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Contents

List of Abbreviations and Acronyms

BMWP	Biological Monitoring Working Panel
CBM	Community Based Management
CU	Commercially Viable Water Supply and Sanitation Utilities
DRA	Demand Responsive Approach
DRWS	Directorate of Rural Water Supply
DWA	Department of Water Affairs
DWF	Dry Weather Flow
ESA	External Support Agencies
GDP	Gross Domestic Product
GMO	Government of Malawi
IBMC	Iishana Basin Management Committee
ILA	International Law Association
ILC	International Law Commission
IPCC	Intergovernmental Panel on Climate Change
IWRM	Integrated Water Resource Management
LWA	Local Water Association
LWC	Local Water Committee
MDG	Millennium Development Goal
NGO	Non-Governmental Organization
NWA	Nile Water Agreement (1929)
NWASCO	National Water Supply and Sanitation Council
O&M	Operation and Maintenance
WHO	World Health Organisation
WPA	Water Point Association
WPC	Water Point Committee
WSSCC	Water Supply and Sanitation Collaborative Council
WWAP	World Water Assessment Programme
WWDR	World Water Development Report

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Introduction

By now it has been clear that urgent action is needed if we are to avoid a global water crisis. Despite the vital importance of water to all aspects of human life, the sector has been plagued by a chronic lack of political support, poor governance and underinvestment. As a result, hundreds of millions of people around the world remain trapped in poverty and ill health and exposed to the risks of water-related disasters, environmental degradation and even political instability and conflict. Population growth, increasing consumption and climate change are among the factors that threaten to exacerbate these problems, with grave implications for human security and development (based on WWAP 2009a, p. vii). "Sub-Sahara Africa, in particular, remains mired in poverty. Its progress towards achieving the Millennium Development Goals lags behind that of other regions. The percentage of population living in absolute poverty is essentially the same as it was 25 years ago. About 340 million Africans lack access to safe drinking water, and almost 500 million lack access to adequate sanitation" (WWAP, 2009a, p. xii).

In order to provide recommendations, develop case studies, enhance assessment capacity at a national level and inform the decision-making process the World Water Assessment Programme, the flagship of UN-Water, housed in UNESCO, was founded in 2000 to monitor all aspects of freshwater issues. The volumes of WWAP: *Water for People* (2003), *Water – a Shared Responsibility* (2006) and *Water in a Changing World* (2009a) and *Case Study Volume* (2009b) provide an authoritative picture of the state of the world's freshwater resources and procure very valuable background information for this course.

The course Water Resource Management comprises 8 chapters: Chapter 1 (The global water crisis) sets the scene and states the challenges. The data given are not always congruent with other figures presented in the course because (1) they are only estimates and (2) they are often based on different literature sources. Chapter 1.3 deals with the impacts of global climate change on the water resources. A small climatology excursus is added for a better understanding of the process of global warming.

Chapter 2 (Science of water) deals with the general properties of water, its global distribution and its use. The path of water from groundwater to waste water and water treatment is shown mainly by an urban example. The problems of rural water supply in Africa are dealt with in chapter 4.2.

Chapter 3 (Water, governance and water policy issues) is divided into two major parts. 3.1 deals with water governance, and here the introductory statement is remarkable that the water crisis appears to be more a crisis of governance than a crisis of resources. So there is still hope to overcome it in the future. On the topic of water governance and water policy issues you will have to write an assignment.

In 3.1.13 the progress in global water related conferences is given. Main attention should be paid to the Dublin conference in 1992, because the four principles (freshwater, participation, women and economic value of water) are referred to several times in the text.

In chapter 3.2 (Hydropolitics) some case studies of water conflicts are presented. Before the Jordan-, Tigris and Euphrates- and Nile basins are dealt with in detail and for a better understanding of the problems, legal principles concerning the sovereignty of states over water resources are explicated in 3.2.1.

Chapter 4 (Water, sustainability and development) is also divided into two major parts, the first dealing more with the social environment and the second more with the natural environment. The case study 4.2.1 (Rural water supply in Malawi) is contrasted with the statements of the World Health Organisation (WHO) for optimisations of water supply and sanitation and their constraints, and 4.3 lays the focus on the role of gender in water and sanitation. You will have to write an assignment on this topic. In 4.4 the inadvertent impacts on hydrological processes are shown, and in 4.5 the environmental effects of large dams are exemplified by the case study of the Aswan high dam.

In chapter 5 (Methods and techniques for water management) some practical tools are presented. For planning purposes the most important one is the Integrated Water Resource Management (IWRM). This method is referred to in many places in the text. So, whenever there is need you might go to chapter 5.1 for clarification and/or further explanation. The biotic index presented in chapter 5.2.4 is mainly applied in Europe. You will have to find out what indexes are being used in your own country.

Chapter 6 (Water and economics) deals with the 'value' of water. You will be required to complete an assignment on the social, environmental, economic and cultural values of water.

Chapter 7 (Management for sustainability) puts the focus on rural drinking water supply. The various technical possibilities of water supply are described and some practical hints are given, and in chapter 7.2 the great importance of operation and management (O&M) is highlighted.

In chapter 8 (Case studies for Namibia and SADC) two examples of a successful application of Integrated Water Resource Management are presented. In Zambia, the application of IWRM, which is at the moment awaiting the necessary legal and institutional structure, will help combat poverty and malnutrition, while in the management of the Cuvelai Basin (Namibia) the introduction of an integrated approach is off to a good start.

For a better understanding the text is supported by a great number of plates.

When working with the text, it is advisable to have it printed out and view parallel the coloured plates on your computer screen. Some of them, where the legend is quite small, you may have to enlarge to 200%.

1 The global water crisis

“At the beginning of the twenty-first century, the Earth, with its diverse and abundant life forms, including over six billion humans, is facing a serious water crisis (Plate 1). All the signs suggest that it is getting worse and will continue to do so, unless corrective action is taken. This crisis is one of water governance, essentially caused by the ways in which we mismanage water. But the real tragedy is the effect it has on the everyday lives of poor people, who are blighted by the burden of water-related disease, living in degraded and often dangerous environments, struggling to get an education for their children and to earn a living, and to get enough to eat.

The crisis is experienced also by the natural environment, which is groaning under the mountain of wastes dumped onto it daily, and from overuse and misuse, with seemingly little care for the future consequences and future generations. In truth it is attitude and behaviour problems that lie at the heart of the crisis. We know most (but not all) of what the problems are and a good deal about where they are. We have knowledge and expertise to begