consequently, headwater agricultural development affects the water flows and associated downstream water quality. Conversely, the resource demands of downstream users may result in the diversion of water, which may have been used for headwater agriculture, from basin headwaters. In some cases, land conversion to agriculture may ultimately cause soil salinization, which effectively poisons the land (21). Similarly, conversion to irrigated agriculture can increase evaportranspiration from crops and alter the regional climate (22, 23).

Historically, the development of water resources focused on modifying the hydrologic pathways of the natural system to provide water for human activities. Over time, the efficiency of some water uses has improved, but the water needs of an ever-increasing population has increased the importance of the quality of the water, particularly in areas of water scarcity. However, the effects of concentrated toxic wastes on human and environmental health generally are not known despite efforts in disease geography and environmental toxicology. The number of new chemical substances, which are released in the environment far exceed those that are monitored or researched to determine their fate, transformation, transport, and environmental or human effects. An emerging issue is the manufacture and release of pharmaceutical chemicals to the environment and their affect on biota. The difficulties in understanding the toxicity is compounded by the environmental complexity added by human activities, such as urbanization. Furthermore, current research of toxicity effects cannot keep pace with the numbers of compounds and the complex interactions of natural settings. Current research on toxicity relies primarily on exposure of biota to various types of runoff, and less on a systematic assessment of mixtures of compounds, which may have symbiotic affects on biota.

Process knowledge about the fate, transformation, and transport of contaminants is not complete, but it is sufficient to provide some technical solutions to many water-quality degradation problems. This knowledge alone, however, will not lead to effective controls on the cascading effects of water-quality degradation. A social and political will to initiate improvements also is needed, particularly in developing countries where economic resources are limited. Policy alone will not solve many of the degradation issues, but a combination of education, policy, scientific knowledge, planning and enforcement of associated laws can provide mechanisms for slowing the rate of degradation and provide human and environmental protection. Such an integrated approach is required to effectively manage land and water resources.

Alteration of the Land and Time Scales of Recovery

As discussed previously, most freshwater is a mixture of water derived from several hydrologic pathways. Consequently, alteration of hydrologic pathways or changes to water quality along a pathway may affect the composition of water with which it mixes. This concept is important to consider in an evaluation or assessment of resources. We are all aware to the consequences of inadequate storage of radioactive waste, yet the same principles apply to substances. The concept that human intervention in the landscape and disposal of substances has resulted in chemical time bombs. The understanding of transport through basin materials has evolved as our attention focused on major human health issues associated with the disposal of toxic substances in the landscape (24). This concept of chemical time bombs has emerged in the past few decades through environmental toxicology investigations and results of environmental remediation. Our perceptions of the risk associated with exposures to toxic substances has likewise evolved (25).

Effective management of land and water resources requires an understanding of spatial and temporal effects of human activities on these resources. For example, the transport time through the soil is a crucial parameter for the transport and retention of various substances, and thus, the composition of water flowing through the soil. Knowledge of the transport time and retention characteristics is needed to determine the susceptibility of the land to causing water-quality degradation by waste disposal. Important natural and human-influenced characteristics of water-quality genesis including spatial and temporal constraints on water-quality evolution are listed in Table 1. For many water-quality issues, the spatial scale is linked to the temporal scale in that short hydrologic pathways can deliver substances to surface waters faster than long pathways. For example, the mobilization of nitrogen (N) fertilizer to cropland may not have an immediate effect on the tropic status of an adjacent stream or lake. The fertilizer rapidly dissolves and is transported vertically through the soil to groundwater, which moves more slowly than overland flow to a stream. However, the fertilizer applied to the land closest to the stream has the best chance of being mobilized rapidly to the stream. But eventually, even the enriched groundwater, that is the longer hydrologic pathway, will discharge to surface water, and also will affect the aquatic biology. The scientific understanding of nutrient transport processes is far from complete, but it has led to an effective management practice, which is to provide buffer zones in riparian areas to *trap* the N before it reaches the stream. In contrast to the rapid mobility of N, phosphorus (P) applied in fertilizer has a much higher affinity for adsorption on soil and other basin material. The dominant mechanism for mobilizing the adsorbed P is soil erosion during rainstorms or snowmelt. Because the P adsorption varies depending on the characteristics of the materials, dissolution of the P fertilizer will depend on the type of fertilizer and the P mobilization will depend on the soil characteristics and water flux (26). For example, P is retained in clay soil and mobilized in sandy soil. Even if you stopped applying the fertilizer today, the nutrient content of the receiving surface water may increase for several decades as the nutrient enriched soil is eroded and groundwater moves slowly to the receiving surface water (27, 26).

As another example, the concentrations of DDT, an insecticide that was banned in 1972 from production and use in the US, remains high in agricultural soils, streamwater, suspended and streambed sediment, and fish in the Yakima River Basin, Washington (28). The Yakima River Basin drains about 16,000 km 2 and contains 250,000 people. Irrigated agriculture in the downstream part of the basin, where the DDT was applied, dominates the economy. DDT is persistent in the environment, effects wildlife reproduction and is toxic to wildlife and humans. Despite declining DDT concentrations in streamwater, which is an integrator of the catchment transport, some of the 1990 streamwater DDT concentrations exceeded 0.1 mg L –1 , which is 10 times higher than the chronic-toxicity criterion for the protection of freshwater aquatic life established by the U.S. Environmental Protection Agency. An important result of research conducted in the basin is that despite the application and persistence of DDT in the lower part of the basin, DDT has been detected in fish throughout the basin even in pristine headwater areas. Consistent with the results of the Yakima River Basin, atmospheric transport and deposition during its wide spread use in the 1960s and early 1970s has been attributed to more than 97% of the loading to the Great Lakes (29).

Most compounds interact with basin materials to some extent, and therefore, are retained to varying degrees. Consequently, the time that water resides in the landscape, referred to as the water residence time, typically is shorter, and in some cases much shorter, than the residence time of a particular substance or contaminant. The location of the contaminant relative to receiving waters (groundwater and surface water) is important for determining the time scale of pollutant affects on the receiving water. The mobility of a substance is slowed relative to the water due to interaction of the substance with the basin materials and imperfect mixing of the waters along hydrologic pathways. Several decades may elapse in small (~10 km^2) watersheds before a substance applied to the land surface is transported to surface water and some surficial aquifers, and the time scale for removal may be several hundred years in very large basins (100,000 km^2) and confined aquifers. Consequently, the clean-up time or duration of removal for substances added to the landscape generally is on the order of human generations.

In addition to listing several major water-quality issues, we have put this concept of residence time into perspective for these issues by providing a spatial scale and temporal scale for the problem and temporal scale for the recovery (Table 1). Although there is some research basis for these numbers, they are inexact and are intended primarily to provide a sense of the relative importance of time and space toward water-quality problem resolution. Recall that for some water-quality issues, the time scale for either contamination or clean up is linked to the spatial scale. Many of the water quality problems occur at small spatial scales, but occur over large areas and in some cases have a global scope.

Nutrient Loading and Estuarine and Marine Water-Quality Degradation

Human alterations and additions to the landscape not only affect freshwaters — the oceans are ultimately the recipients of this alteration most rapidly through transport of degraded water in rivers and more slowly through groundwater transport directly to the coastal zone and through long-term contributions to rivers. The increased river flux of nutrients has resulted in an increase in estuarine eutrophication (30, 31). The frequency and spatial extent of hypoxia and related degradation, particularly the loss of marine life, has been increasing and the increase may be attributed to increased biological oxygen demand accompanying the increasing input of agricultural nutrients (31). Hypoxia is a condition where water has an extremely low dissolved-oxygen content (< 2 $mg\ L^{-1}$), which is typically insufficient to support life that inhabited the area prior to the loss of oxygen (32). The increasing area of hypoxia in the Gulf of Mexico and the role of agriculture and the transport of nitrogen fertilizer in the Mississippi-Atchafalaya River Basin is an example of the effect of human activities on marine biota (33). Average riverine N fluxes are about 500 $kg\ km^{-2}$ (1980-1996), and were about three times larger in 1999 than in 1969. Some of the increase was attributed to an increase in precipitation and runoff. However, 9% of the basin area, which consists of intensive agriculture (Iowa and Illinois), contribute as much as 35% of the N flux in years of average rainfall and 90% of the N flux was from diffuse or non-point sources. These contributions were even higher during flood years, such as 1993 when Iowa (4.5% of the drainage basin area) contributed about 35% of the N flux. Hypoxia also occurs in freshwaters and has likewise been attributed to excess nutrient transport to lakes or reservoirs (15, 34).

Conclusions

Human activities in the landscape result in alterations of hydrologic pathways by physically altering the land, by changing the vegetation, and by artificially routing water to where humans want it. In addition, human activities have affected water quality by additions of substances (gas, liquid, and solid). Human requirements for sustainability, cultural characteristics of the population, socio-economic situation, and the biophysical and climatic setting of the area determine the level of interaction, and subsequently, the rate of land and water degradation. Although downstream and larger scale effects occur, human interactions with land and water resources occur at small scales, where decisions are made by the individuals interacting with the landscape. Consequently, human interactions with the land and with the water should to be addressed (and managed) at small spatial scales (yard, garden plot, field). Effects of human activities on the small scale are relevant to the entire drainage basin. Such analyses, therefore, are not only of interest for the status of a particular landscape, but also to downstream users, who are impacted by management decisions on the upstream area. Local, regional, and global differences in wetness and water flow are considerable, causing varying effects of human activities on land and water quantity and water quality depending on the location within the watershed, the geology, biology, physiographic characteristics of the watershed and the climate of the area. These natural characteristics also greatly control the human activities, which will, in turn, modify (or affect) the natural composition of the water. In addition, the most significant characteristic of water flows (and chemistry) is that they are extremely variability over time and space, particularly in semi-arid areas.

One of the most important factors to be considered in assessing and managing land and water resources is that human activities at all scales affect water quantity and quality. Furthermore, the results of these human activities affect users downstream and in general, everyone lives downstream and is affected by some human impact on the hydrologic cycle. Some of the effects are cyclical, such as the use of water from headwater areas for irrigation in lower parts of a watershed where most of the water is delivered to the atmosphere through evapotranspiration. Other effects are cascading, such as the addition of fertilizers that are leached to surface and groundwater, which in turn, are used for irrigation or potable water supply. Another important factor is that the alteration or addition of substances to the atmosphere, land, and water generally have relatively long time-scales for removal or clean up. The nature of the substance including its affinity for adhering to soil and ability to be transformed affect its mobility and the time scale of removal along hydrologic pathways. Contaminants in groundwater, which eventually either discharges to some receiving surface water or is abstracted for some use, will take much longer to be removed than contaminants added to the land in an area dominated by shallow and short hydrologic pathways, such as a riparian zone in a small watershed. Even in the best case of a short hydrologic pathway, some retention of the contaminant by the soil matrix requires continual flushing of the soil for some time to completely remove the contaminant.

REFERENCES:

1. World Resources Institute, 1996. *World Resources 1996-97.* Oxford University Press, New York, 365 p.

2. United Nations Commission for Sustainable Development, 1997. *Comprehensive Assessment of the Fresh Water Resources of the Worl*d. Geneva, Switzerland, World Meteorological Organization.

3. Lundqvist J. 1998. Avert looming hydrocide. *Ambio* **2**7: (6): 428-433.

4. Falkenmark M, Andersson L, Castensson R, Sundblad K (eds). 1999. *Water a Reflection of Land Use – Options for Counteracting Land and Water Mismanagemen*t. NFR, Swedish Natural Science Research Council, Stockholm, Sweden; 128

5. Hem JD. 1985. Sudy and interpretation of the chemical characteristics of natural water. *U.S. Geological Survey Water-Supply Paper* **225**4; 263 p.

6. Meybeck M. 1996. River water quality: Global ranges, time and space variabilities, proposal for some redefinitions. *Internationale Vereinigung für Theoretische und Angewandte Limnologie, Verhandlungen* **2**6: 81-96.

7. Meybeck M, Helmer R. 1989. The quality of rivers: from pristine stage to global pollution. *Palaeogeography, Palaeoclimatology, Palaeoecology* **7**5: 283-309.

8. Arnold CLJ, Gibbons CJ. 1996, Impervious surface coverage - the emergence of a key environmental indicator. *Journal American Planning Association* **6**2: 243-256.

9. Majewski MS, Capel PD. 1995, Pesticides in the atmosphere.distribution, trends, and governing factors. In RJ Gilliom. (ed.), *Pesticides in the hydrologic syste*m. Ann Arbor Press, Chelsea, Michigan, 214 p.

10. Buser, H-R. 1990, Atrazine and other s-triazine herbicides in lakes and in rain in Switzerland: *Environmental Science and Technology* **2**4: 1049-1058.

11. Lockerbie DM, Clair TA. 1988, Organic contaminants in isolated lakes of southern Labrador, Canada. *Bulletin of Environmental Contamination and Toxicology* **4**1: 625-632.

12. Tanabe S, Hidaka H, Tatsukawa R. 1983, PCB's and chlorinated hydrocharbon pesticides in Antarctic atmosphere and hydrosphere. *Chemosphere* **1**2: 277-288.

13. Sharpley AN. 1993. Assessing phosphorus bioavailability in agricultural soils and runoff. *Fertilizer Research* **3**6: (3): 259-272.

14. Sharpley AN, Gburek W, Heathwaite AL. 1998. Agricultural phosphorus and water quality: sources, transport and management. *Agricultural and Food Science in Finland* 7: (2): 297- 314.

15. Ryding S-O, Rast W. (eds.), 1989. *The Control of Eutrophication of Lakes and Reservoirs*. UNESCO, Man and The Biosphere, vol 1.

16. Correll DL. 1999. Phosphorus: A rate limiting nutrient in surface waters. *Poultry Science* 78: (5): 674-682.

17. Smith VH, Tilman GD, Nekola JC. 1999. Eutrophication: impacts of excess nutrient inputs on freshwater, marine, and terrestrial ecosystems. *Environmental Pollution* **10**0: (1-3): 179-196.

18. Driver NE, Troutman BM. 1989. Regression models for estimating urban storm-runoff quality and quantity in the United States. *Journal of Hydrology* **10**9: (3/4): 221-236.

19. Line DE, Jennings GD, McLaughlin RA, Osmond DL, Harman WA, Lombardo LA, Tweedy KL, Spooner J. 1999. Nonpoint sources. *Water Environment Research* **7**1: (5): 1054-1069.

20. Moldan B, Billharz S, Matrazers R (eds). 1997. *Sustainabillity Indicators*. SCOPE **5**8, Paris, France

21. Ghassemi F, Jakeman AJ, Nix HA. 1995. *Salinisation of land and water resources; human causes, extent, management and case studies*.Australian National University, Centre for Resource and Environmental Studies: Canberra, Australia; 526.

22. Pielke RA, Avissar R. 1990. Influence of landscape structure on local and regional climate. *Landscape Ecology* 4: (2/3): 133-155.

23. Stohlgren TJ, Chase TN, Pielke RA, Sr., Kittel TGF, Baron JS. 1998. Evidence that local land use practices influence regional climate, vegetation, and stream flow patterns in adjacent natural areas. *Global Change Biology* 4: (5): 495-504.

24. Young AL. 1999, Burying Love Canal. *Environmental Regulation and Permitting* 8: (3): 5-14.

25. Howe HL. 1988. A comparison of actual and perceived residential proximity to toxic waste sites. *Archives of Environmental Health* **4**3: (6): 415-419.

26. Haygarth PM, Jarvis SC. 1999. Transfer of phosphorus from agricultural soils. *Advances in Agronomy* **6**6; 195-249.

27. Bohlke JK, Denver JM. 1995. Combined use of groundwater dating, chemical, and isotopic analyses to resolve the history and fate of nitrate contamination in two agricultural watersheds, Atlantic coastal plain, Maryland. *Water Resources Research* **3**1: (9): 2319-2339.

28. Rinella JF, Hamilton PA, McKenzie SW. 1993 Persistence of the DDT pesticide in the Yakima River Basin Washington. *U.S. Geological Survey Circular* **109**0: 24.

29. Strachen WMJ, Eisenreich SJ. 1990, Mass balance accounting of chemicals in the Great Lakes. In DA Durtz (ed) *Long range transport of pesticide*s: Lewis Publishers, Chelsea, Michigan; 291-301.

30. Hodgkin EP, Hamilton BH. 1993. Fertilizers and eutrophication in southwestern Australia— setting the scene. *Fertilizer Research* **3**6: 95-103.

31. Jorgensen BB, Richardson K (eds). 1996. *Eutrophication in Coastal Marine Ecosystems.* American Geophysical Union, Washington, D.C.; Coastal and Estuarine Studies, **5**2: 272.

32. Burnett LE. 1997. The challenges of living in hypoxic and hypercapnic aquatic environments. *American Zoologist* 37: (6): 633-640.

33. Goolsby DA, Battaglin WA, Lawrence GB, Artz RS, Aulenbach BT, Hooper RP, Keeney DR, Stensland GJ. 1999. Flux and sources of nutrients in the Mississippi-Atchafalaya River Basin — Topic 3 Report for the integrated Assessment on Hypoxia in the Gulf of Mexico. NOAA Coastal Ocean Program Decision Analysis Series No. 17. NOAA Coastal Ocean Office, Silver Spring, Maryland, USA 129 p., http://wwwrcolka.cr.usgs.gov/midconherb/hypoxia.html, 19 January 2000.

34. Rast W, Thornton JA. 1996. Trends in eutrophication research and control. *Hydrological Processes* **1**0, 295-313.

THE HUMAN RIGHT TO WATER

by

Peter H. Gleick

The 21st century is going to begin with one of the most fundamental conditions of human development unmet: universal access to basic water services. More than a billion people in the developing world lack safe drinking water that those in the developed world take granted. Nearly three billion people live without access to adequate sanitation systems necessary for reducing exposure to water-related diseases. The failure of the international aid community, nations, and local organizations to satisfy these basic human needs has led to substantial, unnecessary, and preventable human suffering. An estimated 14 to 30 thousand people, mostly young children and the elderly, die every day from water-related diseases. At any given moment, approximately one-half of the people in the developing world suffer from disease caused by drinking contaminated water or eating contaminated food (United Nations, 1997b). A diverse array of individuals, professional groups, private corporations, and public governmental and non-governmental interests has recently stepped up efforts to better manage and plan for meeting basic water needs in the next century. The outcome of these efforts will be vital to the health and well-being of billions of people. Access to a basic water requirement is a fundamental human right implicitly supported by international law, declarations, and State practice. In some ways this right to water is even more basic and vital than some of the more explicit human rights already acknowledged by the international community, as can be seen by its recognition in some local customary laws or religious canon.

A transition is underway making a right to water explicit (1). As we enter the 21st century, governments, international aid agencies, non-governmental organizations, and local communities should work to provide all humans with a basic water requirement and to guarantee that water as a human right. By acknowledging a human right to water and expressing the willingness to meet this right for those currently deprived of it, the water community would have a useful tool for addressing one of the most fundamental failures of 20th century development.

Is There A Human Right to Water?

The term "right" is used here in the sense of genuine rights under international law, where States have a duty to protect and promote those rights for an individual. The question of what qualifies as a human right has generated a substantial body of literature, as well as many organizations and conferences. The initial impetus to human rights agreements was to address violations of moral values and standards related to violence and loss of freedoms. Subsequently, however, the international community expanded rights laws and agreements to encompass a broader set of concerns related to human well-being. Among these are rights associated with environmental and social conditions and access to resources.

Gleick (1999) answers the question of whether individuals or groups have a legal right to a minimum set of resources, specifically water, and whether there is an obligation for States or other parties to provide those resources when they are lacking. This question has not previously been adequately addressed. This paper concludes that international law, international agreements, and evidence from the practice of States strongly and broadly support the human right to a basic water requirement.

What is the value of explicitly acknowledging a human right to water, as the international community has explicitly acknowledged a human right to food and to life? After all, despite the declaration of a formal right to food, nearly a billion people remain undernourished. One reason is to encourage the international community and individual governments to renew their efforts to meet basic water needs of their populations. International discussion of the necessity of meeting this basic need for all humans is extremely important – it raises issues that are global but often ignored on the national or regional level. Secondly, by acknowledging such a right, pressure to translate that right into specific national and international legal obligations and responsibilities is much more likely to occur. A third reason is to help keep a spotlight of attention on the deplorable state of water management in many parts of the world. A fourth reason is to help focus attention on the need to more widely address international watershed disputes and to help resolve conflicts over the use of shared water by identifying minimum water requirements and allocations for all basin parties. Finally, explicitly acknowledging a human right to water can help set specific priorities for water policy: meeting a basic water requirement for all humans to satisfy this right should take precedence over other water management and investment decisions.

Defining and Meeting a Human Right to Water

What are the implications of a human right to water? A right to water cannot imply a right to an unlimited amount of water. Resource limitations, ecological constraints, and economic and political factors limit water availability and human use. Given such constraints, how much water is necessary to satisfy this right? Enough solely to sustain a life? Enough to grow all food sufficient to sustain a life? Enough to maintain a certain economic standard of living? Answers to these questions come from international discussions over development, analysis of the human rights literature, and an understanding of human needs and uses of water. These lead to the conclusion here that a human right to water should only apply to “basic needs” for drinking, cooking, and fundamental domestic uses.

Translating the Right to Water into Specific Legal Obligations

If we accept that there is a human right to water, to what extent does a State have an obligation to provide that water to its citizens? While the many international declarations and formal conference statements supporting a right to water do not directly require States to meet individuals' water requirements, human rights law obligates States to provide the institutional, economic, and social environment necessary to help individuals to progressively realize those rights. In certain circumstances, however, when individuals are unable to meet basic needs for reasons beyond their control, including disaster, discrimination, economic impoverishment, age, or disability, States must provide for basic needs. Meeting this minimum need should take precedence over other allocations of spending for economic development. This will require a redirection of current priorities at international and local levels, and it is likely to require new resources be invested as well.

It seems likely that an appropriate mix of economic, political, and social strategies can be developed to reliably provide for basic needs. And despite a growing emphasis on markets, if a "market" system is unable to provide a basic water requirement, States have responsibilities to meet these needs under the human rights agreements discussed above.

Unless international organizations, national and local governments, and water providers adopt and work to meet a basic water requirement standard, large-scale human misery and suffering will continue and grow in the future, contributing to impoverishment, ill-health, and the risk of social and military conflict. Ultimately, decisions about defining and applying a basic water requirement will depend on political and institutional will.

Summary and Conclusions

This presentation and the original paper review evidence of international law, declarations of governments and international organizations, and State practices and conclude that access to a basic water requirement must be considered a fundamental human right. The major human rights treaties, statements, and formal covenants contain implicit and explicit evidence that reinforce the application of rights law in this area. If the framers of early human rights language had foreseen that reliable provision of a resource as fundamental as clean water would be so problematic, it is reasonable now to suggest that the basic rights documents would have more explicitly included a right to water. A formulation appropriate to the existing human rights declarations might be:

> "Every human being has an inherent right to have access to water in quantities and of a quality necessary to meet their basic needs. This right shall be protected by law."

Would the recognition of the human right to water actually improve conditions worldwide? Perhaps not. The challenge of meeting human rights obligations in all areas is a difficult one, which has been inadequately and incompletely addressed. But the imperatives to meet basic human water needs are more than just moral, they are rooted in justice and law and the responsibilities of governments. It is time for the international community to reexamine its fundamental development goals. A first step toward meeting a human right to water would be for governments, water providers, and international organizations to guarantee all humans the most fundamental of basic water needs and to work out the necessary institutional, economic, and management strategies necessary for meeting them.

REFERENCES:

1. Gleick, P.H. 1999. The Human Right to Water. *Water Policy*, Vol. 1, pp. 487-503.

RULES AND ROLES IN WATER POLICY AND MANAGEMENT

- Need for clarification of rights and obligations

by Jan Lundqvist

Making "water everybody's business"

The impending water crisis has necessitated a systematic review of the prevailing water policy. Water is increasingly high on national and international agendas. Most prominent among current efforts in this regard is the work of the World Commission on Water. Based on regional and sector reviews and consultations, involving thousands of partners around the world, the Commission will present a World Water Vision (WWV) at The Second World Water Forum in The Hague on the World Water Day in March 2000. It is hard to imagine anything more global than that.

Global thinking must be linked to local action. The opposite linkage is equally important; local capability must be duly recognised in visions at various levels. It is repeatedly stressed in various policy documents and statements that some of the most vital management options and decisions are, and should be, at the level of the water user or, rather, group of users. For various reasons, there is often a gap between visions and declarations at the global level and the very landscape, town area or village where people are and where water problems are experienced. This is perhaps natural since it takes time before a (new) policy can be translated into action. In this sense, a major challenge is to develop a strategy through which visions can be most effectively implemented.

The landscape with its particular upstream/downstream dynamics and with its various actors, constitutes the interface where policy and (mis-)use of water and land are confronted with each other. To make a difference from a mirage, a vision must be encompassed by the "doers". A whole range of decision makers, from the high policy making level to the level where day-to-day decisions are made concerning actual water use *and* disposal of water after use, must be involved. At least, there must be some degree of co-ordinated approach which, in turn, presumes transparent rules and regulations supported or accepted by the various stakeholders. If not, the problems related to water will continue. Most likely, they will increase rather than decrease. Proper management of water and related resources is not likely to be realised until and unless water is made "everybody's business" as declared in the World Water Vision.

Making "water everybody's business" implies various things. It explicitly widens the view on who should be actively engaged in efforts related to water management. The notion transcends conventional interpretations of central concepts such as suppliers – beneficiaries. Dichotomies of this kind carry unfortunate connotations. Invariably they have been interpreted as if some people in society should be the active and responsible part in water management, whereas others should be the receivers of water or water services. As pointed out by Hector Garduno in his paper, water resources management has traditionally paid little, if any, attention to actual use of water. Similarly, the links between water utilisation and water flow and water quality parameters have largely been missing in water resources management discussions. Modification of flow and quality parameters can be seen along the upstream-downstream dimension.

Focus on water use

The impending water crisis has three main components. One refers to a growing imbalance between the amounts of water that are available in the landscape, on the one hand, and the escalating demands on this finite and vulnerable resources for various functions in society, on the other. Secondly, the increasing rates of withdrawals of water for various purposes in society represent a threat to the continuous functionings of ecosystems and, generally, environmental sustainability. A third component concerns the risk of an hazardous and unacceptable degradation of quality. All three components have a clear upstream-downstream configuration.

In the first case, the climatic context is, of course, a basic factor. But in addition to the climatically induced shortages and other problems that a harsh climate entails, it is also true that scarcity to a large extent is man-made. Demographic trends constitute one obvious cause for increasing scarcity. The ratio between number of people per flow unit of water – or its inverse form; the amount of water per inhabitant - has been used as a standard indicator of water scarcity. A clearly worsening trend of this ratio has been an important driving force behind the concern for a water crisis. To put the challenge in a proper perspective, it is relevant to mention that the notion of increasing water scarcity is, in a sense, misleading. It is not water that is becoming more scarce, but the number of people and people's wants that are becoming more plenty. Moreover, the geographical correlation between demographic and economic trends and water availability is poor.

Recent discussions about water scarcity have been broadened in important respects and a much more clear reference is made to water use. Numerous reports have, for instance, illuminated that the efficiency in the actual use of water in various activities and sectors is relatively low. This is typically the case in irrigated agriculture. If water is used lavishly in one sector, or by one group of users, comparatively less water will be accessible for other users. Re-use is, of course, an option but it is not possible after consumptive use and the options are reduced if quality is affected. Another intensely debated aspect of man-made scarcity refers to the allocation of water between incompatible use options. If water is in short supply and if it is allocated to a sector or activity which yields a low return per unit water, the possibilities to satisfy various development objectives of society are reduced as compared to a situation where water is allocated to activities that could generate a comparatively high return per unit of water. A given amount of water can only be used for one purpose at a time. The use of water will thus reduce the options of re-use one way or another.

It is thus of paramount importance to recognise that the major components of the impending water crisis are related to water use, not to water supply. So far, much more attention has been devoted to quantitative aspects of the water challenge as compared to the quality aspects. Notions such as “water scarcity”, “water stress” and also “water supply” refer primarily to a quantitative lack of water or technical challenges to overcome poor access to water. Similarly, conflicts over water have mostly been interpreted in terms of high ratios of number of people per flow unit of water. Currently, and for the future, the degradation of water quality is, however, a major worry.

Threats of water quality degradation

Pollution, in particular, is closely associated with water use and the way that waste water and other waste products are disposed. Members of the household, farmers, industrialists, etc. are the main actors in this connection. Pollution from the various sources varies in terms of degree of persistence and geographical configuration. Bacteriological contamination and nutrients dominate from the household sector and in the animal waste. Compared to substances that are emitted from production activities in the industrial, agricultural and transport sectors, the load from the household sector is generally not accumulated into an environmental debt. The aggregate load from a very large number of households makes this threat of a water and environmental degradation sizeable. So far, the impact from household pollution has been a major factor in the impairment of human health.

Currently and for the future, the heavy water pollution from industrial development, as reported in the cases presented in this book, is a case in point. Although the current situation in the various cases is described as dramatic, it is also obvious that few observers have until quite recently anticipated the magnitude of the threat nor the speed by which it has unfolded. The threat of quality degradation is much more elusive in character as compared to quantitative water problems. There is often a time lag between the event/activity that caused the pollution and its consequences. Many of the polluting substances are, moreover, not possible to see nor to smell and the consequences are quite difficult to anticipate. It may take years before the damage is manifest and, unfortunately, also before cause-effect relationships may be properly understood.

As for the current situation and the near future, the technologies and activities which would be required to reduce or eliminate pollution might not be accessible, for financial reasons or because of the structure of the industrial sector(s) concerned. Even if they are accessible, the use of environmentally sound technologies might have non-desirable social implications. “Clean production” technologies, for instance, tend to be labour saving and presuppose another type of industrial organisation as compared to many existing, but polluting, technologies. Trade-offs between environmental values and social and economic benefits are often emphasised. While it is true that choices have to be made in this regard, it may also be asserted that many of these contradictions are the result of poor management practices and a failure to enforce adequate legal and regulatory measures.

Hence, there is very good reason to admit that averting a looming water quality degradation is quite a complex and difficult task but also that the consequences of a continuous degradation are serious. The detrimental effects are no longer only observed in terms of effects on human health. Degradation of water quality will also have negative repercussions for ecosystem functioning and for the economy. The best strategy to reduce the threat of water quality degradation is to focus on the activity or the site where the problem is generated, e.g. the industry, town area or agricultural field. End-of-pipe strategies, i.e. building of treatment plants and similar structures may, of course, mitigate some of the consequences of poor water quality but in the long term it is necessary to reduce the load of pollution itself. It would be an illusion to think that a reduction of pollution can be achieved if the responsibility of the various users of water, and land, are not clarified and adhered to. A combination of clear rules for water use in the various sectors and what kind of responsibilities, that are associated with the water rights is one pre-requisite to accomplish this objective.

Water management is currently often discussed in terms of “partnerships” and “contracts” between various groups in society. Closer and more open links between those who provide water services and those who are offered and receive these services are a natural component in this new perspective on water management.

Modifying water’s behaviour or water users’ behaviour?

Escalating water scarcity has profound implications for society as well as for processes in the landscape. Adaptation to the growing scarcity and the threat of quality degradation must increasingly be conceived of in terms of social changes in society. Technological improvements will, of course, remain one basic component in efforts to better management and utilisation of whatever amounts of water that are available. But a heavy reliance on technological solutions to the impending water crisis might be elusive. There is ample evidence to show that *even if* society, at any point in time, adopts best available technology (BAT), with due consideration to what is economically feasible, water resources are often inadequate to meet aggregate demand or they are too vulnerable to neutralise impacts caused by human activities. The continuously increasing pressure on finite and vulnerable water resources is the natural consequence of changes in society. Some of the problems thus created could probably be more easily solved through modification of human behaviour rather than through “pure” technical applications. The notion of demand side management, for instance, implies that efforts should be devoted to modify human behaviour and perceptions and not only modify water’s behaviour.

Changing human behaviour is obviously quite demanding and it is a gradual process where various institutions in society play a crucial role. The legal system and the regulatory framework constitute one basic component. The education system and various arenas where information and knowledge can be exchanged, represent another component. The common denominator in this connection is to modify the behaviour of the water user in a direction which contributes to improved overall water management.

Water rights and right to water

An active involvement of the users in efforts to improve water management presumes that their roles are properly defined and that the rules concerning water use are clarified. Formal water rights are essential in this connection. In short, these must include clear provisions for entitlements to water: how much water that will be provided or how much that may be extracted and under what conditions water services are provided. With reference to the discussion above, the conditions must also cover aspects related to pollution and waste water handling. Hence, formal water rights encompass a set of rights but also a set of associated obligations or responsibilities on the part of the user.

The discussion about the formal water rights and how to implement these into practice refer to water resources management in general and makes an integrated approach possible. Parallel with the discussion about water rights, there is a related argument, which stresses that water should be considered a Human Rights issue. A valid and important point in this connection is that water is a necessity for life and that a large number of premature deaths are found among people who have poor access to water. Every effort that would ensure easy access to adequate amounts which would satisfy basic human requirement for everybody at all times, is therefore something that should be regarded as a matter of highest priority.

Nobody would deny or question the moral and ethical significance of the principle of a Human Right to water. It is also important to stress that easy access to drinking water is an highly prioritised issue in most, if not all countries, and something which is widely supported. But since the objective behind the principle is not achieved in practice, it becomes imperative to discuss how easy access to water can be realised. It is important to ponder over the practical implications of the two concepts and to what extent and in what sense the two notions differ (see Table 1). In terms of the actual implementation of the two notions, there are a number of aspects which need to be sorted out. It is, for instance, important to discuss how the various aspects of responsibility are dealt with. It is also important to try to anticipate how the notions may be interpreted by various groups of people in society. In addition, it is relevant to ask what kind of coverage the principles have on the overall management of water.

Formally, it is only the State who is in a position to guarantee that the rights are being met. In this sense, there is no difference between the two principles. In a rights based approach the responsibility of the State becomes, however, relatively more pronounced since the role and obligations of informal institutions and the water users themselves remain unspecified. The users are disconnected from obligations and tend to be regarded as passive receivers of water services from a benevolent State. To be successful, the implementation of the strategy of Human Right to water presumes that the position of the State or Government is strengthened, for instance, that adequate financial and other resources are at the disposal of the State. Alternatively, it presumes that the formal Government apparatus is more efficient than is generally the case.

Water rights	Human Right to water
⇓ Presume associated obligations on the part of the water user ⇓ Clear rules and roles ⇓ Water is made everybody's business ⇓ Pre-requisite for efficient, equitable and ecologically sound water utilisation	⇓ Top down approach ⇓ Disconnects users from obligations ⇓ Discourages efforts to own solutions ⇓ Unclear rules and roles

Table 1. *A schematic presentation of a few characteristics associated with the principles of Water Rights and Human Right to Water (a rights based approach).*

The experience in many countries indicates that an increased reliance on the State for water services may be rather frustrating. For want of adequate resources and other reasons, promises by the State are only partly met although it is quite common that vows of improvements in water provisions are made. For the poor and disadvantaged segments of society a political rhetoric is no solution and a better approach might be to rely on the capacity that can be developed within the civil society. The rationale behind the current stress to involve representatives of civil society in water management is basically that the formal water management system does not have the ability to fully cope with management obligations on its own. Extending the obligations of the State, without a corresponding mobilisation of the capacity of civil society, does not seem to be the most promising approach. This is not to deny that the State plays an important role in water management and, notably, in the administration of formal water rights as discussed by Hector Garduno in his article.

The rights based approach focuses on water supply aspects solely. The issue of disposal of waste water is, for example, a non-issue in discussions of the Human Right to water. In view of the contemporary discussion about the risk of a serious degradation of water quality, it is surprising and unfortunate to overlook the problems associated with disposal of water after use. Apparently, there is a need to connect the rights based approach with the wider discussion about water use as touched upon above and which fits well into the notion of water rights.

Finally, it is relevant to consider the coverage of the principle of Human Right to water. As argued by Peter Gleick in his paper, it should refer to an amount that is required for basic human needs. This is obviously an important and valid argument, which many support, although not all advocates of a rights based approach. In practice, it is difficult to draw a distinguishing line between the limited amounts of water that could be considered as a human rights quantity and water provisions more generally. Handling of this principle at a community level is probably quite complicated. In a long-term perspective, a viable social and economic development presumes an integrated approach where the various functions of water in society and in the landscape are taken into consideration.

Easy access to safe drinking water is one of the pre-requisites for improvements in human health and welfare and an important means to prevent unnecessary human sufferings. Priority for such provisions is a characteristic feature in water policy and there is overwhelming support for this position, from political representatives and from society a large. Still, well over a billion people do not enjoy easy access to safe water. From what has been discussed above, it seems that an improved joint effort by communities and the State is the most promising and the necessary approach to arrive at a water use that will facilitate the reaching of social and economic objectives. Among other tings, such an approach should include arrangements where the rules are specified in terms of rights and obligations and an identification of the roles of the various actors.

WATER RIGHTS ADMINISTRATION IN DEVELOPING COUNTRIES: A PREREQUISITE FOR SATISFYING WATER NEEDS[1]

by

Hector Garduño

Water rights administration and demand management

Water resources management has traditionally emphasized assessing water availability rather than water use, and solving water problems by increasing supply instead of reducing demand. Due to increasing water pollution, shortages and conflicts among uses, users and geographical areas, a supply-oriented approach will lead to severe water shortages and reduced use options in the near future. As a result of the logic of the hydrological cycle, the detrimental consequences of a conventional supply oriented approach will be particularly noticeable in downstream areas. Therefore, more emphasis should be placed on water demand management and conservation of the quality of water sources.

Water demand management usually includes introducing water saving technologies and public participation as well as water rights transfers to activities that make more beneficial use of water from social, ecological and economic viewpoints. But realistic water demand management and pollution control programs cannot be designed or implemented without a fair knowledge of who uses how much water and for what purpose, as well as who the wastewater dischargers are and what the quality of their discharge is. Moreover, users and wastewater dischargers may not be willing to participate in such programs unless they have legal certainty on their rights to abstract water and to discharge wastewater under a certain effluent standard.

Probably the most difficult component of a water law to cope with is water rights administration. This involves the granting of water abstraction and wastewater discharge permits and thereafter monitoring compliance of users with the terms and conditions of such permits. This difficulty stems from the complexities of the water cycle and the many historical, social, ecological, economic and political circumstances that influence water uses, but also from the fact that in many cases laws and regulations are drafted with limited regard for the institutional capacity to "absorb" them.

[1] This paper is adapted from Garduño, H. "The Experience of Mexico and Other Selected Countries in the Implementation of New Water Legislation", paper presented at the NAMREV/FAO Workshop on Water Law and Administration, at Windhoek, Namibia, 28-29 July, 1999. The FAO's Development Law Service sponsored the study.

This paper summarizes the experience in water legislation implementation in four developing countries, i.e. Mexico, Uganda, South Africa and Sri Lanka.

The "Regulatory Feasibility Assessment"

Water rights administration is difficult, mainly because laws and regulations are drafted with limited regard for the institutional capacity to "absorb" them. Indeed drafting a law is such a politically demanding issue that it is difficult paying attention to regulation drafting and to the implementation tools that will be required once the law and regulations come into force. The diagram in Figure 1 offers a pragmatic approach, which could be called a "Regulatory Feasibility Assessment (RFA)". The left-hand side block shows the steps from water policy to implementation, which are usually taken in an isolated manner. An eight-year period is shown for the sake of stressing the fact that these are usually lengthy processes, during which a first drafting and consultation stage precedes adoption of each document. The RFA approach consists of parallel drafting of water policy, act, regulations and implementation tools, linked to capacity building. This approach enforces permanent feedback among lawyers in charge of drafting and water rights administrators in charge of implementation.

PERMANENT FEEDBACK	Year							
	1	2	3	4	5	6	7	8
Policy	----	----	XX	XX	XX	XX	XX	XX
Act		----	--X	XX	XX	XX	XX	XX
Regulations		--	----	XX	XX	XX	XX	XX
Implementation tools			----	--				
"Paper simulation"			--	--				
CAPACITY BUILDING			----	--X	XX	XX	XX	XX
Pilot implementation				X	X			
Gradual implementation					X	XX	XX	XX

--- Draft preparation and consultation

XX Adopted

***Figure 1**. A schematic illustration of the various steps that have to be taken into consideration in water policy formulation and implementation.*

The following two hypothetical examples are presented to clarify the proposed approach. Firstly, recent international and national water policies stress the need to consider ecological water requirements. This is a basic principle to sustainable development, even to the survival of humankind and it should be promptly acted upon, lest credibility and confidence in the principle be lost. However, making this principle operational is extremely difficult. Let us assume that a draft national water act provides for allocation of water to productive uses only after allocating water to ecological needs. The draft regulations may state that to compute water ecological requirements, the needs of all associated natural resources and living organisms as to maintain biological diversity, shall be taken into account. One of the implementation tools, a technical procedure for determining the water ecological requirements, should then specify how to establish the physical, chemical and biological functional relationships between water, other natural resources and living organisms. If, before actual adoption of the act, regulations and procedure, one simulated implementation, maybe one would discover that the proposed procedure could be applied only to some specific river basin with enough available data. Therefore, a signal would be sent to the draftspersons, scientists and engineers asking them to conceive a more realistic approach that could be applied for all river basins in the country. Another signal would be sent in order to improve the civil servants' capacity in order to be prepared to deal with this complex issue once the act, regulations and implementation tools were adopted. After adoption of the legal instruments the approach would consist of testing procedures in some pilot river basins and gradually implementing of the water rights administration system in the rest of the country. Lessons learnt from implementation may be used to periodically improve implementation tools and capacity building programs.

The second example refers to another common flaw. Drafting of act, regulations and procedures is usually carried out from the water authority's perspective, the result being that existing users and applicants for new water or waste discharge permits may not understand those documents and may not have the technical or financial capacity to comply with their provisions. During the drafting process empathizing with them or even by including in the process some users and potential applicants would bring in their viewpoints. This approach would also permit taking into consideration users' needs in the capacity building programs.

Anticipation pays

This study has taken advantage of the experiences in four developing countries in drafting and implementing their water legislation in order to distil guidelines and recommend carrying out a RFA, which may help in preparing "implementable" legislation. It would be worthwhile carrying out similar studies in other developing and developed countries. The paradigm in this approach is “anticipation pays”. In order to complement the advocated pragmatic approach, it would be necessary to assess the effectiveness and efficiency of said implementation in the field. By doing so in several case studies, probably additional guidelines could be distilled that would help in drafting water legislation that in fact accomplish a more equitable and efficient water resources allocation. Such an assessment should, however, not only serve the purpose of facilitating the drafting of new legislation elsewhere. It should also be a means to assess the performance of the regulations, i.e. a Regulatory Impact Assessment (RIA), the purpose of which should be to modify existing regulations. Supposedly, a RIA would in many countries show that the institutional and administrative framework is the weak link. The most rational approach in such cases would be to allocate resources to strengthen the institutional and administrative framework through various types of capacity building efforts. A more radical objective would be to question the existing regulations and to work out a new policy and associated regulatory framework.

MANAGING CONFLICTS IN UPSTREAM/DOWNSTREAM WATER RELATED INTERESTS IN RIVER BASINS

by

Evan Vlachos

Introduction

The presentation is organized around four major topics, i.e., the context of change and major transformations related to water resources planning; present and alternative mechanisms in water management and the problems of river basin interdependencies; managing and resolving water conflicts and new avenues of cooperation; and, finally, innovative efforts for a shift from crisis to risk management, especially in terms of institutional capacity building and with regard to mediation as an important mechanism in an increasingly complex and transboundary resource environment.

The context of change

It has become increasingly apparent that interdependence, globalization, ecosystemic unity and sustainable development throw new light to traditional understandings of the socio-political nature of water. River basins can become an expression of transboundary water regimes in environmental politics (from regional to transnational scales). Such regimes can be defined either as a set of norms, rules, or decision-making procedures that produce some convergence in the actors' expectations in water related issues; or as explicit rules specified in legal instruments regulating actions (such as compacts, conventions or protocols).

The mismatch between political boundaries and natural river basins, becomes a focal point for the variety of difficulties reported in the literature vis-a-vis joint planning, allocation of costs, advantages of scale, exercise of power and coordination, and the whole range of issues associated with integrated, holistic management. Cooperation and conflict are, then, expressions of the same quest for improving effective planning and management, for promoting new ways for sustainable development, and for accommodating the realities of geography to the social context of shared water resources.

Alternative mechanisms in water management

The comprehensiveness of water resource planning has been the subject of controversy and debate in the literature. It has been recognized, however, that in order to be able to maximize the benefits from any water resource project a larger systemic analysis of the surrounding environment is needed, a broadening of the traditionally narrow planning and management approaches, and an increased sensitivity to decision-making problems associated with multi-objective and multi-purpose actions. A framework for such comprehensive management approaches would include a mix of such considerations as natural conditions (e.g. aridity, global change); variety of uses (irrigation, municipal uses, water quality, effluent control, etc.); sources of supply (surface, groundwater, mixed); and socio-demographic conditions (such as population growth, urbanization, industrialization, etc.). Essentially, planning and management should combine a space-time-quantity-quality balance.

In considering such a complex, multi-dimensional context, we should not despair as to the complexity and uncertainty associated with long-range, integrated approaches in any natural resources planning and management. What is being described is the order of life at the end of the 20th century, a turbulent, fast-changing socio-political environment that has been enlarged by global environment considerations of total interdependence. The caveats for all those attempting holistic, integrated approaches to shared water resources (at whatever level), include flexible, comprehensive, multi-dimensional, adaptable, long-term responses. It is an iterative process of continuous exchange, problem reformulation, and adaptation to shifting goals and objectives.

Managing and resolving environmental conflicts

As many authors have repeatedly pointed out, there is a long history of water-related disputes from conflicts over access to adequate water supplies to intentional attacks on water systems during wars. Such conflicts, tensions and frictions are expected to increase as growing populations, urbanization and economic development will require more water for agricultural, municipal and industrial uses. At the same time, water availability may be coming up against what Falkenmark has described as the "water barrier," namely a level of supply below which serious constraints to development will arise. Such limits may be further stretched by potential climatic anomalies which in turn could intensify regional conflicts between upstream and downstream users.

In discussing water conflicts, we may want to recognize three distinct phases, i.e., conflict creation, conflict management, and conflict resolution. In the first, the emphasis is on diagnosis, anticipation and prevention, problem architecture, and joint fact-finding. The second phase denotes a stage for the development of confidence and trust through such mechanisms as mediation, arbitration, neutral expert fact-finding, etc. Finally, conflict resolution involves consensus building and depolarizing of conflicting interests through public finding processes or adjudication.

Public participation and negotiation become tools in maximizing agreement when there are disagreements not only as to the nature of the problem but also as to desirability of certain outcomes (goals). More important, "citizen participation," and "public involvement" have become not only the noble cries of an environmentally conscious society, but also the presumed imaginative tools for creative planning and for the achievement of a broad consensus for desired action. Similarly Alternative Dispute Resolution (ADR) revolves around collaboration for addressing a wide range of environmental disputes. ADR involves three phases: problem setting (problem definition or problem architecture), direction setting (predominantly negotiations over substantive problems), and implementation (systematic management of interorganizational relations and monitoring of agreements). All alternative processes proposed (e.g., direct negotiations, mediation, conciliation, etc.) could allow the parties to reach a faster, more timely, and hopefully, more appropriate resolution of disputes. But there is an apparent dilemma in all such recent developments of participatory decision making or joint planning. As it has been noted withing the last decade or so, societies have tended to advocate the simultaneous growth of participatory democracy and of expertise in decision making. It becomes difficult to maximize both of these value preferences and strains appear between the idealized conceptions of citizen participation and the harsh demands or pragmatic considerations of public policy making and implementation, especially when they entail transboundary relations.

Towards innovative water management efforts

The common thread in any discussion of transboundary water conflicts emphasizes how new strategies are needed because water resources problems are becoming both highly complex and globalized. Some even argue that the traditional spatial environmental envelope has collapsed and project boundaries - and their impacts and consequences - are now much more diffuse. Thus, there is a need for bringing back an approach that requires drastic measures of ecological rehabilitation, innovative institutional mechanisms, and a balance between autonomy and cooperation. Given such considerations, there are three responses that we should consider. First improve efforts towards the utilization of "hydrodiplomacy" in terms of understanding alternative dispute resolution and conflict management efforts to transboundary water resources. Second, recognize again the river basin approach as a cooperative mechanism and authority, and as being much more sensitive to ecosystemic and social interdependencies. And, third, place particular emphasis on integrated water resources management (including the building of more robust water resources institutions).

The end result of such a posture would be a contingency preparedness for change, the ability to copy pragmatically with the challenges of upstream/downstream interdependencies, the appreciation of long-term planning, and diversity and flexibility in thinking and practice. Such a combination would be based on integrated management for efficient and equitable water use; on principles of regional cooperation; on functionally interrelated problems and projects; on reducing in advance points of friction and stress; on understanding the contextual forces and conditions of change; and, on eliminating competing and conflicting situations through risk management. Water can, then, become a realistic and thoughtful instrument for balanced approaches and a useful tool for managing long-standing competitions, confrontations, and outright conflicts about shared natural resources.

THE RELEVANCE AND ROLE OF WATER LAW IN THE SUSTAINABLE DEVELOPMENT OF FRESHWATER

Replacing "Hydro-sovereignty" with "Hydro-solidarity" and horizontal solutions

by

Patricia Wouters

Everyone lives downstream – except the lawyers; they commute from Mars. Repeated statistics forecast imminent global water scarcity with disastrous consequences. International experts promote solutions based on sound economics, science and enlightened and enhanced political commitment. Absent from the integrated-water-resources strategy are considerations of fundamental principles of water law -- a serious shortcoming. The development and implementation of a comprehensive forward-looking integrated water resources management scheme must include water law as an integral component. This is especially important in upstream / downstream situations where conflicts of water use are increasingly inevitable. Vertical proposals to the complex issues of freshwater resource management must be replaced by truly responsive horizontal solutions.

Credible Responses: Are Economics, Politics and Science Enough?

Projections for the year 2050 show that 66 countries with about two thirds of the world population will face moderate to severe water scarcity (1).

Water has now found its place on the international agenda, or so it appears. Years ago, experts identified the urgent need to anticipate and plan for the imminent global water crisis (2).

Unfortunately, their call for action, only now being embraced by the international community, has received an incomplete and piece-meal response (3). Solutions based on sound economics and science and enlightened committed political will, backed up by a "framework for action", comprise the current response. Absent from the current (and most of the past) integrated-water-resources-management movement(s) is the recognition of the relevance, role, and effective application of, fundamental legal principles of "water law" (4). This shortcoming will undermine any attempt at sustainable water resources management. Given the threat of "water wars" around the globe, the results of such an approach may have serious consequences world-wide.

Conflicts of Uses: The Upstream / Downstream Paradigm

As human populations grow, as improving standards of living and industrial expansion increase the water requirements, and as escalating need for food in dry climate areas increases the need for irrigation, water and water supply systems are increasingly likely to become both objectives of military action and instruments of war (5).

This paper reviews the relevance and role of water law in responding to one of most difficult, yet most common, problems: upstream / downstream conflicts over (scarce) water resources, both within and beyond State borders. Does water law facilitate, or hinder, the creation of "hydro-solidarity" in this context? What is the role of water law in managing (scarce) water resources?

Who is entitled to *what* water? Is the upstream user permitted to unilaterally develop the waters flowing in a transboundary river? Can the downstream user sustain its existing uses based upon its early appropriations of the river's waters? What level of pollution or other adverse impact, if any, is permitted? What protection is there for environmental needs – who protects ecosystems, in-stream uses and other "voiceless" stakeholders' interests? The theme "everyone lives downstream" emphasizes these issues and highlights the potential for conflicts over scarce water resources.

How to respond to these complex problems? Scientists (engineers and hydrologists) propose models to enhance supply, reduce demand, or to promote more efficient use. Economists suggest that the market should determine viability of development, i.e. that tradable water rights would lead to the most efficient use of water and promote sustainability (6). Without political endorsement, even the best of river basin management schemes could never be implemented on the ground. But at each stage in the planning, design and implementation of a water management system, important legal issues must be considered. Who owns the water being developed? Are there restrictions on its use? How will conflicts-of-uses between different stakeholders' interests be resolved? What rules apply to changing circumstances in the future? How will disputes be resolved? Answers to these questions will directly affect every water project.

Regulating Upstream / Downstream Conflicts: The Role of Water Law

It is not easy to say who owns water.

It is . . . evident that what has to be shared between those upstream and those downstream in a river basin is not the water currently going in the river as the Convention on the Non-Navigational Uses of International Water Courses suggests, but rather the rainfall over the river basin (3.)

Law, in particular, as the formal instrument of orderly change in society, plays a pivotal role, even though this role has not always been readily recognized (7).

Does (water) law have a role to play in the regulation of upstream / downstream conflicts over scarce water resources? Are there limitations to a “water law” approach in this perspective? The prevailing misperception is that laws are outdated, rigid, mostly unenforceable or not enforced. Some allege that the laws that do exist succeed only in consolidating the extreme positions of the competing water users, resulting in highly-charged adversarial claims, counter-productive to effective conflict resolution. In the arena of national water law, this may mean protracted and expensive litigation or administrative hearings. In transboundary (interstate) water law cases, the situation may be complicated by questions of standing or jurisdiction, and litigation might also be lengthy and costly. At the international level, in the absence of consent to dispute settlement procedures, the adversely affected State may be subject to unilateral harmful acts of other sovereign States, without recourse to quick effective remedies. Is this the case in practice?

In fact, it is rare that extreme assertions of water rights are adhered to in competing claims for water at the national, transboundary or international levels. Instead, assertions of “hydro-sovereignty” (extreme claims of water rights based on sovereignty) have given way to the more equitable and reasonable approach based on accommodation of the needs of competing water of all stakeholders -- a more pragmatic, middle-of-the road strategy. At the national level, this means updated and more flexible regulatory measures, including the creation of decision-support models, the creation of “water banks” to meet evolving needs of competing users, and the evolution of tradable water rights. At the transboundary (interstate) level, equitable solutions are achieved through compacts (interstate agreements) or hearings of experts (i.e. Special Masters). At the international level, the United Nations International Watercourses Convention (1997) and numerous multilateral and bilateral treaties provide guidelines on allocation of the uses of transboundary waters and provide for the prevention and peaceful resolution of water conflicts. The substantial treaty-practice in this area supports the proposition that watercourse States agree that they are entitled and obliged to use their transboundary watercourses in accordance with the principle of reasonable and equitable use.

At all three levels, water law plays an important role in establishing the substantive and procedural “rules of the game” and thereby provides stability, predictability and flexibility to the regime governing water use.

In summary, water law:

1. Defines the legal entitlement to water and identifies the rights and obligations tied to water use and thus provides the prescriptive parameters for its development. (point of departure)
2. Provides the framework to ensure the ongoing integrity of the regime (i.e. monitoring, regulation, compliance, dispute avoidance and settlement).
3. Permits the rational modification of existing regimes (i.e. to meet changing needs).

Are these issues relevant to the contest between upstream and downstream water users? One commentator considers that “the process of developing a legal system achieving effective compliance requires that a community – local, national or international -- Knows, Wants, Has, Obeys / complies with, and Effectively complies with the principles and practices of the legal regime (KWHOE)” (8). An astute observation that applies not only to legal processes, but to development proposals across the horizon of water resource development initiatives. Consider the engineer's proposal that optimal use of the water system would involve constructing a big dam, or an economist's suggestion to introduce water markets. The legitimacy of either project would depend on the community's endorsement, arrived at through the same stages of the KWHOE process. The issue is not "knowing and wanting water law that is enforceable and enforced", but involving water law as a meaningful part of the larger process. The goal must be to replace vertical proposals (referring to disciplinary responses) for water resource development with integrated solutions arrived at through horizontal approaches (referring to interdisciplinary responses). Water law and its implementation can not and should not operate in a vacuum. The problem of the prevailing approach to water resource development is the lack of transparency, understanding and complementarity of the fundamental principles that apply in each discipline. With a view to increasing the accessibility of water law, the next part briefly summarizes water law in practice.

Responding to the Current Challenge: Water Law in Practice

At a global political level the growth of the environmental movement and the end of the cold war have perhaps been the most significant factors that have affected water management as they have other issues. Getting the balance "right" between environmental protection and the use of water for human development has steadily become more prominent in the debates over the last 25 years. The end of the cold war has increased the concerns over governance in many countries and also reduced the imperative for aid. Significantly, it has led to globalisation and a greater role for the private sector (9).

Water development issues must be viewed in an overall context. In conflicts between upstream and downstream users, the scenario at all levels (national, transboundary and international) is much the same: the downstream user generally develops first and is keen to preserve into perpetuity these senior-in-time uses. The upstream user is thus placed in the unenviable situation of justifying the legitimacy of new uses, which almost certainly will adversely affect the existing uses downstream. At the national level, water law should operate to regulate this dispute in accordance with the relevant national and federal legislation. What happens when this is not the case? In the U.S.A., two different systems govern water use -- prior appropriation in the West (first in time, first in right) and riparian rights in the East (water rights run with land ownership). In disputes between watercourse States, both within and between these two rights-based systems, the U.S. Supreme Court determined that the principle of "equitable apportionment" proscribed a State's activities related to transboundary freshwaters (10). This concept, in turn, evolved to form the basis for the principle of "reasonable and equitable utilisation", a customary rule of international law that governs the legitimacy of uses at the international level (11).

Is the principle of reasonable and equitable use an effective (and enforceable) rule to assess and allocate lawful uses in an upstream / downstream scenario? Critics challenge the vagueness and inoperability of the standard created by this principle. And yet, clearly the flexibility of this principle is its real strength. As one commentator discussing the concept of fairness in international law asserts, "to some extent indeterminacy is inherent in all rule-creating discourse" (12). It does not follow, however, that indeterminate or flexible rules cannot be applied in practice. As a fundamental cornerstone of the law of torts, the "reasonable man (woman) test" has worked well in hundreds of years of litigation. Is there any reason that a "reasonable State" test could not also work well in practice? The particular strength of such an approach is its adaptability, and thus direct relevance, to changing demands on the water system. It permits consideration of the specific factors applicable to each individual river basin at the time and in the context of the planned development. This primary rule of allocation, found in customary law and contained in the UN Watercourses Convention, provides the fundamental point of convergence with other disciplines and with their respective water experts. In determining the legitimacy of new or increased uses, in contests for water, this principle requires that all relevant factors be considered in the assessment of a reasonable and equitable use. This is the mechanism that invites consideration of more than just the "blue" water found in the rivers and aquifers, but opens the inquiry to include the "green" water, environmental ecosystemic water, and, even, "virtual" water. The weight of each of these factors depends on the situation being addressed and the overall assessment of what constitutes a reasonable and equitable use will depend on the circumstances of each case. The implementation of this process requires expert input from across the horizon of water resources disciplines.

Often, the peaceful management of freshwater resources is linked to broader policy issues, such as global security, water as a strategic instrument, environmental protection, good governance, poverty eradication, human rights, and so forth.

The importance of these linkages must not be overlooked. Rarely are watercourse use agreements concluded on considerations driven primarily by optimal use criteria. The situation is more complex, involving cross-sectoral bargaining and trade-offs. Despite this complex context, river basin development is premised on one common goal -- that the water resource development be sustainable. Achieving this vision, and addressing water resource development in its relevant context, highlights again the need for a horizontal approach to seeking an integrated solution to the problems that arise.

Water law continues to evolve. At the international level, increased transparency and more inclusive public participation and access to information and to transboundary remedies (i.e. the principle of non-discrimination) has been introduced in forward-looking international agreements. Other more specific concerns are addressed in treaties focusing on water and health, and aimed at limiting transboundary impact (i.e. recognizing the notion that "prevention pays off"). New initiatives include the proposed European Union Water Framework Directive (innovations include adopting the river basin catchment as unit of management, full cost recovery, river basin management plans – a unique forward-looking plan for integrated water management across Europe)(13) and the UNECE / UNEP sponsored projects on monitoring compliance and public participation (14).

Current responses to water problems around the world involving upstream / downstream contests at the national and international level demonstrate the success of horizontally driven responses. Examples at this seminar include: resolution of the urban water management conflicts in the metropolitan region of Sao Pãulo (15), the evolution of river parliaments in India (16), the comprehensive Murray Darling management agreement (17), and others. At the international level, the UNECE Helsinki Transboundary Watercourses Convention continues to yield positive results in some of Europe's formerly most polluted and international rivers. The Convention is a good example of how a framework agreement can facilitate a range of specific responses on the ground. Similar developments have occurred under the umbrella of framework treaties concluded on the Mekong (the "Mekong Spirit")(18), the Columbia, and the Colorado (17), to cite only a few examples.

Yet problems remain. Consider Turkey's unilateral development of the Tigris-Euphrates, the hard negotiations between Israel and the Palestinians over insufficient shared aquifers, and the ongoing contest between Egypt and Ethiopia over the Blue Nile. Scientists, economists, engineers, and hydrologists have all made their case(s) for resolving these problems of water scarcity. Another range of actors also influence these processes. The involvement of Environmental Support Agencies (ESA's), such as the World Bank and donor agencies, in the development of freshwater resources around the world, should not be overlooked. With past success in brokering the settlement between India and Pakistan on the Indus (19), the World Bank is hopeful that its involvement with the Nile riparian States will lead to a similar positive result on the Nile. However, this raises the question of what role should be played by ESA's in water resource development.

Future Goals: Enhancing the Potential for Hydro-Solidarity in Upstream / Downstream Water Conflicts through Horizontal Solutions

Water scarcity will affect most of the world's population in the future. The potential for conflict will be especially apparent in upstream / downstream contests over transboundary waters. *Who* will be entitled to use *what* water? What response can water experts provide to this question, made all the more compelling by the threat of future "water wars"?

Devising effective plans to meet the impending water crisis requires more than better science. Substantive issues on the ground, such as conflicts of uses between upstream and downstream users (especially in the case of water scarcity), need to be anticipated and addressed by a team of informed experts. An integral part of this team is the water lawyer, whose role it is to apply his or her expertise, in concert with other water specialists, in response to particular problems relevant to the project being considered. It is for the water lawyer to assess and evaluate the existing legal framework within which the development is to take place and to identify revisions to that framework if necessary. These processes do not occur in isolation, but must be informed and assisted by the horizontal range of water experts required to address the problems inherent in upstream / downstream and water scarcity situations.

On the substantive issues, legal entitlement based upon claims of absolute hydro-sovereignty (including absolute claims of prior appropriation or riparian rights) are counter-productive to sustainable and peaceful water resources development. A system of water law based on the principle of equitable and reasonable use facilitates cooperation basin-wide and in so doing fosters the evolution of hydro-solidarity, see Hungary v. Slovakia (20).

Forward-looking, evolutionary by its nature, the principle of reasonable and equitable utilisation, complemented by appropriate procedural rules (i.e. exchange of information, notice, consultation and negotiation, monitoring and compliance mechanisms, including dispute settlement), is an inclusive rule that can be effectively applied to assess the legitimacy of water use. By leveling the playing field for all stakeholders (at all levels) and permitting the consideration of all relevant factors, the rule of equitable use is a valuable instrument that serves to prevent adversarial claims of hydro-sovereignty. Implementation of the principle encourages a dialogue focussed on accommodating a range of needs, as compared with disputes over water "rights". In this context, Parties are more inclined to seek equitable solutions based on mutual compromise.

How are the conflicts of uses between the multitude of stakeholders involved in upstream / downstream situations to be resolved? No one discipline can offer an effective answer. This paper has demonstrated the relevance and role of water law in defining, refining and applying the legal framework necessary to transform assertions of hydro-sovereignty into pacts of hydro-solidarity. It is a mammoth task that requires the horizontal input of the entire range of water experts.

Right . . . is the child of law: from real laws come real rights; but from imaginary laws, from laws of nature, fancied and invented by poets, rhetoricians, and dealers in moral and intellectual poisons, come imaginary rights, a bastard brood of monsters (21).

REFERENCES:

1. World Water Council, "The International Water Policy Think Tank" (1999)

2. SIWI 1997, *Mar del Plata 20 Year Anniversary Seminar: Water for the Next 30 Years, Averting the Looming Water Crisis*

3. M. Falkenmark, "Competing Freshwater and Ecological Services in the River Basin Perspective – an expanded conceptual framework", In: *"Towards upstream/downstream hydrosolidarity"*. Proceedings SIWI/IWRA Seminar

4. P. Wouters, *"The Legal Response to International Water Scarcity: The UN Watercourses Convention and Beyond"*, German Yearbook of International Law 2000 (forthcoming)

5. M. Falkenmark and J. Lundqvist, "*World freshwater problems – call for a new realism"* (1997), Stockholm Environment Institute, p. 9, referring to P. Gleick, "*Water and conflict*" (1993), International security 18:79-112

6. M. Solanes and F. Gonzalez-Villarreal, "*The Dublin Principles for Water as Reflected in a Comparative Assessment of Institutional and Legal Arrangements for Integrated Water Resources Management"* (Global Water Partnership, Background Paper No. 3

7. I.F.I. Shihata, "*Good Governance and the Role of Law in Economic Development*", *in* A. Seidman, R.B. Seidman, T.W. Wælde (eds), "*Making Development Work"* (Kluwer Law International, 1999)

8. T. Allan, "*Water Scarcity and Water Rights: An Economic Perspective"*, *in* "Securing Water Rights and Managing Water Scarcity", Conference papers (1999, CEPMLP University of Dundee)

9. Note CG 99/5, Framework for Action (FFA) Report, Global Water Partnership 4th Annual Consultative Meeting, Stockholm 12-13 August 1999, p. 3.

10. G.W. Sherk, "*Dividing the Waters"* (Kluwer Law International, 1999)

11. L. Caflisch, *"The Law of International Waterways and Its Sources," in* R.St.J. Macdonald (ed), "*Essays in Honor of Wang Tieya"* (Nijoff, 1993), p. 115-129

12. T. Franck, *"Fairness in the International Legal and Institutional System,"* see P. Wouters "*Rivers of the world. Fundamental principles of international water course law*" (Kluwer Law International , forthcoming)

13. European Union General Secretariat Brussels, 20 May, 1998 Working document ENV/98/127 SN/3041/1/98 REV 1 OR.EN (26 May 1998)

14. P. Wouters, Experts report on compliance with international water agreements, prepared for the United Nations Economic Commission for Europe, October 1999 (unpublished manuscript)

15. B. Braga, "Urban Water Management Conflicts in the Metropolitan Region of Sao Pãulo", In: *"Towards upstream/downstream hydrosolidarity"*. Proceedings SIWI/IWRA Seminar

16. A. Agarwal, "River Parliaments for Bringing Together Upstream and Downstream Users – Some Indian case studies", In: *"Towards upstream/downstream hydrosolidarity"*. Proceedings SIWI/IWRA Seminar

17. J. Pigram, "Towards upstream-downstream hydro-solidarity – Australia's Murray-Darling River Basin", In: *"Towards upstream/downstream hydrosolidarity"*. Proceedings SIWI/IWRA Seminar

18. Agreement on the Cooperation for the Sustainable Development of the Mekong River Basin, 5 April 1995 (*entered into force* April 1995)

19. G. T. K. Pitman, *"The Role of the World Bank in Enhancing Cooperation and Resolving Conflict on International Watercourses: The Case of the Indus Basin", and* S. Salman, *"Sharing the Ganges Waters between India and Bangladesh: An Analysis of the 1996 Treaty", in "International Watercourses: Enhancing Cooperation and Managing Conflict*" (S. Salman, L. Boisson de Chazournes (eds), World Bank Technical Paper No. 414, 1998)

20. Case Concerning the Gabcíkovo-Nagymaros Project (Hungary v. Slovakia), 1997 International Court of Justice, General List No. 92, (Judgement of 25 September)

21. J. Bentham, "*Anarchical Fallacies"* in J. Bowring (ed.) *Works* vol. 2 (1843), p. 523.

THE MANAGEMENT OF URBAN WATER CONFLICTS IN THE METRO-POLITAN REGION OF SÃO PAULO

by

B.P.F.Braga

In Latin America, after the democratization process in the 1980's, public pressure imposed new models of management in the water sector. These new models have been extremely successful in bringing the political class more aware of the water problems., as illustrated by the Brasilian example. Public pressure forced congressmen to propose a new Federal Constitution in 1988 in which environmental and water issues are explicitly considered. The paper discusses the technical, legal and institutional aspects of integrated water management in the Upper Tiete basin in the metropolitan region of Sao Paulo with 16.5 million inhabitants and the largest industrial complex in Latin America. Emphasis is placed on the conflicting interests of upstream and downstream groups in the basin. A successful experiment of integrated water resources planning on a watershed basis is described, where modern decision support systems technology is combined with effective public participation.

Introduction

Urban water management is certainly the most important water resources issue that managers will face in the next millenium. The basic reason for this is very straightforward if one observes that today approximately 75 percent of the world population live in urban areas. In some developing countries this number is already much greater. In the State of São Paulo, Brazil, for example, 93 percent of the population live in urban areas. This is a tendency in the developing world, which accounts for 85 percent of the Planet's population. Such a high population concentration certainly will pose problems of integrated management involving water, soil and air ecosystems.

In the past the issue of planning and management in the water resources sector was treated as a problem with the single objective of maximizing economic efficiency. More recently, however, the concept has evolved to incorporate other facets of the decision making process including issues such as: environment, social and political impacts, equity and the like. In less developed countries, however, where levels of use of energy are low, social imbalance is high, uneven distribution of income is common, it is very difficult to implement these modern concepts. Emergent economies of the world face today the challenge of growing economically and at the same time conserve their natural and environmental resources. In Latin America after the democratization process that took place in most countries after the 80's, public pressure though NGO, professional associations, etc. imposed new models of management in the water sector. These new models have been extremely successful in bringing the political class more aware of the water problems and in many countries have resulted in effective measures to improve the quality of life of many basin dwellers.

The Brazilian experience is no exception to this rule. Public pressure, after the democratization process that took place in 1983, forced congressmen to propose a new Federal Constitution in 1988 in which environmental and water issues are explicitly considered. Professional associations related to water resources, lead by the water management commission of the Brazilian Water Resources Association, played a definite role in the technical and institutional arrangements for implementation of integrated water resources management in the country. This paper discusses the technical, legal and institutional aspects of integrated water management in the Upper Tiete River basin in the metropolitan region of Sao Paulo (MRSP). Emphasis is placed on the conflicting interests of upstream and downstream groups in the basin. A successful experiment of carrying out the integrated water resources planning of this region on a watershed basis is described. Modern Decision Support Systems technology with effective public participation are used in the Basin Plan development.

The Upstream-Downstream Issue – Sharing Environmental Resources

There are some basic water management principles that must prevail if one wishes to address the issue of hydrosolidarity. The first one is to recognize that water quantity and quality can not be treated separately. This, however, does not imply we must have the same institutional setting to take care of both subjects. What seems more logical is that a management system involving different institutions and stakeholders defines the best practice for the prevailing conditions. The second one is that we should look for dominant alternatives so that trade-offs can be made in an optimal way. This means that some Decision Support System, easy to use on the part of the decision-makers, must be developed to assist the decision-making process at the basin level. Most of the time interest groups face cognitive conflicts rather than conceptual conflicts. The third principle is that economics play a definite role in the management of any natural resource. Water is no exception to this rule. Hence, proper water use implies charging for abstraction and charging for returning used water to the natural water bodies. On top of this, everyone has to have authorization from the established government to perform such abstraction and return.

Finally, the sine-qua-non condition to address the upstream-downstream issue is the existence of an adequate legal apparatus to water resources management. It is quite unlikely that under conflicting interests stakeholders can have sustainable agreements without having well established legal rules. Of course, this is a necessary condition but other elements should be present. Certainly one of these elements is the willingness to negotiate among the interested groups. Another important element is that each interested group sees clearly the possibility of trading-off benefits and losses in the negotiation.

Brazil has presently one of the most advanced legal systems related to environment and water resources management. According to the Brazilian Federal Constitution (Section 24-VI) the Union, the States and the Federal District are jointly responsible for the legislation regarding forests, fisheries, nature conservation, protection of the soil and natural resources, protection of the environment and pollution control. However, the Union has the charge of legislating privately with respect to water and energy as well as to fluvial, lake and coastal navigation. Section 22 allows the States to legislate complementary through specific legislation regulating these matters. The current constitution, however, does not allow the States to legislate supplementary to attend the peculiarities of such a large territory as Brazil. Section 21-XII states that the Federation shall explore, directly or through authorization, concession or permission the hydroelectric potential of the water courses. This exploitation, however, must be performed in articulation with the States where the development is planned. Although the form of articulation depends on specific law, the constitutional principle opens the possibility of States to condition the permits to their own interests.

It is a Federal duty to implement the National Water Resources Management System. Section 21 - XIX requires the creation of this system by the Federal Government, which is also responsible for defining criteria for issuing water permits in the country. Complying with this section of the Federal Constitution, the National Water Resources Law was enacted in January 8, 1997. This federal law defines the National water resources policy and creates the National Water Resources Management System. According to the law the National Water Resources Policy (NWRP) seeks to assure the sustainable and harmonic use of water resources towards the promotion of development and social well being of the Brazilian society.

From a legal point of view it can be appreciated that the conditions for sharing water resources in Brazil are well established. The present regulation proposal of the Federal Water law calls for a joint legal instrument to issuing water permits and to charging for water use and effluent discharges. The existence of water commissions operating on a watershed basis allows the participation of water users and non-governmental organizations together with the federal and state governments in the decision process. Several states have already implemented water commissions in their major river basins with great positive impact. In the next section the complexity of the decision process in the Upper Tiete River basin in the State of São Paulo is described. It will be appreciated that regardless of the necessary legal conditions established there is still a long way to achieve the ideal cooperation between upstream and downstream users.

Conflicting Interests in the Metropolitan Region of São Paulo and Surrounding Areas

The MRSP includes the city of Sao Paulo plus 39 adjacent cities occupying an area of 8,050 km^2 , with 1,500 km^2 of urbanized area. The present population is about 16.5 million, with estimates of about 19 million for the yea r 2010. This region (Figure 1) is

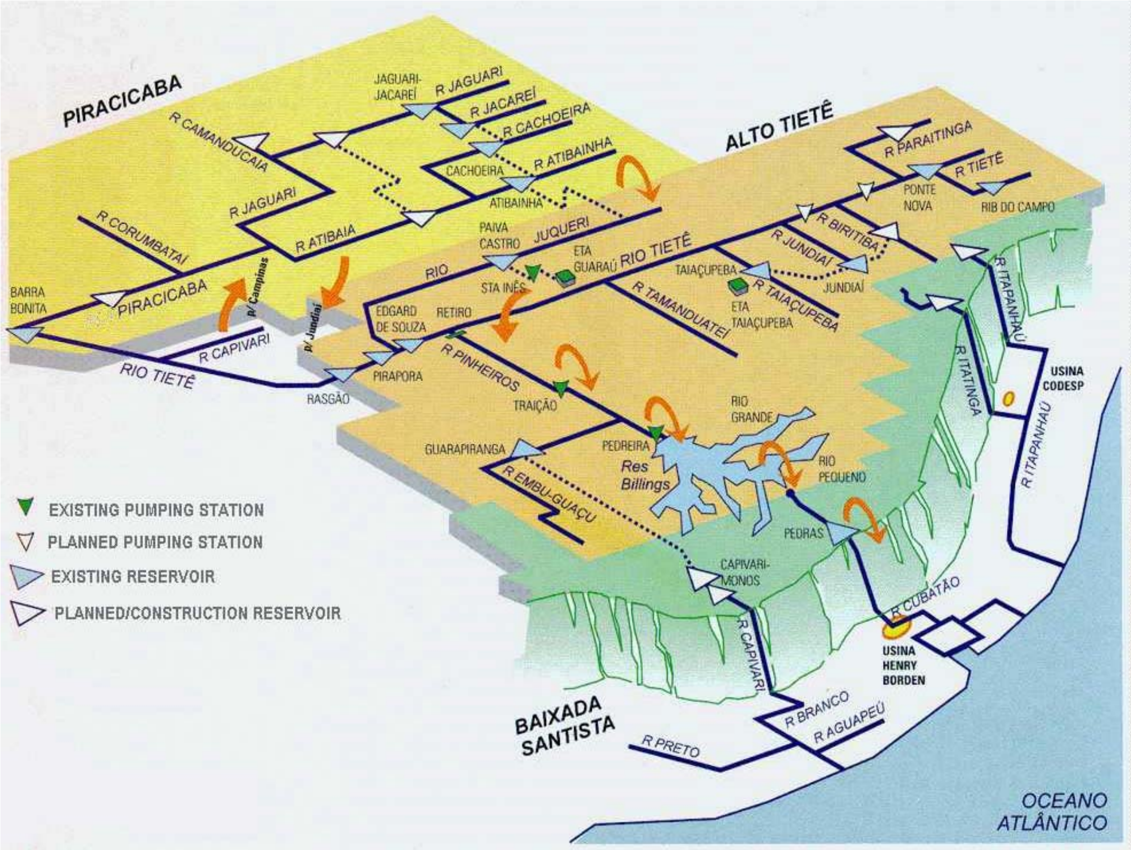

Figure 1. *The Metropolitan Region of São Paulo Water and Related Basins*

the largest urban concentration and th e largest industrial complex of Latin America. Its industrial output encompasses around 27% of the national total production and 62% of the state total. Population represents approximately 52% of state total of 33 million inhabitants. An extremely high population growth rate in the last 30 years has posed tremendous demands on water supply and water quality control. Urbanization has led to extensive imperviousness of the basin and consequent frequent urban flooding. In Figure 2 it is shown the urban growth of this basin in this century.

The Metropolitan São Paulo at the beginning of the century had a population of 300,000 occupying only 0.6 percent of basin area. Mainly due to the low demand for different water uses at this time the region did not have any significant water disputes. It was not until 1930 that the city of Sao Paulo became an important urban conurbation and its water resources were then directed towards generating power and supplying water to domestic consumption. By 1955 the city achieved the status of an industrialized urban society. More critical water and energy shortages occurred, as well as floods, with growing socio-economic losses.

Figure 2*. Urban Development in the MRSP and the Upper Tietê River Basin in the XXth Century*

The first hydroelectric power plant in Brazil was inaugurated in 1901, at the Paranaíba dam, on the main Tietê River downstream from Sao Paulo. As it was impossible to construct a large reservoir at Paranaíba without affecting the city of Sao Paulo, a second dam, Guarapiranga, was built in 1908 on the Embu-Guaçu river, which is a tributary of the Pinheiros river. In 1912 the Paranaiba power plant had its capacity enlarged to 16 MW and expansion of its capacity continued in the years following. A severe drought occurred in 1924 and the first ever power shortage was recorded. In order to cope with the drought, several improvements were made to the system, such as the Serra do Mar project in 1927. The main objective of this system of dams namely Pedras, Edgard de Souza (at the earlier Paranaiba site), Pirapora, Billings and Guarapiranga, plus the pumping stations of Traição, Pedreira and Edgard de Souza, was to reverse the natural flow of the Tietê and Pinheiros towards the Billings reservoir. From there water was transferred to the Pedras reservoir and using a 750 m hydraulic head generated electric power at Henry Borden hydropower plant. This very inventive system allowed an increase in the installed power of region to more than 600 MW and consequent industrialization, development and urbanization of the region. The lack of adequate wastewater treatment in the years that followed the industrialization of the region produced a very low quality of the waters in the upper Tietê River basin.

Because of urbanization and of the low gradient of the Tietê river (average 17 cm/km) flooding became a major issue in the basin. Besides the economic losses, floods in this basin represent a public health threat due the poor water quality in the rivers.

Upstream-Downstream Issues

From the scenarios previously outlined, two conflicting situations request urgent treatment: the high water supply demand in contrast with low availability within the upper Tiete river basin and the wastewater effluent that flows towards continental lands (following the natural flow of Tiete river downstream) or towards the Billings reservoir through pumping stations along Pinheiros river. The latter situation shall be gradually reduced with the multi-billion dollar program of the State Government to clean up the waters of the Tiete in MRSP ("Projeto Tiete").

Grassroots groups representing the interests of the local population are trying to avoid the wastewater disposal into their regions. Before 1992 the operational practice involved the pumping of 50% of Tiete river flow at confluence with Pinheiros river into Billings reservoir and subsequent use for hydropower generation in Henry Borden power plant. Despite the large active storage capacity of Billings reservoir (1,200 million of m3) it became a very large oxidation pond. Thus the main problem associated with this way of operating the system is anoxic conditions at Billings reservoir. On the other hand, if wastewater is discharged only to Tiete river downstream, this presents a similar problem mainly for the cities along the water course. After 1992, State Constitution provision imposed that, under normal hydrological conditions, no water should be diverted to Billings reservoir. The only exception is during flooding conditions when the Pinheiros channel capacity is limited by the backwater of the Tiete river and for safety reasons water has to be pumped back to the Billings reservoir. This present situation has transferred the problem of anoxic conditions of the Billings reservoir to the reservoirs in the lower Tiete river downstream of the MRSP. The complexity is now even greater because of the foam that is produced downstream of the spillways and reach riparian communities.

Transboundary issues

The water supply problem also presents a spatial conflicting situation between two important regions: the MRSP and the Piracicaba river basin (Figure 1). In the 70`s a major water supply inter-basin transfer scheme was implemented to bring water from the Piracicaba River basin to the MRSP. This system transfers water by gravity, from Jaguari, Cachoeira and Atibainha rivers into Paiva Castro reservoir, where water is pumped to a treatment station 300 m uphill. This inter-basin transfer is named "Cantareira system" and allows a continuous transfer of 33 m3/s of water to the MRSP.

The Cantareira system has been the main source of water supply for the MRSP. Its conception was made in a period that the rate of industrial development in the countryside of Sao Paulo State was still low when compared with the MRSP. Thus, in the beginning of the 70's water taken from Piracicaba river basin had a small impact on the local communities. In the 80`s and 90`s, however, this region experienced an explosive growth with accelerated demands for domestic and industrial water supply, irrigation and wastewater dilution. The current situation of Piracicaba river basin reveals an opposite scenario in terms of development. This river basin includes 12.400 Km2, encompassing around 8.5 % of total population of the state with distribution highly concentrated (87%) in urban areas. Water demands are growing in both basins and consequent conflicting situations tend to become critical in the next 5 to 10 years ahead.

Resolving the Conflicts

In Figure 1 it is shown in different colors three of the 22 Water Management Units (WMU) of the State of São Paulo: the Piracicaba, Upper Tiete and Baixada Santista. Each of these units has a Basin Committee (BC), which has members from the State Government, municipalities and the organized civil society. The BC is responsible for the planning and management of the water resources in the WMU. In the present case of the MRSP, located in the Upper Tiete WMU, the actions taken by the BC will have impacts in the neighboring WMU and in the downstream WMU (lower Tiete WMU). A major effort is underway by BC of the Upper Tiete to develop a water resources master plan for this WMU.

This is an integrated water resources plan, involving all the actors in the basin and the BC of the neighboring and downstream WMU. Conflicts among water uses and water users are being systematically dealt with through the use of a multiobjective decision support system. This DSS allows the involvement of the public at early stages of the planning process. The legal and institutional constraints are encompassed in the planning model together with economic and environmental variables. The DSS uses a priori assessment of decision-makers preferences and several methods are available (Hierarchical analytic method, ELECTRE II and Compromise Programming). A typical display of the DSS using method ELECTRE II is shown in Figure 3.

The developed Multiobjective DSS allows the participation of the members of the BC in the decision-making process. Using interactive displays like the one shown in Figure 3 next page, each member of the BC enters his or hers preferences in a simulated poll station. That is, secrecy is warranted in the process. Only, a composite statistical summary showing which alternative has a high frequency as best preferred among the members of the Committee is disclosed at the end of each round. The process is repeated allowing each member of the BC to chance his or hers weights to successively achieve a consensus alternative.

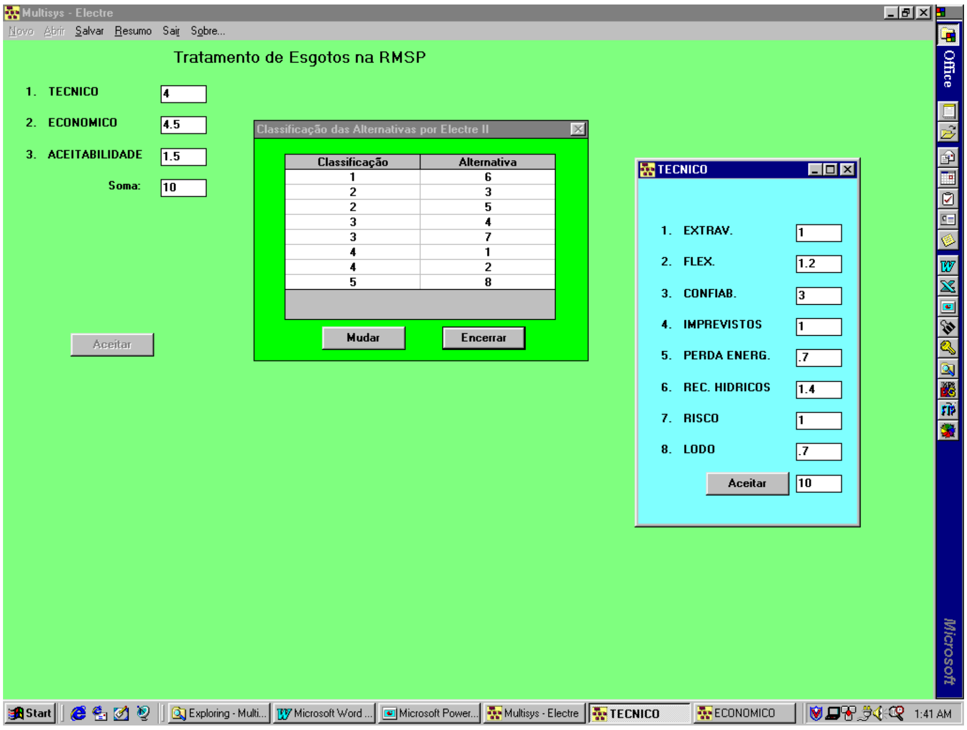

Figure 3. *Multiobjective Decision Support System for Multiple Decision-Makers in the MRSP*

Preliminary results have shown that the approach is feasible and should be attempted not only in less developed countries but it should be utilized in the more developed societies where public education and involvement are higher.

Conclusions

A successful exercise of systematization of the so-called "upstream-downstream conflict" in an urban water resources planning environment was described. The setting is the Metropolitan Region of Sao Paulo, where several hydraulic works built over the last 100 years resulted in very complex operational issues involving interest groups in different parts of the Upper Tietê River Basin. A major effort is underway towards developing a master plan for the basin with the participation of the organized civil society, municipalities and the State of São Paulo Government.

From the lessons learned in this region it can be safely stated that the upstream-downstream water and environmental management problem can only be resolved if basic elements are present in the analysis. These include, among others: (a) a clear definition of trade-offs which necessarily include economic, social and environmental variables, (b) a legal and institutional framework for sustainable agreements and (c) a decision support system that allows effective public participation at the early stages of the negotiation process.

THE IMPLICATIONS OF URBAN DEVELOPMENT FOR WATERSHEDS AND WATER SUPPLIES IN RAPIDLY GROWING, DEVELOPING WORLD CITIES

The case of Tegucigalpa, capital of Honduras

by

Michael D. Lee

Many urban areas that are undergoing extensive growth find that urban expansion often encroaches onto formerly greenbelt watershed areas surrounding drinking water reservoirs or overlying aquifer recharge zones. The expansion of shanty-towns, industrial parks and other land-use modifications encompass previously rural watershed lands and the demand for resources, food, fuelwood, and building materials strips much of the remaining land of its forest and soil cover. This article focuses on Tegucigalpa, the capital of Honduras, its very rapid expansion, and the severe problems generated in one of the key watershed areas of the city water supply system. The case of Tegucigalpa illustrates how international pressures to privatize water services and promote downstream water concerns may further contribute to the range of upstream watershed problems by curtailing protection efforts.

Protecting the water source of a city

In the most general of terms, the closer the water source and its watershed to a city when developed, the lower the capital cost due to the avoidance of building a long overland water transmission system, all things remaining equal. In many developing countries, the urban planning framework is weak, with few controls on citizens' or corporations' use of private watershed and recharge area land, and a lack of co-ordination between government sectors concerning the protection and exploitation of state-owned lands. Existing land-use regulations and environmental protection laws designed to prevent water resource deterioration, while often more than adequate on paper, may not be applied due to a lack of will and/or the necessary resources for monitoring and enforcement. Sources may undergo rapid deterioration if contributing watershed or recharge area lands are not protected from point and non-point source pollution and from damaging hydrological modifications. The rapidly expanding cities generate incredible demands for affordable building space close to the existing city infrastructure; for a convenient supply of livestock, vegetables and other foodstuffs; for plentiful building materials including lumber, sand, gravel, fired bricks and tiles; for firewood for cooking and heating; and for space for recreation. These demands continue to grow each year with the rising urban population.

Developing country cities often face the staggering responsibilities of trying to maintain and expand water service coverage to urban residents in the face of increasingly antiquated infrastructure, crushing debt crises and shortages of investment capital, increasing costs, shortages in skilled personnel, and many other economic and technical difficulties. In the light of these downstream challenges, it is perfectly understandable, therefore, why water sector managers ignore or at least fail to prioritise water resource protection through watershed and recharge area management. Any lack of watershed and recharge area protection in developing countries must be seen as a tremendous cause for concern because it threatens to undermine the sustainability of water supplies and compromise water quality, risking human health impacts at worst and increased per capita water supply costs at best. At the same time, in many instances the carryover storage volumes in reservoirs and aquifer recharge rates are being reduced, and the quality of the raw water is declining and hence the difficulty and cost of water treatment are increasing. Clearly, this is a model the water sector cannot afford to promulgate.

Out of sight, out of mind

Clearly, watershed protection is not without a number of trade-offs, ones that become harder to make the less the long-term environmental benefits of upstream protection can be quantified and valued. In addition, the negative impacts of land-use change and incremental pollution loading usually occur in a manner that is gradual, delayed and clandestine and thus do not grab attention in the same way that the impacts of a ruptured main or water-borne disease outbreak would.

The key watersheds on which a city depends will often be geographically separated from the city in some upstream location or, where the city is located within the recharge area, may be of a much larger scale. While they may be close enough to be readily damaged by urban growth and resource demands, they are nonetheless far enough removed geographically or perceptually to remain largely unseen. Thus a psychological disconnect may exist in which residents fail to appreciate the nature of their water supply system and the conflicts affecting it.

Public perception of the value of and status of watersheds may therefore be very difficult to raise to crisis-level even when crises may indeed be present or imminent, particularly if there are few local champions of watershed protection in the form of a high-profile and persuasive environmental lobby. Adding this factor to the many pressing and competing claims on limited public coffers and the often exponential growth in the demand by a city and its residents for natural resources, many of which are derived from surrounding watersheds, it is evident that achieving the two pre-conditions necessary for a wholehearted commitment to watershed management is not an easy task.

The capital city of Honduras

The example of Tegucigalpa, the capital city of Honduras, provides a useful and graphic illustration of this phenomenon. In 1950, Tegucigalpa had an estimated 72,000 residents and covered only a few km^2 (1). Its population is currently estimated at around one million, growing at well over 50,000 per year and now covers more than 100 km^2. The city is served by three principal watershed and recharge areas within a 10-50 km radius of the city centre but along with its growth, the sustainability of the city's water sources has been placed at great risk by the failure to adopt systematic, effective, and long-term source protection.

Tegucigalpa is located in a site not well suited for the development of a large city, sitting in a bowl-shaped depression fringed by steep slopes along the upper reaches of the Choluteca River (1). The Guacerique River is a tributary to the Choluteca and joins it at the southwestern edge of the city. It's watershed feeds the Los Laureles reservoir which was built in 1974 to meet the Honduran capital's growing water needs and is relied upon to provide around 30% of the potable water supplied to residents (2). Once several kilometres from the edge of the urban limits, the developed land now encompasses the dam site and is spreading further out into the watershed. Sized to meet at least 20 years of additional demand, rapidly increasing water usage and reduced reservoir capacity from siltation led to earlier than expected water shortages, prematurely requiring the building of the La Concepción dam and reservoir in the adjacent, less accessible Rio Grande watershed. Finally completed in 1993, this new dam supplies around 50% of Tegucigalpa's users, with around 20% of the capital's demand met mostly from springs and wells located in the protected La Tigra cloud forest reserve to the north-east of the city.

The watershed has been the site of a wide range of public and private sector developments over the years that have directly conflicted with its role as a key water source. They have included: the building of high-density public housing on the hillslopes fringing the municipal reservoir; the construction of military bases, industries and training institutions along tributary streams; the routing of the city's major peripheral transport route along the edge of the reservoir; the development of large poultry plants immediately upstream; and the commercial extraction, both illegal and legal, of firewood from headwaters areas. By 1995, due to its proximity to the rapidly expanding capital, agricultural and urban activities had come to occupy around 20% of the land area of the watershed, with an estimated 75% of these lands supporting uses generally considered incompatible with its function as a drinking water source area (3).

Urban land use had increased over thirteenfold in the 20 years prior to 1995. As a consequence, it is estimated that the Los Laureles reservoir continues to rapidly fill up with sediments. Average erosion rates from hillslopes have conservatively been estimated to cause a loss of more than 200,000 m^3/year of carryover storage from siltation, or more than 2% of its volume annually, with some feeling that this could be an underestimate (i.e. more like 5%) although no formal study has been completed. Treatment costs of water from the reservoir are relatively high compared to the other municipal sources due to the more elevated turbidity levels and higher faecal coliform counts found in the raw water. Treatment chemical inputs, mostly imported, are thus very heavy, particularly of aluminium sulphate, coagulation polymers, lime and chlorine, as are maintenance costs for sand filters.

Laws and ordinances in place but not applied

As with many developing nations, the Guacerique watershed typifies a situation in which, on paper, there are many, adequate levels of environmental protection in place befitting its important status as a major water source. However, as is often the case, these protections have largely been ignored by decision-makers charged with putting them into practice. Prior to the opening of the Los Laureles reservoir in 1974, the Honduran government declared the whole watershed as a Protected Forestry Zone in January 1973; a status that remained on the statutes throughout the period in which the changes in the watershed described herein took place. In 1981, the zone surrounding the reservoir, including areas now occupied by housing developments, the Tegucigalpa ring-road and other government-financed and private development projects were declared by the Tegucigalpa Metropolitan Authority a protected area with restricted development. Numerous other laws and ordinances limit the kinds of activities that have already taken place within the watershed, but seldom have they been applied. A more detailed assessment of the most striking of these activities can be found in Lee (3).

One of the clear outcomes of this tapestry of land-use developments has been to create a wide range of contamination sources of both a non-point and point nature (3). Because of the high nutrient loading from sewage and farm runoff, the reservoir has been seen to suffer from occasional algal blooms and an excessive growth of water hyacinths that proliferate, die and then taint the drinking water with decaying organic material, colour, taste and odour, each of which affects the cost of treating water leaving the reservoir. Bacterial counts are high in the raw water and high sediment loads have added greatly to water treatment costs and are thought to have significantly reduced the annual yield from the reservoir by limiting the important carryover storage from the monsoonal rainy season to the five-six month dry season that characterises Tegucigalpa's semi-arid tropical climate (4).

Pressure to expand city water supply system

Although financially weak, the water company has been under great pressure to expand water service in the fast-growing capital to meet government targets for urban coverage which increased nationally from 41% for the 1975-80 to 87% for the 1990-96 period (5). With an emphasis on the downstream side of the business and the simple reality that watershed management, unlike mains repair, billing or water treatment, is a line item that few customers directly sense or miss, there has been a general lack of commitment to watershed management on the part of decision-makers. However, for the lack of action by other actors, water company staff took on the watershed management role beginning in the mid-1980's even though they had no real statutory responsibility. But government austerity measures required by the International Monetary Fund as part of debt renegotiations forced government agencies to cut spending, with this hitting the semi-autonomous bodies such as the water and energy companies particularly hard. In 1995, the watershed management budget was slashed by more than 50%, technical staff and labourers were dismissed, and an intent to cease operations completely was announced by the general management. Thus, in the case of the national water company, the decision was made in 1995 to phase out its watershed management unit. The water company's responsibilities were limited to the water supply generation and distribution infrastructure and the management of the land area in its immediate vicinity. Since then, watershed management efforts in the Guacerique and other Tegucigalpa watersheds have been reduced to a nominal level.

Losses caused by lack of attention

The situation in Tegucigalpa clearly brings into focus the biophysical implications of the failure to co-ordinate national and municipal policies in managing and protecting the watershed, and the legal and institutional impediments that have given rise to this situation. These include the lack of clear zoning restrictions and institutional commitments to watershed protection (3). The resource inefficiency and social costs of failing to integrate the planning and management of key resources including the land, soils, forests and water of the Guacerique River watershed are also clear. The lack of co-ordination between government departments has led to government projects that have directly caused a range of avoidable environmental and fiscal externalities for the water sector. These include the loss of investments in watershed reforestation areas bulldozed to make way for development projects; active surface water reservoir storage loss through accelerated sedimentation from erosion-plagued development project sites; and increased water treatment costs related to biological and sediment contamination from development project facilities.

Downstream concerns tackled at expense of upstream issues

In its recent Human Development Report (5), the United Nations Development Program provides an updated agenda for action to achieve sustainable consumption patterns and poverty reduction. In the area of water and sanitation, key measures are said to be greater government commitment to providing universal access to clean water and sanitation, removal of price subsidies and more efficient demand management, investment in infrastructure repair and expansion, and increased community-run services. As is often the case in such reports, emphasis is heavily on the downstream component of the water supply system. Repairing leaks in pipes, providing connections to poor households, encouraging water use efficiency – these are all critical elements but must be balanced by an upstream perspective.

It is perfectly understandable that water system engineers, schooled in hydraulics or construction, or water system administrators, schooled in public finance and accounting, have downstream priorities. Clearly, UNDP are right to emphasise their four key agenda actions. Increased efforts are needed to reverse the situation in which many developing nation urban distribution systems like Tegucigalpa's persist in haemorrhaging 50 percent or more of treated water on the way to customers. However, these downstream concerns must not be tackled at the expense of the upstream issues. The situation facing developing country cities like Tegucigalpa suggests that the failure to adequately care for the health of watershed and recharge areas of existing and future water source developments can be expected to have a range of undesirable and undermining effects.

Watersheds to be seen as assets

It is clear that to ensure sustainable, healthy water supply systems, an appropriate level of investment must be made in watershed stewardship as a proportion of total water sector expenditures, even though it may not lead to any short-term revenue improvements, coverage expansion or other similar hot-button target goals.

International donor agencies and national water agencies alike need to take seriously the notion of watershed and aquifer recharge area protection in developing countries, particularly around the fastest growing cities. They must pay greater attention to the professional development of management teams and to the adequate funding of systematic programs of land-use management, pollution prevention, and monitoring and enforcement of environmental legislation. A risk exists that a perverse impact of sectoral privatisation efforts to try and achieve greater public efficiency and service sustainability may be the short to medium-term phase-out or scale-back of watershed protection activities and capacity building. This is likely to be particularly true in situations such as Honduras where the responsibilities for such watershed management were voluntarily assumed by water agencies rather than required by statute. It would thus seem that donor and technical assistance agencies need to find appropriate mechanisms that will help ensure that in the drive to cut costs and balance cash-flows, watershed management and other forms of environmental protection are not sacrificed in the process. Many of the benefits of watershed management are in the form of avoided costs rather than enhanced revenues, unlike infrastructure improvements, metering, and other downstream measures. Watersheds and recharge areas need to be treated as assets in the same way that water supply infrastructure such as dams, pipelines and treatment plants are. In other words, the environmental services and the water production function provided by the watershed need to be given an explicit value and protected accordingly, regardless of whether the land itself is actually the property and hence the responsibility of the water agency. Developing nation water agencies need adequate incentives to ensure that an appropriate budget allocation for sustainability measures such as watershed protection is made.

REFERENCES:

1. Davidson W.V., 1994. Honduras. In Greenfield, G.M. (Ed) 1994. *Latin american urbanization*. Greenwood Press. Westport.

2. van der Horst A., 1995a. *Impactos del crecimiento de las actividades humanas en la cuenca del Río Guacerique en la cantidad y calidad de agua en el embalse de Los Laureles, Tegucigalpa, Honduras*. Final report to SANAA. August 1995. Tegucigalpa, Honduras.

3. Lee M.D., 1996. Multiple resource needs and multiple conflicts in urban watersheds in developing countries: the case study of the Guacerique watershed, Tegucigalpa, Honduras. *Proceedings of the Integrated Management of Surface and Groundwater*. UCOWR Annual Meeting, July 30-August 2, 1996. San Antonio, Texas.

4. van der Horst A., 1995b. *Costos de restauración de los daños ambientales provocados por el proyecto "Ciudad Mateo"*. Report to Ministerio Público, Tegucigalpa, 29 November, 1995. Honduras.

5. UNDP, 1998. *Human development report 1998*.Oxford University Press, Oxford.

TOWARDS UPSTREAM–DOWNSTREAM HYDROSOLIDARITY:

Australia's Murray-Darling River Basin

by

Dr John J Pigram

The Murray-Darling basin is made up of a mosaic of contrasting and competing circumstances and community interests. These contrasts represent formidable impediments to realising the mutual dependence and commonality of interests required to achieve and maintain true hydrosolidarity across a river basin. The paper discusses Australia's Murray-Darling basin, draining more than 1 million km2 , and the attempts made to coordinate the development and management of the river systems of the basin. Based on the Murray-Darling Basin Agreement in 1993, the main regulating body is the Ministerial Council consisting of land, water and environment Ministers from each of the State Governments involved and the Federal Government. A commitment to hydrosolidarity is shown by the imposition in 1997 of a moratorium on further water diversions from the system with consequences in terms of redistribution of entitlements. The degree of hydrosolidarity is all the more impressive in view of the widespread incidence of salinity and algal contamination across the basin and the fragmented organisational structure in place to administer this large and diverse region.

Introduction

A river basin is made up of a mosaic of contrasting and often competing biophysical, economic and social circumstances, and community interests. Only along limited reaches of a river basin is it possible to identify much commonality of attitude or purpose by the inhabitants. More typically, the segmentation of natural and human components of the basin is reflected in conflicting attitudes towards the single unifying element present – the river system.

Those living upstream tend to value the riverine environment primarily for its aesthetic appeal and perhaps its recreational role, rather than its economic function. Further downstream, the value of water for economic purposes becomes paramount to service agricultural, urban and industrial needs. The emphasis is on maximizing the quantity of water available, with some level of biophysical degradation acceptable as a trade-off against economic viability and regional development. In the lower reaches of the basin, the riverine environment is degraded further from contaminated effluent, so that aquatic life, wetlands, estuaries, and the coastal zone, are frequently compromised by eutrophication and sedimentation.

These contrasts represent formidable impediments to realizing the mutual dependence and commonality of interests required to achieve and maintain true hydrosolidarity across a river basin. Yet, there are some instances where progress is being made towards coordinating upstream-downstream interests and reconciling and integrating apparently incompatible claims on the resources of a river basin. Australia's Murray-Darling Basin is an example of where a degree of hydrosolidarity is emerging in response to pressing needs for coordinated resource management. This example is all the more impressive in view of the widespread incidence of salinity and algal contamination, across the Basin and the fragmented organizational structure in place to administer this large and diverse region.

The Murray-Darling Basin

The Murray-Darling Basin (Figure 1) encompasses Australia's largest river system draining an area of more than one million square kilometers (approx. one-seventh of the mainland) in the southeast of the continent. The Basin is the nation's most important agricultural region, accounting for between 30 and 40 per cent of total production from Australia's resource-based industries, from over one million hectares of irrigated land extensive livestock enterprises. Nearly two million people live in the Basin and its resources support more than twice that number beyond its boundaries, including 1.25 million people in the capital of South Australia, Adelaide.

Management of the resources of the Murray-Darling Basin typifies many of the problems which beset the task of unifying contrasting biophysical regions and socioeconomic circumstances in a river basin. The major rivers flowing through the region rise in the eastern highlands draining subtropical climate zones in the north and alpine areas further south, with annual rainfall varying from 1200 millimeters in the mountains to 150 millimeters in the arid west of the Basin.

In the early 1980s, the condition of the Murray-Darling River system was described as, "… the major agricultural, environmental question in Australia today" (1). The problems are highlighted by the fact that most of the Basin contributes little to the overall river system with the overwhelming contribution coming from the Snowy Mountains in the southeast. Moreover, although the Murray-Darling Basin does not encompass international borders, it does cover five different state and territory governments, which, in Australia, have constitutional responsibility for management of water (and other resources). Thus, marked differences in climate, water availability and other biophysical parameters, are further complicated by contrasting approaches to water management between the various administrations, and between them and the Federal Government which has overall financial responsibility.

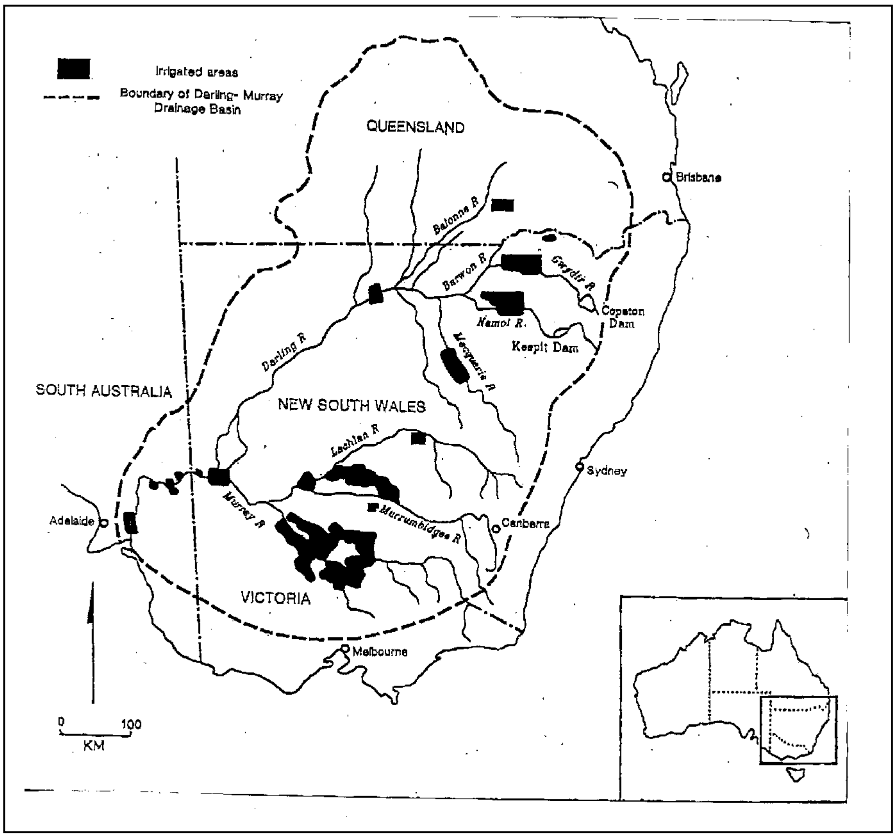

Figure 1. Murray-Darling Basin.

The Coordination Process

Since early this century, attempts had been made to coordinate the development and management of the river systems of the Basin. In 1917, the River Murray Commission was established under the River Murray Water Agreement. The major priorities were river regulation and construction of storages, weirs and locks to facilitate the regulation, reliability and sharing of the waters of the River Murray. However, the Commission's jurisdiction did not extend to other major tributaries, such as the Darling River. Moreover, the State of Queensland was not a party to the Agreement, despite accounting for almost one-quarter of the drainage basin.

For more than 60 years, the River Murray Commission's focus remained firmly on water quantity. However, as salinity problems become obvious, the Commission's role was broadened and in 1982, new legislation recognized the fact that management of the Basin's water resources should encompass issues of water quality. Yet, the Commission remained an advisory body with no authority to enforce water quality provisions, particularly on the sources of pollution in upstream tributaries.

Clearly, the constitutional situation and the institutional arrangements in place at the time were unable to address the problems of interstate rivers entering the Murray-Darling Basin. It was simply not possible to handle some of these environmental problems on a state-by-state basis. The necessity for a new organizational structure was recognized in which parochial and vested interests must give way to a national perspective. Water and water-related resources do not respect artificially created political boundaries. What was required was spatial integration of the planning and management of resource functions on a broader, interregional scale.

Despite objections to what was seen as the creation of a new state, the River Murray Commission was replaced in 1985 by the Murray-Darling Basin Ministerial Council. In 1991, Queensland the state furthest upstream in the Basin, agreed to join, with the Australian Capital Territory having observer status. In 1993, the Murray-Darling Basin Agreement was given full legal status, putting into effect the longstanding objective that "the river and its tributaries be looked on as one". To achieve this, the Agreement established new organizations at the political, bureaucratic and community level.

The Murray-Darling Basin Ministerial Council consists of land, water and environment Ministers from each of the State Governments involved and the Australian Federal Government. Its functions are to set policy and define broad directions for the management of the natural resources of the Basin. Its charter is to promote and coordinate effective planning and management for the equitable, efficient and sustainable use of water, land and other environmental resources; specifically to:

- maintain and improve, where possible, water quality for all beneficial uses;
- control and prevent land degradation;
- rehabilitate resources where possible, to ensure their sustainable utilization;
- conserve the natural environment; and
- maintain and improve the sustainability of agricultural development in the Basin.

The Murray-Darling Basin Commission is the executive arm of the Ministerial Council, advising it on issues of environmental management throughout the Basin. In relation to water, these include:

- regulation of the River Murray, allocation of water shares to each state, and coordination of river management under state jurisdiction;
- maintenance of flows and water quality for a range of purposes;
- enhancement of water quality by encouragement of more appropriate land use practices and better practical means of waste treatment and off-river disposals;
- coordination of the preservation of native fish and the riverine environment; and
- coordination of the management of wetlands.

The good sense of this approach can be seen by reflecting on a number of these issues. For example, the effects of pollution and waste disposal are not confined to a point source; fish do not observe state jurisdictions when rivers transcend political boundaries; and wetlands frequently extend across state borders.

The Commission's effectiveness largely depends on the cooperation and support of participating governments. Rather than basing decisions on the priorities of individual states, it bases them on the interests of the Basin as a whole. In this respect, the Commission is assisted by a Community Advisory Committee which provides independent advice on the views of the Basin's communities regarding resource management issues. Representation on the Committee of regional and special interest groups from throughout the Basin is seen as one of the most important factors in strengthening community participation and empowerment and assisting in the realization of the Commission's objectives (Figure 2).

For the Record

How successful have the Murray-Darling Basin Agreement and its component organizations been in coordinating the management of the Basin's resources and promoting hydrosolidarity?

According to Millington (1996), formerly Deputy President of the Murray-Darling Basin Commission, the Agreement provides a secure and flexible model for river basin management. Specifically, the Agreement:

- clearly identifies specific water shares for each state;
- includes quality as well as quantity aspects;
- requires each state to refer development proposals within its part of the Basin to the Commission for review;
- requires the Commission to report on resource impacts and to identify and research knowledge gaps; and
- involves the community in strategy development.

Millington considers that the Agreement has led to a cohesive shared vision for the Basin and common ownership of basinwide policies and initiatives. Certainly, within a relatively short period of time, the Agreement has contributed to a number of substantial achievements within the context of a community-driven Natural Resources Management Strategy. This Strategy is seen as the "cornerstone" of the efforts of the Murray-Darling Ministerial Council and the Commission to achieve integrated, sustainable planning and management of the Basin's resources.

Natural Resources Management Strategy

The Strategy provides the philosophical and management framework for achieving the key objectives of the Murray-Darling Basin Agreement. It is a blueprint for joint, coordinated, community and government action to address a broad spectrum of resource management issues designed to:

- use resources in a way that is ecologically sustainable;
- restore degraded resources;
- maintain biodiversity; and
- preserve cultural heritage

Funding to implement the Natural Resources Management Strategy is divided between knowledge-based or research activities (40%) and onground programs of works (60%). The knowledge-based category covers investigations into the aquatic and riverine environment, groundwater, land and vegetation, salinity and drainage, cultural and historic sites, native flora and fauna, and education and information. Onground works are directed to those measures where there is an agreed, perceived community benefit.

The Natural Resources Management Strategy provided the framework for a series of associated, component measures, among them:

- a Salinity and Drainage Strategy
- an Algal Management Strategy
- an Irrigation Management Strategy
- a Dryland Management Strategy
- a Community Education Program

An Integrated Flow Management Strategy has also been developed aimed at restoring an improves flow regime to rivers in the Basin. These measures are backed up with a range of computer-driven models and analytical tools to help ensure that the component strategies remain well directed and can be evaluated as to the extent that their objectives are being met.

Hydrosolidarity Challenged

A good test of the commitment to hydrosolidarity under the Murray-Darling Basin Agreement came with the imposition of a "cap", or moratorium, on further diversions of water from the Basin river systems. This controversial measure was agreed to in 1997 in order to ensure the retention of sufficient environmental flows in the system to support a healthier aquatic and riverine environment. The cap limits the amount of water that can be taken from the rivers of the Murray-Darling Basin to what could have been diverted in 1993/94, i.e. given the level of development and capacity of the irrigation system and infrastructure that prevailed at that time.

Essentially, the introduction of a cap on diversions means that water needs for future irrigation development must be met from within the cap limits, which vary between states and which are adjusted for water use in wet and dry years. Problems have arisen in implementing the cap because or significant differences between the four Basin states in water policies, in water allocation procedures and security of supply, in water use and crop requirements, and in the level of maturity of water resources development. The State of New South Wales, which has the highest share of Basin diversions (57.4%), is the state where the cap has the greatest impact and where opposition to it from irrigators is strongest. Implementation of the cap is inevitably leading to redistribution of existing water entitlements through expansion of water trading. If holders of presently inactive ("sleeper) licenses start to use or trade their water entitlements, there must be a reduction in current allocations under the cap. One of the problems with water trading is that environmental interests are opposed to entering the water market to acquire or dispose of water for environmental purposes. The attitude is that capped water is a residual available for irrigation or other consumptive uses, after environmental needs have been met.

Apart from environmental demands on water, landholders in upstream catchments in the Basin have long claimed a share of water running off their lands. In 1998, a decision was made to allow these landholders to harvest up to 10% of runoff into small farm dams for their use. This concession is seen by environmental interests as having potential to compromise the cap and is opposed by landholders downstream because of possible reductions in stream flow. Once again, the fragile nature of the whole-of-Basin approach, or the supposed community of interests along a river system, is exposed by apparently irreconcilable claims on the Basin resources, between upstream and downstream.

Upstream/Downstream Solidarity under Stress

The Murray-Darling Basin Agreement and its constituent bodies and strategies are held up as a strong and useful model for integrated river basin management. The institutional arrangements in place certainly have many of the elements conducive to reconciling and rationalizing competing interests for basin resources. A feature of particular merit is a vigorous and coordinated level of community awareness and a well developed participation process.

Yet, when tested against specific decisions and initiatives designed to share the resources of the Basin between users, uses and communities, it becomes clear that much remains to be done before effective, integrated management of this important and productive region becomes a reality. Whereas the organizational structure and institutional arrangements represent important steps towards sound integrated river basin planning, contrasts in the resource endowment, in the level and scale of resource development, and in the political interpretation and application between States of supposedly Basin-wide management initiatives, reveal clearly the gulf between upstream and downstream perspectives. Hydrosolidarity still has some way to go even in Australia's Murray-Darling Basin.

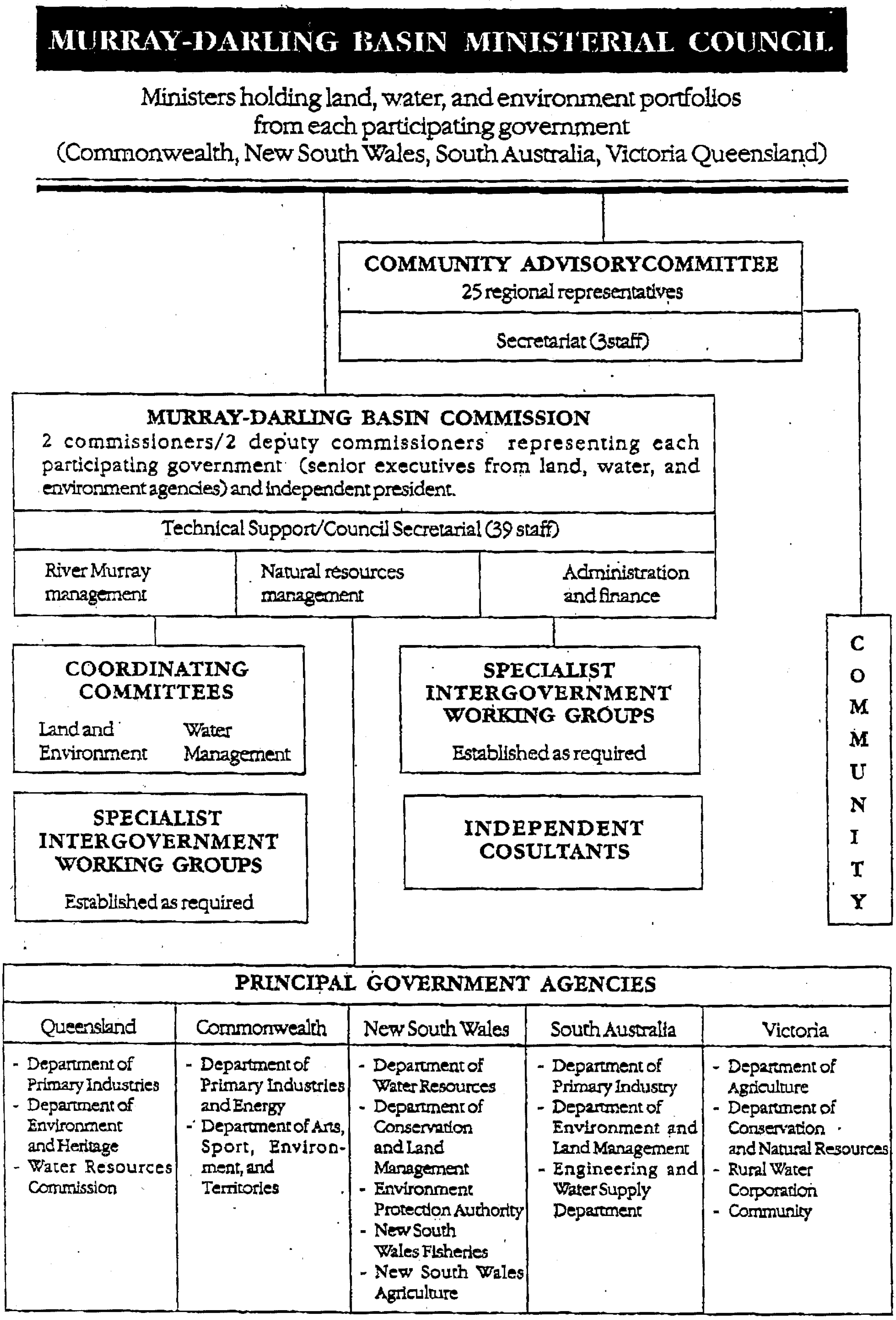

Figure 2. *Murray-Darling Basin Ministerial Council*

REFERENCES:

1. Kerin, 1982,, “Salinity, Agriculture and the Murray River”, Radical, 12(1)6-7

2. Millington, 1996, “The Murray-Darling Basin Experience”, p. 104-133 in “Towards effective Water Policy in the Asian Pacific Region” (ed. W.L. Ariens), Manilla, Asian Development Bank

THE YELLOW RIVER: MANAGING THE UNMANAGEABLE

by

Edwin D. Ongley

Hydrosolidarity in the Yellow River is a complex and difficult task, especially as this river has sediment problems that are unique in the world. The balancing of discharge needed for sediment management, relative to that needed for augmentation of water supply within and outside the basin, and to conserve threatened ecosystems downstream, presents a series of compromises that must rank as amongst the most challenging in basin-wide management of major world rivers. Until such time as South to North diversions are in place, the Yellow River is the only major water supply to the North China Plain where water scarcity is now estimated to be some 40 bm^3 annually, representing 70% of the flow of the Yellow River. The hydrological management of the Yellow River Erosion involves three major factors: erosion and sediment transport, flooding and river desiccation in the downstream reaches. This paper outlines several major development projects in the Yellow River basin that are attempting to achieve hydrosolidarity while, at the same time, providing needed water supplies to water-scarce parts of the basin.

Introduction

The Yellow River (Huanghe) basin, the cradle of Chinese civilization, is known historically in China as the "River of Sorrow". This sobriquet reflects a difficult environmental and hydrological condition which is as old as time and which has been exacerbated in modern times by natural and anthropogenic factors. With its devastating floods and high sediment loads the Yellow River has been the focus of Chinese hydrology and sediment management for more than two millennia and provides an object lesson on the perils of sectoralized development plans and the need to plan and manage on an integrated basin-wide basis.

In modern times the Yellow River Conservancy Commission provides a focus for integrated basin management. Nevertheless, the Commission is, at best, playing catch up with a wide range of cumulative problems which have no easy solution. Regional development pressures and competing regional agendas within the basin, political imperatives at the national level that impact on water management regionally, and economic and social pressures continue to provide troublesome ground for achieving "hydrosolidarity" within the Yellow River Basin.

The Yellow River, the second longest river in China, rises in the mountains of the Qinghai Plateau in western China, and flows some 5,500 km to the Bohai Sea (part of the Yellow Sea) off the eastern coast of China. The Yellow River acquires the largest sediment concentration of any large river in the world – up to a kiligram per litre of suspended matter – and transports an average of 1.6 Gtonnes (billion tonnes) of sediment per year, as it traverses the Loess Plateau. Although erosion of the Loess Plateau is an historical phenomenon, it is exacerbated by unsustainable land practices. Rapid sedimentation and infilling of reservoirs has greatly changed both the hydrological management of reservoirs (to enhance sediment flushing) and the economic factors in dam planning and construction in this river basin. Part of the sediment load (400 Mtonnes) is deposited on the channel bottom when the river flows onto the great North China Plain causing accretion of the bed which, because of flood control measures to contain the river to its banks, has resulted in the bed of the river being up to 10 meters above the surrounding land and is known as a "suspended river". For this reason the channel of the Yellow River is the hydrological divide between the Hai River to the north and the Huai river to the South. On an historical basis the Yellow River has deposited some 1.2 Gtonnes into the coastal zone and another 400 Mtonnes into the deeper portions of the Bohai Sea however more recently due to change in discharge these numbers have been revised downwards 1.0 Gtonnes annually of sediment into the Yellow River Delta for the period 1950-1987.

Flooding is a major historical problem in China and has caused millions of deaths over the millennia. Flooding of the Yellow River in 1117 killed more than one million persons; 340,000 in 1642; 18,000 in 1933; and 890,000 in 1938 (due to breaching of the dyke by Chiang Kai-shek) (1). Flood protection works since 1949 have greatly diminished both the risk of flooding and of loss of life. Major flooding is a constant threat, with flooding in 1998 and 1999. Hydrological sciences are an ancient and fundamental art in China – a country which is dominated by floods and sediment in a large portion of its territory and which are an integral part of the historical identity of China.

In this paper we focus on the middle and lower parts of the Yellow River basin where the greatest development pressures lie, and where the major environmental problems exist. In the Yellow River there are three over-arching hydrological issues that dominate planning and management of the river basin; these are: (1) erosion and sedimentation; (2) flooding; and (3) in recent times river desiccation

Amongst the many development and related environmental issues, the major issues tend to be:

- Augmentation of water supply for urban, industrial and agricultural use, especially in the middle and lower parts of the basin.
- Plans to divert water from the Yellow River basin to other cities in northeast China.
- Sediment control in the middle basin, and sediment management in the lower basin.
- Specific industrial issues, such as coal production in the middle basin, oil and gas extraction in the delta region and their water requirements and related environmental impacts.
- Habitat preservation in the delta region, especially in regards to river desiccation.
- Pollution control, especially in the lower part of the basin.
- Delta and coastal zone management.

In this overview we shall focus on upon several major projects in the basin that reflect both the development issues and those natural phenomena that influence the management decisions in the basin. All issues have upstream/downstream considerations and are integral to any hydrosolidarity that may be achieved in the basin.

Erosion/Sedimentation ~ Managing The Source

The Yellow River is almost unique in the world in that a significant amount of the discharge has to be allocated for sediment management (sediment flushing) (2). As noted in Table 1 this has been estimated by Leung (3) at 20-24 billion m^3 – an amount that is some 40% of the mean annual discharge. The importance in reducing sediment is seen in the following estimates: Leung postulates that a 50% reduction in sediment load will result in an additional 10 billion m^3 of water available for other uses, an amount equal to some 20% of the total flow. This amount falls within the range of water shortages that had been predicted by Leung by the Year 2000 (8.5 – 16 b m^3). Discharge management, to be achieved with construction of the Xiaolangdi Dam near the river's entrance to the North China Plain, is expected to enable managed flow levels sufficient to carry fine sediment across the Plain and to the delta.

Table 1: **General Water Budget for the Yellow River[1]**

Mean Annual Input of Surface Water to YR	=	58	billion m^3
Withdrawals (Irrigation etc. - to 1987)	=	37.6	
Flow to Sea	=	20.4	(30.8 1976-87)[2]
			(17.06 1986-94)[2]
Estimated Flow for sediment flushing	=	20 - 24[1]	
ADD			
Additional diversions proposed for Beijing, Tianjin, Qingdao, etc..			

= Water Deficit by Year 2000 of 8.5 -16 billion m^3

Reduction of sediment load by 50% can save up to 10 billion m^3 annually

1. Abstracted from G. Leung, 1996 (3) 2. From UNDP, 1997 (4)

It is estimated that some 83% of the 1.6 Gtonnes of sediment in the Yellow River comes from the Loess Plateau. Therefore, part of the basin-wide strategy is to reduce sediment loads into the river from the Loess Plateau through an extensive system of key dams and warping dams that will both control flooding (key dams) and cause sediment accretion (warping dams). Experience suggests that a 50% reduction of sediment loading to the Yellow River is possible (Table 1). Generally, the engineering approach being adopted is to identify the most vulnerable areas to erosion (some 121,000 km^2 has been identified as key areas for such projects).

There is a long history to Chinese control of sediment in the Loess Plateau. Past work is noted in Table 2 and forms part of a long-term plan that is noted in Table 3.

Table 2: Past Efforts At Erosion Control

Loess Plateau = 640,000 km^2
Sediment Yields (to 20,000 t/km^2/yr) = 83 % of YR sediment

1950-1989: Primary Control in 163,000 km^2 with

- 8,700 km^2 damland and floodplains created
- 75,000 km^2 afforestation
- 30,000 km^2 terraced
- 20,000 km^2 sown grassland
- 3 million soil and water conservation works

Result: Reduction of annual sediment load into Sanmenxia Station by 250 million tonnes over last 20 years. Other treated tributary rivers show 50% sediment reduction.

Table 3: Long Term Sediment Control Objectives on the Loess Plateau

121,000 km^2 of gullies amenable to core projects

- 18,000 key dams
- control over 75,600 km^2

Objective: Reduction of 40 - 50 % in sediment load of Yellow River. River training in Delta region to maintain sediment transport and channel stability.

Part of the plan is being implemented through the World Bank's Loess Plateau Watershed Rehabilitation Project. This project incorporates several physical and societal objectives, including the construction of land development and erosion control works in the most vulnerable tributary catchments in the provinces of Inner Mongolia, Shanxi, Shaanxi, and Gansu, and institutional development to improve technology transfer and quality of life. This project encompasses some 15,600km^2 of the approximately 640,000 km^2 of the Plateau. Activities are noted in Table 4.

Table 4: Loess Plateau Watershed Rehabilitation Project[1]

Focuses on 15,600 km^2 of highest sediment runoff

- Afforestation: 2,700 km^2
- Grasslands: Established on 1,550 km^2
- Orchards: 270 km^2

Sediment Control Dams

- Key Dams (236) -- control major flood events
- Warping Dams (2,208) -- cause sediment deposition
- Gully control with brush check dams

1. World Bank, 1994 (5)

Augmenting Water Supply ~ Dams And Diversions

The overall discharge and water supply situation is noted in Table 1. Extensive parts of the Yellow River basin are desperately short of water. This has a profound negative impact on poverty, on (irrigated) food production, and on industrial and coal production in the middle portion of the Yellow River. Compounding this are the serious problems of current and future water shortages for all of the major cities of the North China Plain – Beijing, Tianjin, Qingdao, and for industrial and irrigation uses outside the basin. The World Bank (6) reports that water shortages on the North China Plain now amount to some 5 bm^3 for municipal and industrial uses, and 35 bm^3 for agricultural purposes. In total, this is some 70% of the total long-term average flow of the Yellow River.

The national government is engaged in planning for major transfers of water from South to North, especially from the Yangtze River. The "East Line" project carries water from the lower Yangtze River to the lower course of the Yellow River (city of Jinan) however it is so polluted that extension of the diversion to the port city of Tianjin has been postponed. Other plans for diversion of water from the central Yangtze basin to the middle portion of the Yellow River basin and onwards to Beijing and Tianjin remain in the planning phase.

The Wanjiazhai Water Transfer Project, another World Bank project, located in Shanxi Province (Table 5) in the middle reaches of the Yellow River, illustrates the dilemmas for water resource planners. This project is also an example of the probable future of the Yellow River, where some 27 major dams are planned (19) or built (8). The project is designed to divert 1.2 billion m^3 (some 2% of the long-term mean flow) from the main channel for use within this chronically water-short region of the middle Yellow River basin. Although the project area lies within the basin of the Yellow River it is not known to this writer how much, if any, of this flow will be returned to the main stem. This information is not contained in the final EIA report (7).

Table 5: Water Supply Problem in Shanxi Province[1]

Water Demand > Water Supply by x2
Per caput water utilization = 41% of Chinese average

Industrial Production:
50% of national coal production
50% of aluminum production

Irrigation: Water need is x2 of water supply
Household Water Use
26 - 95 l/day (Chinese mean = 174 l/day)
(WHO recommended = 100 l/day)

1. World Bank, 1996 (7).

The water crisis in this region is underscored by the World Banks' assessment of the local situation where, "…in the cities of Taiyuan (the capital) and Datong … surface water supplies have virtually dried up, and groundwater has been overextracted to a degree leading to land subsidence of over 3 meters in many places. …. Farmers … resorted to irrigating with untreated industrial waste; miners are often unable to bathe because of lack of water; people living above the third floor have no piped supply because pressures are too low … ."

It is curious to note that the Chinese concluded that, " … impact of diverting the water …. on the downstream provinces is minimal since provincial withdrawals … is governed by agreed water allocations .. determined in 1986" (8). Yet, discharge records at the Delta show that annual flow during the period 1986-1994 is almost half that of previous decade. One wonders what will be left of the long-term flow if the same logic is used for the many new diversions planned in the future. Nevertheless, knowledgeable hydrological engineers, studying river desiccation downstream (see below) have determined on an hydrological basis that, at least insofar as desiccation is concerned, discharge quantity is sufficient providing there is increased storage upstream.

River Desiccation

"River Desiccation" is not precisely defined in hydrological terms but implies seriously reduced stream flow relative to long-term records and may include a complete drying out of the channel for periods of time. In the lower course of the Yellow River desiccation (no flow) of 1-20 days in most years is reported from at least as early as 1972, but increasing to 75, 122, 133 and 200 days in 1992, 1995, 1996 and 1997. The phenomenon is most pronounced in the period March to June. While there has been some speculation that desiccation is climatically induced, it is reported that for a given rainfall in the 1980's, runoff in the Yellow River was 10 billion m^3 less than the 1950's, and sediment load was 0.5 Gtonnes less than 1950's. It is concluded that upstream development and diversions, and the success of programs of water and soil retention in the middle reaches, have caused reduced flow in the Yellow River and that climate change is not a significant factor (9).

Desiccation has a serious influence not only on water supply but also on dilution of effluents and on the aquatic and wetlands environment of the Delta which are important staging areas for bird migration. For water management, the challenge is to: (1) mitigate desiccation by upstream discharge regulation; (2) manage conflict within and between upstream and downstream users; and (3) deal with the issue of water and soil conservation within the whole watershed .

Water Pollution

Water quality management is becoming a key factor in managing water availability in China. Water scarcity and the cost of diversion schemes have focused attention of the central government on the need to remediate water quality across the country so as to increase water availability for a wide range of beneficial uses, including environmental uses which are now precluded because of seriously impaired water quality. In Shanxi province in the middle Yellow River, for example, the mining industry has so polluted surface water that it is of no value for other uses and which contributes directly to water scarcity.

While not necessarily an upstream/downstream problem in terms of pollution cause and effect, it becomes an upstream/downstream problem when one factors in the necessity of implementing basin-wide remediation planning so that the range of point and nonpoint source impacts within the basin are considered in the process of determining an optimal pollution control strategy and minimum investment strategy to achieve remediation goals.

It is noted above that water quality has become a central issue in the failure to deliver water to the city of Tianjin. For the Yellow River it is reported (Table 6) that 71% percent of river length is highly polluted and is almost double that of the Chinese average. In the downstream and Delta regions there is serious surface and groundwater pollution from industrial effluents and oil/gas extraction and refining activities. These levels of pollution impose a financial burden on downstream communities for drinking water control, and on aquatic ecosystems that become impaired due to excessive levels of pollution.

Table 6: Water Quality of the Yellow River (as Percent of River Length)

Water Quality Class. (1 = Best Quality)	Level 1 %	Level 2 %	Level 3 %	Level 4 %	Level 5 %	>level 5 %	Highly Polluted Level 4 - >5 %
Yellow River	1.1	5.8	22	40	15	16	71
Total for China	6.1	26	21	28	8.3	11	46

(after Zhang & Zhang, 1998)

Different authors have divergent views on water quality of the Yellow River. Seventy-one percent of river length is reported by Zhang & Zhang (10) in Table 2 as highly polluted and is almost double that of the Chinese average. In contrast, Zhang et al. (1997) claim that the Yellow River as a whole meets Level 2 standard, with serious pollution in the most downstream areas. Weng (personal comunication) using data from the Ministry of Water Resources' national water quality inventory confirms that the aggregate values reported in Table 6 are the correct ones. Water pollution is not only a problem within the basin, but extends into the coastal and marine environment with serious impacts on marine life and the commercial fishery.

CONCLUSIONS

Hydrosolidarity in the Yellow River is a complex and difficult task, especially as this river has sediment problems that are unique in the world. The balancing of flow needed for sediment management, relative to that needed for augmentation of water supply within and outside the basin, and to conserve threatened ecosystems downstream, presents a series of compromises that must rank as amongst the most challenging in basin-wide management of major world rivers. The Yellow River Conservancy Commission and the national government are fully aware of the challenges and are committed to achieving a solution which, while not satisfying everyone, will represent an optimal solution given the reality of water shortage, the unique natural conditions, and the economic situation.

ACKNOWLEDGEMENTS

The writer has worked in China for a decade and has benefited from the friendship and wise counsel of many individuals. Some data for this paper was drawn from the Yellow River Home Page developed by Prof. G. Leung of the University of Massachusetts who, in his Home Page, provides insight into what does and doesn't work in sediment management. Most importantly, I have learned over the years in China and other developing countries that hydrosolidarity is as much a humanistic achievement as a technical achievement.

REFERENCES:

1. United Nations, 1983. Experiences in Flood Prevention and Control in China. Chapter 3 of *Flood Damage Prevention and Control in China*, Natural Resources / Water Series No. 11, Dept. of Technical Co-operation for Development, United Nations, New York.

2. Lin, B., and Long, Y., 1988. A study of the total load transport by the Yellow River. In Bordas, M.P. and Walling D.E. (Eds), *Sediment Budgets*. IAHS Publication No. 174, International Association of Hydrological Sciences, Wallingford, United Kingdom, 483-496.

3. Leung, G., 1996. "Yellow River Home Page" by G. Leung, and including own work referenced to: G. Leung, 1996. Reclamation and sediment control in the Middle Yellow River Valley. *Water International*, 21(1), 12-19.

4. UNDP, 1997. *Support for Sustainable Development of the Yellow River Delta*. UNDP Project No. CPR/91/144, Final Report. Dongying, Shandong, China.

5. World Bank, 1994. *Loess Plateau Watershed Rehabilitation Project*. Staff Appraisal Report, Report No. 12593-China. The World Bank, Washington. (Retrieved from World Bank Web site).

6. World Bank, 1997a. *Wanjiazhai Water Transfer Project*. Staff Appraisal Report, Report No. 15999-CHA. The World Bank, Washington. (Retrieved from World Bank Web Site).

7. World Bank, 1996. *Wanjiazhai Water Transfer Project* – Environmental Impact Assessment: Final Report (Executive Summary in 10 chapters). The World Bank, Washington. (Retrieved from World Bank Web Site).

8. World Bank, 1997b. *Wanjiazhai Water Transfer Project*. Project Information Document. Report No. PIC 1470. The World Bank, Washington. (Retrieved from World Bank Web Site).

9. Zhang, Q, Wang, Z-Y., He, S., Hu, C., 1997. The Yellow River Mouth Harnessing and Water Resources. UNDP Project No. No. CPR/91/144 *"Support for Sustainable Development of the Yellow River Delta"*. Dongying, Shandong, China.

10. Zhang, Q., and Zhang, X., 1998. Current Key Water Issues For Sustainable Development In China. Draft Manuscript. Institute of Water Resources and hydropower Research, Ministry of Water Resources, Beijing, China.

RIVER PARLIAMENTS FOR BRINGING TOGETHER UPSTREAM AND DOWNSTREAM USERS

– Some Indian case studies

by

Professor Anil Agarwal

In India the water systems have been rapidly deteriorating under the impact of rapid population growth, urbanisation, industrialisation and agricultural modernisation. River Basin Parliaments consisting of upstream-downstream society institutions are currently discussed to coordinate and bring together the upstream and downstream users to understand each others problems better, and to put joint pressure on the State. The paper refers to five cases of small rivers - now flowing round the year thanks to water harvesting efforts - where River Parliaments have been formed.

Indian cities have mainly been growing up along rivers or built on traditional water harvesting systems. India has a long history of urbanisation going back to the Indus Valley civilization, which was one of the world's earliest urban civilizations with very high levels of urban planning. Living with water has been, therefore, a long standing paradigm in India.

But over the years the management of surface water systems and people's relationships with rivers and other water systems has been rapidly deteriorating under the impact of rapid population growth, urbanisation, industrialisation, agricultural modernisation and changing consumption patterns. The toxins produced by this combined demographic-economic process have led to enormous water pollution. Most Indian rivers today, except the extremely big and remote ones, are extremely polluted.

This poses an extremely serious threat to the health of urban India, because urban citizens are heavily dependent for their drinking water supply on surface waters. The growing use of ground water in cities is also proving to be a public health threat because of the growing pollution of groundwater resources.

The pollution of rivers poses a unique dimension of "hydrosolidarity" between upstream and downstream users. At the moment there is no concept like river basin planning in India for water quality purposes. There are no controls on pesticides flows, for example, from agricultural farms into rivers. There are many cases emerging in which pollution upstream is leading to severe public health problems downstream.

The speaker presented three case studies of the problems that have emerged in the Sabarmati basin, the Yamuna basin and the Bhavani and Noyyal river basins (1).

When environmental governance is not upto the mark, the civil society acquires a very important role in fighting for appropriate change in governing systems. The concept of making River Parliaments consisting of upstream-downstream civil society institutions is currently being discussed by the Centre for Science and Environment (CSE) to coordinate and bring together the upstream and downstream users to understand each other's problems and to jointly put pressure onto the State to improve its river basin management within a participatory framework.

The speaker also presented a case study of efforts which has been made in this context for five small rivers that have been revived through water harvesting efforts by village communities. Now that these rivers have been revived and flow round the year, the communities within the river basins have formed River Parliaments to ensure good land water use within the river basin so that the river stays alive and both polluting and overexploitative activities are kept under control.

REFERENCES:

1. Narain, Sunita, 1999, "We all live downstream: Urban industrial growth and its impact on water systems", *Proceedings Stockholm Water Symposium* 1999, Stockholm International Water Institute. Stockholm.

FOCUSING ON THE UPSTREAM/DOWNSTREAM INTERDEPENDENCIES AND CONFLICTS OF INTERESTS

- *Steps and procedures towards coping with management challenges*

by M Falkenmark & J Lundqvist

Introduction

Everybody lives downstream

Recently, renewed attention has been given to the upstream/downstream relationships in river basins. Aptly captured by the motto of The World Water Day, 1999, "everybody lives downstream", the most basic fact of the hydrological cycle has been highlighted. We are all downstream of the rainfall. It is also a fact that a majority of the world's population rely on water that, to various degree, has passed through upstream areas. What happens there in terms of land use, water regulation, diversions, pollution, etc. is of vital interest to those who live downstream.

By now, it is well documented that some rivers are running dry in their downstream portions, at least for part of the year. This is the case even for some of the migthiest rivers of the world (see contribution by Ongley, (1)). The most plausible explanation for river desiccation is to be sought of in terms of changes in land and water use in upstream parts of the catchment. Less well documented but equally significant, the quality of the water when it reaches downstream users, or the estuary and sea is below any reasonable, decent standard. It cannot be used and it should not be used. But in the absence of an alternative, it is, in fact, used. And even if it is not "used" in a conventional sense, people, flora and fauna are still exposed to it. About two thirds of the world's population live in coastal, i.e. downstream, areas and this proportion is likely to increase rather than to decrease. It is not only the health of people that is affected. Farmland, ecosystems and industries, are all dependent on water. A combination of river desiccation (reduced water flow) and increased load of pollutants is obviously detrimental for a range of development opportunities and options. According to a high level panel associated with the World Commission on Water for the 21st Century, the World's rivers are in crisis: "Some are Dying, Others Could Die …. More than one-half of the world's major rivers are being seriously depleted and polluted, degrading and poisoning the surrounding ecosystems, thus threatening the health and livelihood of people who depend upon them for irrigation, drinking and industrial water" (2). This grave statement is, of course, most applicable for downstream segments of the river basins.

Shortcomings of conventional concepts and management approaches

In wise water resources management, upstream/downstream linkages should be duly considered. We are basically referring to a sort of upstream/downstream allocation of water in a basin. We should also pay attention to what happens to water quality after use since a degradation of quality may jeopardize, or at least curtail, development options and environmental sustainability. These kind of consequences are, of course, particularly noticeable in downstream areas of a basin. The upstream/downstream dimension is often conceived of as an international issue and concern has consequently primarily been expressed in connection with the development and utilisation of water resources in international river basins. This is perhaps not surprising since development opportunities and options of some countries or regions literally depend on what is happening to the water source, which is situated in another country upstream. At the same time, people in upstream areas, of course, have a legitimate claim on the basin resources within their sections of the basin.

At a national level, the prevailing approach to water development and utilisation in most, if not all, countries, puts more stress on allocation between different sectors rather than on upstream/downstream interdependency and interaction. The same principal problem is, however, noticeable within river basins in a national context as in international river basins. There is obviously a need to discuss upstream/downstream relationships in two important aspects: (i) what are the reasonable claims and the efficient and fair utilisation of basin resources in the various parts of a basin, (ii) what kind of management system is required to deal with the threats of water quality degradation.

Apart from a lack of proper attention to upstream/downstream considerations, the predominant water management approach tends to be piecemeal, which, no doubt, can be rational and efficient, but it also tends to be compartmentalised, i.e. it lacks proper co-ordination and integration. Typically, the understanding of interactions between land and water is lacking. A division of tasks and responsibilties between line Ministries is necessary for various reasons. It is hardly conceivable, for instance, to have one Ministry dealing with all relevant water related issues under one roof. But there must be some kind of coordinationg mechanism through which an integrated water management may be facilitated and executed. To facilitate a pro-active, anticipative planning for the most worthwhile use of water and other resources, a better co-ordination between various sectors and interests is required.

Another shortcoming in conventional conceptions is the focus on water provision with no or scant concern about what happens to water after it has been used. The rapid degradation of water quality of the rivers of the world, as mentioned above, may be seen as an unfortunate sign of such neglect. It is also an illustration of a faulty understanding of how land use, in a wide sense, has an impact on water quality. Water after it has been used is also part of the water source for people who are living in downstream positions. The direct relation between water utilization and water disposal and the associated links between water quantity and quality is often neglected due to prevailing institutional and organizational structures of society. It is probably also a logical consequence of a pre-occupation with development issues rather than with a sound balancing of exploitation and conservation interests.

A third issue that warrants attention is the ambivalence concerning the notions of "right to water" and "water rights". The former has been propagated for a number of years as an important policy imperative. In practise, the notion is quite vague, partly due to the fact that there is no inclusion of responsibility on the part of the user in connection with a rights based approach. The notion of water rights represents a broader concept where roles and rules of the different actors in water management are identified.

Conceptual framework

The invisible water behind plant production and ecological services

During the first session of the Seminar, some basic concepts were elaborated. Links between land use and consumptive water use were discussed. Water use statistics only gives information on direct use of liquid, visible water in the blue water branch. But the largest water use is in terms of consumptive use of the unvisible water as evapotranspiration in connection with plant production (3). There is also a complementarity between the green and the blue water branches that has to be paid attention to, particularly in tropical climates. The reason is that land use in terms of, for instance, forestry activities, will have a significant effect on the size and temporal dynamics of the various branches of the hydrological cycle. Changes in land use will lead to changes in rain-water partitioning and thus in the amounts of "green" and "blue" water, i e the fractions of rainfall that will be available as soil moisture (green water), groundwater, surface flows (blue water), etc. The inclusion of the green water concept in the overall water balance of a catchment leads to the conclusion that was has to be shared between those living in the catchment is basically the precipitation over the catchment rather than just the blue water that currently happens to flow in the river.

Plant production is the result of a fundamental ecological service on which humanity depends. There are also other services to pay attention to. Freshwater plays a fundamental role to sustain ecological processes and services which play a vital role in society. Folke & Gordon (4) in their contribution stressed the importance of a neglected area in water management of double invisibility: invisible freshwater flows are needed to produce invisible but essential ecological services. Freshwater is associated, directly or indirectly, with many different types of ecosystem services: chemical services like denitrification, physical ones like sedimention, interception and soil permeability, and biological ones like biomass production, fish production, seed dispersal and pest insect control. They gave a couple of examples on the relations between water flows and ecological processes in the catchment, examplifying how unintentional side effects of human activities tend to cascade over large temporal and spatial scales. In the Australian wheat belt, native shrub and woodlands had been replaced by annuals with increase in runoff, water logging and salinisation as a result. In South Africa, alien woody vegetation without natural enemies have invaded large areas, considerably reducing runoff.

Water - a reflection of land use

One of the principally new issues that will have to be properly addressed by the next generation of decision makers is the trade-offs between development and utilisation of freshwater for production of food and other tangible products to support a growing world population, on the one hand, and the freshwater required to support the ecosystem services which are indispensible for a sustainable society, on the other (5, 6). Humans have to manipulate various landscape components in order to satisfy needs and wants in society (3). Land has to be manipulated through clearing, tillage, drainage etc to allow biomass production and harvesting. Water has to be manipulated through digging and drilling of wells, building of pipelines, canals and reservoirs to make water accessible when and where needed. Such manipulations will necessarily have side effects, most of which are non-desirable and often difficult to anticipate. Water tends to play an active role in generation of such side effects, basically in three different ways :

* its complex interactions with vegetation and soil, easily producing water partitioning changes between the evaporating part and the runoff part;
* water's role as a unique solvent on continuous move, picking up anything that is water soluble and carrying it along;
* the cascading or chain effects brought about by water cyle continuity and linked to the integrity of the water cycle.

In a long term perspective attention has to be paid to creeping, unvisible changes linked to such water movement and quality transformations taking place in the landscape.

For example, attempts to increase agricultural and, generally, biomass production imply that relatively more water is consumed, i.e. returned back to atmosphere as evapotranspiration, and that a comparatively smaller fraction of the rainfall will reach groundwater aquifers and the river. Moreover, an increase in food and biomass production often requires irrigation, which means that water is withdrawn from water courses. Changes and intensification of land use also tend to reduce the infiltration capacity of the soil and reduce its water holding capacity. Together, these changes amplify the seasonal pattern of surface water flows, i.e. an increased risk of floods in connection with the rainy season and desiccation during the end of the dry season. It has been observed that agricultural droughts are becoming a serious problem even in cases where there is no meterological drought, i. e. crops suffer from deficits of soil moisture while there is abundant rainfall (7, 8). Desiccation of a river or desiccation of (part of) a landscape may thus occur even in cases where the annual flow is not reduced but where water partitioning parameters are altered.

Changes in land and water use are not only affecting hydrological parameters. Desired benefits in terms of production of food items and other goods are associated with environmental impacts which are often non-intended and not-anticipated, but which invariably are detrimental in some respect.

Water pollution and efforts to spur development

Water quality degradation is currently causing a critical reduction in the amount of water that can be safely used for for human consumption but also for agricultural and industrial purposes as stressed by Peters&Meybeck (9). Variations in water quality caused by natural processes must be compared with the cyclical and cascading effects of human activities in terms of their quantity and quality implications. It was stressed that it may take a very long time to remedy some of the undesirable effects from changes in land and water use. The quality of groundwater and surface water at any point in the landscape reflects the combined effect of many processes along the pathways. Degradation of water quality through land use activities and waste disposal in one part of the landscape has implications for downstream users in other parts of the area. The transport time through the soil is a crucial parameter for the movement and retention of various substances. A better understanding of the temporal dimension is important in order to pro-actively determine the susceptibility of the landscape to contaminant disposal. Key measures for slowing the rate of water quality degradation is a combination of policy development, education and research to increase and spread the general understanding, and development of appropriate laws.

A striking and discomforting feature is that the most serious pollution and the one that is increasing most rapidly emanates from efforts to spur development. Heavy metals, salts, persistent organic pollutants, for instance, are by-products and waste products from industry, agriculture and transport systems, which tend to multiply in connection with efforts to boost development. This kind of "development pollution" represents a new type of pollution in many places. Contrary to the bacteriological contamination which has been a typical feature of poverty and decay, and which is closely associated with human behaviour and activities in the household sphere, the "development pollution" consists to a large extent of non-degradable substances emitted from development activities. These substances accumulate in soil and biological material and are transported by wind and water over large distances (10).

Throughout the seminar, reference was made to the huge financial expenditure which is required to deal with the problems but also to the economic benefits that are at stake if nothing is done, but which could be reaped if proper steps are taken. The close association between much desired development activities that generate employment, export earnings and, generally, improvement in the standard of living, on the one hand, and the huge amounts of pollution which, so far, have been an integral component of human efforts to spur development, on the other, represents a serious dilemma. When GNP doubles, the pollution load may 5-fold. Western models of development have turned out to be disastrous in monsoon countries where the consequences of a given pollution load are amplified by the deficiency of dilution flow in the river during the dry season. Another striking feature is that the growth of urban and industrial complexes, which are nested with socio-economic change and development, has been very rapid.

The pace of urban growth and decay has been unprecedented. Few observers anticipated the speed of this change some 10-20 years ago. As we will see below, pollution is already extremely severe in cities in various countries. In India, for instance, there are even signs of social mobilization with groups of citizens marching up the river in search of the industry polluting their water source. Clean up plans exist but are not implemented due to multiple barriers: lack of legislation with adequate enforcement possibilities, corruption, lobbying and unholy linkages, and lack of appropriate administration and institutions. The heavy investments required to reduce pollution and to clean up the damage already incured, may be unmanageable for the individual polluting industry. That is, at least, invariably the argument. No doubt, the industries are one of the most significant culprits and they must take their share of responsibility. Required investments can, however, not be seen as ordinary running costs for the industry in question. Special loan schemes which make it possible to continue with the industry, while reducing pollution, may be motivated by the likely benefits for society at large; mitigation of poverty, creation of jobs, foreign exchange earnings, etc. Abating pollution by closing down factories might curb pollution but it is certainly a poor policy as far as poverty alleviation and socioeconomic progress is concerned.

Conflicts of interests, water rights and right to water

Intensified resource exploitation and increasing difficulties to satisfy aggregate demand easily lead to conflict of interests and challenges in terms of who should be given water on a priority basis and on what conditions. Conflicts may be excercerbated by the mismatch between political boundaries and river basins as emphasised by Vlachos (11). Water conflicts have three phases: conflict creation, conflict management and conflict resolution. Public participation and negotiations have become fundamental tools in cases where there have been disagreements regarding both the nature of the problem and the goals to be strived for. Strains tend to appear when idealized conceptions of citizens' participation collide with harsh demands or pragmatic considerations of public policy making. A government is wise in trying to reduce, in advance, points of frictions and stress. Especially in water stressed situations, water could "become a realistic and thoughtful instrument for balanced approach and a useful tool for managing long-standing competitions, confrontations, and outright conflicts about shared natural resources".

A better integration between water policy and citizen's participation should be seen in a wider context of the the legal and regulating system. Water law, as discussed by Wouters (12), serves the purpose to define "rules of the game", be a framework for conduct and be the basis for the evolution of a regime. Some of the unresolved issues concern how the legal and regulatory system can be operational with regard to both the supply side, how water pollution should be attended to and how incompatible claims for water can be dealt with.

With increasing competition for finite water resources it is relevant to elaborate on the principles which should guide the provision of water services. A vivid discussion centred on the notions of the "(human) right to water" versus "water rights". The difference between the concepts is more than one of semantics. One line of argument, in support of the first concept, was that access to a basic water requirement of good quality is a fundamental human right, implicitly and explicitly supported by international law, declarations and State practice. The issue of "human rights" to adequate amounts of water to satisfy basic human needs was highlighted by Gleick (13). He stressed that approximately half the population in the developing world at any one time is suffering from disease due to contaminated water or contaminated food. Access to a basic water requirement should therefore be seen as a fundamental human right, even more basic than some of the more explicit human rights.

There was a long disussion whether there already exists a human right to water or not. The notion primarily refers to the small amounts of water required to cater for the basic human need of water. Seen from an upstream/downstream perspective, the notion of human right to water seems to be more related to the protection of water quality than to water volume, since so limited amounts are required to cater for basic human requirement. It must, however, be of high quality. In comparison, the water needed to produce food for the population may be some 80 times larger.

Another line of argument was that it is crucial to properly define the water rights and to make them “visible“, cf Lundqvist (14). Mismanagement and inefficient use and ineffective access of water is often due to an unclear or biased jurisdiction over water, coupled with a tendency to take water (provision) for granted. It is important to develop a policy which clearly defines the rules and the roles vis-á-vis water management. An integral part of such a policy would be a consideration to weak segments of the population and to the environment. Water rights should, moreover, be linked to reciprocal responsibilities on the part of the water user. A policy which stimulates the thought that water provison is the responsibility solely of an authority or somebody else, is obviously counter to the idea that water must be made “everybody’s business“ (2). In the rights based approach increased pressure is primarily put on the State and other formal decision making units, whereas nothing is said about the role and obligations of the water user him- or herself.

Regional cases of upstream/downstream problematique

A river basin constitutes a mosaic of contrasting and competing biophysical, economic and social circumstances and community interests (15). Such contrasts represent formidable impediments to realizing the mutual dependence and commonality of interests required to achieve and maintain true hydrosolidarity across a river basin.

The regional cases presented at the Seminar illustrated the complexity of the upstream/downstream problematique, and the differences as regards the problem profile between different basins. It also showed that, as a consequence, the approaches to the challenges and conflicts of interest varied significantly.

<u>*River depletion and pollution may turn rivers into sewers*</u>
Pollution in *India* is generating a sizeable environmental damage (16). Since most of the pollutants from industry and other development activities are long-lived, the damage is not only temporary but contributes to a growing environmental debt. IBRD has estimated that about 45% of the environmental damage in India is derived from water of degraded quality. Similarly, it is estimated that some 70% of the length of the Yellow River is heavily polluted (1). In Sao Paulo, a very rapid economic growth and influx of population has created an enormous pressure on available water and other resources in a very small area in a very short period of time (17). Pollution of the Upper Tiete River in the metropolitan region of Sao Paulo is heavy and is now recognised as a common cause for conflicts, apart from the other consequences. Although much less dramatic, the downstream consequences of upstream activities were also illustrated from the Murray-Darling Basin in Australia (15). This basin displays the same set of challenges as mentioned above - the developments have led to a situation where the “riverine environment lacks aesthetic appeal“. Irrigation is a major water use which depletes the river and adds the problem of salinity to the water quality problematique. Since the mid 1960’s governments and communities in the lower basin have been increasingly

concerned about deteriorating water quality due to salinity (18). The River Murray Commission was therefore broadened in the 1980's and new legislation introduced (15).

As reported by Narain (16), several Indian water courses contain water, that is much too polluted to drink. The river Bhadar, for instance, flows though Jetpur, a town with a large dyeing industry. By the time it reaches Dhoraji, a town in Gujarat, the river does not contain any water worthy of use, but actually only untreated sewage and industrial effluents. The river has even turned crimson with chemicals. Since the late 1970's the city inhabitants have been protesting against the situation. After 14 years of litigation, they finally won the case in 1997. The Gujarat High Court ordered closure of polluting units upstream till effluent plants were installed. However, since the livelihood of 30 000 people employed in those industries was at stake the units were allowed to reopen. Similar stories were told for other rivers such as the Noyyal in Tamil Nadu, an ephemeral river carrying water only in the monsoon period. During the rest of the year it is, in practise, a sewer for the untreated sewage and industrial effluents from Coimbatore and Tirupur towns - the Manchester of India. In the case of Bhavani river, also in Tamil Nadu, vigilance of the people paid off in the sense that a court order effectively closed down the pulp and paper industry, which was allowed to start only when the court was satisfied that the factory had set up its effluent treatment systems.

The upstream/downstream disputes are difficult to solve. As formulated by Narain for the case of Yamuna river: "can Delhi ask Harayana farmers to reduce use of pesticides and fertilisers at the risk of reducing food production?" Also the conventional approach for waste and sewage management, built on the concepts of end-of-pipe treatment has serious limitations: the costs are very high; strong capable institutions are needed together with a culture that promotes transparency and accountability, as well as high order of discipline; regulation of pollution control is often weak; and the institutions needed for that purpose at the local level are also weak. Most important, though, is that end-of-pipe solutions does not remove the source of pollution. To do that, it is necessary to change production technologies which is complicated in terms of access to clean technologies, management and, particularly, since modern, clean technologies tend to be capital intensive but do not employ many workers.

Lack of attention to city water sources under threat

The vulnerable situtaion of many developing country cities under rapid expansion was illustrated by the dilemma of the capital of Honduras (22). So much efforts have had to go into maintaining and expanding the water supply infrastructure that the protection of the raw water recharge area has remained ignored. In many developing country cities, the key recharge area on which the water supply depends tends to be close enough to be damaged by urban expansion but far enough to remain largely unseen perceptually. The damage caused to the raw water source from land use change and additional pollution loads tends to occur in a gradual and delayed manner. Lack of attention to water source protection must be seen as a tremendous cause fo concern since it in fact threatens to undermine the sustainability of the city's water supply system. International pressures to privatize water services and improve water supply coverage may further contribute to the problems by curtailing protection efforts by the water company.

The silt trauma and pollution in Yellow river

In the Yellow river, a major and unique problem is constituted by the tremendous sediment load (1). An estimated 40% of the flow is required "just" to move sediment. Also water quality management is becoming a key factor in water management in highly water-stressed regions in N China. In Shanxi province in the middle reaches of the Yellow river, the mining industry has so polluted the river water that it is of no value for other uses. This contributes directly to water scarcity, i e scarcity of usable water. In the remediation process, a basin approach has to be taken so that the range of point and non-point source impacts within the basin are considered in order to arrive at an optimal pollution control strategy and minimum investment strategy. The water quality problem has in fact become a major issue in the failure to deliver water to the large city of Tianjin. 71 % of the river length of Yellow river is reported as highly polluted. The levels of pollution impose a financial burden on downstream communities for drinking water control as well as serious impacts on aquatic ecosystems, marine life and the commercial fishery.

In conclusion, a common denominator for all the river basin cases was the threats posed by the huge amounts of pollution loads in combination with reduced flow. In periods when water flow is reduced, or in stretches where the river is desiccated, the dilution effect is minimised. The consequences for human health, functioning of ecosystems and the options to use water for production purposes are serious. Obviously, the result in a desiccated river bed can only be that the river is turned into a sewer. A hydrocide is in the making or may already be observed.

Steps and procedures towards upstream/downstream hydrosolidarity

Addressing incompatible claims

The discussions confirmed the need to take the challenges associated with the goal of reaching upstream/downstream hydrosolidarity seriously. The concept itself needs to be scrutinized and properly defined, and mechanisms and procedures through which it can be approached, must be identified. During the seminar a number of examples were provided where apparently incompatible claims to the basin resources have been addressed.

River basin commissions for upstream/downstream stakeholder dialogue

What should be strived at is upstream/downstream partnerships, developed as a dialogue based on a "needs approach" rather than a "rights approach". Catchment commissions are needed but have to be of reasonable size to allow such a dialogue. Examples exist in Australia and Brazil. In India with its democratic traditions river parliaments have recently started to form (see below). In many countries, some kind of basin institution has been formed.

The status and power vested in the institution varies. In Australia, the Murray-Darling Ministerial Council, which originates from attempts made early during this century to coordinate development efforts and management tasks of the river Murray, was given full legal status only in 1985 (15). It is composed of the Ministers in the basin states of land, water and environment respectively. In 1991 the last state joined the Council. The Council is supported by a Basin Commission as its executive arm. Community participation is secured through a Community Advisory Committee composed of representatives of special interest groups. A community driven Natural Resources Management Strategy is seen as a cornerstone in the overall efforts of the Council.

In Sao Paulo, the dawn of the present attempt to involve all the actors in the basin in the preparation of an integrated water resources plan is more recent. It stems from the democratization process that started in 1983. Involvement of the public in the early phases of the planning and negotiation process is facilitated by an easy-to-use but multi-objective decision support system. This is needed to look for dominant alternatives so that trade-offs can be made in an optimal way.

The complexity and magnitude of the upstream/downstream challenges in the Yellow River and the political imperatives at the national level, makes it a rather special case. There is a Conservancy Commission which has existed for many years and which is the basis for planning in the Yellow River, providing focus for integrated basin management. The principal issue is the problem of regional development pressures and conflicting regional agendas.

Social mobilization

One key towards upstream/downstream hydrosolidarity is social mobilization, i e making water everybody's business. Investments in civil society institutions are important. As a logical consequence of growing pressure on finite and vulnerable water resources, the social resources of society become of increasing importance (19). Citizens have various roles to play. They must assume various management tasks but they are also needed as “watchdogs“ vis-a-vis State institutions and vis-a-vis industrial and commercial interests. To fulfill these roles, there is a need for basic research on water issues, and a proper “water literacy“ among the public.

From India, an interesting example of the formation of “*river parliaments*“, was given (20). The failure of the State management paradigm - which is the dominating paradigm today, but certainly not historically - has sparked off various attempts by the civil society to build institutions through which the challenges could be handled. State bureaucracy - which is said to have been invented by the British, but perfected by people in India - provides a weak institution; it lacks adequate financial and other resources, it is incompetent and it is corrupt. When environment governance is not seen as good enough, the civil society acquires an important role in fighting for a change. The river parliaments consist of upstream-downstream civil society institutions. The aim is to coordinate and bring together the users making it possible for them to understand each other's problems and jointly put a pressure onto the State.

Involving citizens, users of the land and investors

A strong and viable civil society can, however, not function in the void of access to basic research and understanding of the environmental and other consequences of pollution. There must also be partnerships and arenas for communication and dialogue. Formal institutions of State cannot be substituted by those of civil society. Both types of institutions are necessary. Water law has an important role to play as a promoter of collaborative action and should not only be assigned the role to resolve conflicts. Several speakers iterated that discipline and a responsible behaviour is an important pre-requisite in the attempts to reach upstream/downstream hydrosolidarity and a sound natural resources stewardship. Such discipline cannot be prescribed and dictated by law and regulation alone but could be the result of social change, improvements of "water literacy", sharing of management responsibilities etc.

In the Murray-Darling Basin, the Community Advisory Committee has been instrumental in the struggle against the rising water salinity in the lower river reaches (18). One of the first activities of its Natural Resources Management Strategy was to strike an equitable balance between the competing needs of river protection and land management. The strategy provides each state with a clear definition of its obligations and rights. The program of work involved the construction of groundwater interception works along the river to intercept highly saline water before it enters the river. This strategic land management program involves community groups developing comprehensive land and water management plans for their regions. In view of the limited number of salt disposal entitlements, every opportunity to reduce salt disposal to the river is explored. This has forced major improvements to irrigation practices and water use efficency. A strong feature is the cost-sharing approach taken with a major share of the implementation costs being provided by the community.

Equally relevant and encouraging is that investors might be made interested in pollution aversion by publicly asking them: will you allow your investment to pollute the river - our lifeblood? Very few investors would, of course, answer "yes" to such a query.

Decision support system to cope with complexity

As already touched upon, decision support systems will have to be developed. In terms of planning, multi-objective decision-support systems which allow the involvement of the public in an "anticipative planning", i e at an early stage of the planning process, is another important but logistically complicated approach. Principles for trade off are essential: on the one hand a maximizing of the socio-economic benefits for development without, on the other, compromising essential ecological services of terrestrial and aquatic ecosystems, essential for the life support system in the basin. Support is needed in terms of regulatory system, institutional cability, and legal and enforcement tools. A realistic time frame of several decades will have to be accepted for the necessary changes towards a reasonable upstream/downstream hydrosolidarity.

Institutional capacity to act

Capacity building is a key concept in connection with efforts to create and/or strengthen institutions for improved water resources management. "Capacity" implies an ability to act, to enforce, to implement policy, etc. Institutions and regulations which do not function are of no avail. Many countries have "wonderful laws and regulations" but they are not enforced. There should be some kind of "Regulatory Impact Assessment" with a report-back system to those who have initiated and supported the institution (21). Support to institutions that do not function as anticipated must be subject to scrutiny.

Final remarks

In the Seminar, experiences from different river basins were brought together and discussed in the light of recent conceptual development in terms of terrestrial and aquatic ecological services, hydrological response changes generated by land use conversions, including soil conservation programmes. Parallel with the natural science aspects, a constructive dialogue revolved around some of the most pertinent social aspects of management. The main conclusion drawn was that a truly interdisciplinary dialogue between various groups of stakeholders is needed in order to arrive at what may be seen as an efficient and equitable and reasonable sharing between upstream and downstream water-related interests. Proper attention has to be paid both to the special characteristics of rivers in monsoon climate, and to the consumptive water use of water in biomass production to avert the recurrence of a river desiccation, as witnessed in the Yellow river.

REFERENCES:

1. Ongley, E. 1999, The Yellow River: Managing the Unmanagable, In: *"Towards upstream/downstream hydrosolidarity",* Proceedings SIWI/IWRA Seminar

2. World Water Council,1999. (http://worldwatercouncil.org; Press release 29/11/99)

3. Falkenmark, M. 1999, Competing Freshwater and Ecological Services in the River Basin Perspective - An expanded conceptual framework, In: *"Towards upstream/downstream hydrosolidarity",* Proceedings SIWI/IWRA Seminar

4. Folke, C. & Gordon, L. 1999, Ecohydrological Landscape Management for Human Well-being, In: *"Towards upstream/downstream hydrosolidarity",* Proceedings SIWI/IWRA Seminar

5. Lundqvist, J. (ed.) 1999. "*A new dimension of water security"*. FAO Technical Report, in press

6. Rockström, J. (et al.) 1999, Linkages between water vapor flows, food production and terrestrial ecosystem services. "*Conservation Ecology"*

7. Lal R., H.H. and Dumanski, J. 1999, Desertification control to sequester C and mitigate the greenhouse effect. In: N.J. Rosenberg, R.C., Izaurralde, and E.L., Malone, (eds.), *Carbon sequestration in soils – Science, Monitoring, and Beyond*, Proceedings of the St. Michaels Workshop, December, 1998, Chapter 3, pp 83-130. Battelle Press, Columbus, USA

8. Rockström, J. & Falkenmark, M. 1999, Semi-arid crop production from a hydrological perspective: Gap between potential and actual yields, *Critical Reviews in Plant Science*, in press

9. Peters, N. & Meybeck, M. 1999, The linkage between freshwater availability and water quality degradation - Cyclical and cascading effects of human activities, In: *"Towards upstream/downstream hydrosolidarity",* Proceedings SIWI/IWRA Seminar

10. Lundqvist, J. 1999, High Withdrawal Ratio Implies a New Water Policy. Paper prepared for Annual Conference of European Geophysical Society, The Hague. "Physics and Chemistry of the Earth", (forthcoming), Part B, Vol. 25

11. Vlachos, E. 1999, Managing conflicts in upstream/downstream water related interests in river basins, In: *"Towards upstream/downstream hydrosolidarity",* Proceedings SIWI/IWRA Seminar

12. Wouters, P. 1999, The relevance and role of water law in the sustainable

development of freshwater - Replacing "Hydro-sovereignty" with "Hydro-solidarity" and horizontal solutions, In: *"Towards upstream/downstream hydrosolidarity",* Proceedings SIWI/IWRA Seminar

13. Gleick. P. 1999, The Human Right to Water, In: *"Towards upstream/downstream hydrosolidarity",* Proceedings SIWI/IWRA Seminar

14. Lundqvist, J. 1999. Rules and Roles in Water Policy and Management

15. Pigram, J. 1999, Towards upstream/downstream hydrosolidarity: Australia's Murray-Darling River Basin, In: *"Towards upstream/downstream hydrosolidarity",* Proceedings SIWI/IWRA Seminar

16. Narain, S. 1999, Stockholm Water Symposium Proceedings

17. Braga, B. 1999, The management of urban water conflicts in the metropolitan region of São Paulo, In: *"Towards upstream/downstream hydrosolidarity",* Proceedings SIWI/IWRA Seminar

18. Falkenmark, M. et al 1999, "*Water – A reflection of land use. Options for counteracting land and water mismanagemen"t*. Natural Science Research Council, Stockholm

19. Ohlsson, L. & Lundqvist, J. 1999. The Turning of a Screw – Social adaptation to water scarcity. In: *"New dimensions in water security",* Adapting to Growing Water Scarcity. FAO Technical Report

20. Agarwal, A. 1999, River parliaments for bringing togethr upstream and downstream users – Some Indian case studies, In: "Towards upstream/downstream hydrosolidarity", Proceedings SIWI/IWRA Seminar

21. Garduno, H. 1999, Water rights administration in developing countries: A prerequisite for satisfying water needs, In: *"Towards upstream/downstream hydrosolidarity",* Proceedings SIWI/IWRA Seminar

22. Lee, M. 1999, The implications of urban development for watersheds and water supplies in rapidly growing, developing world cities - The case of Tegucigalpa, capital of Honduras, In: *"Towards upstream/downstream hydrosolidarity",* Proceedings SIWI/IWRA Seminar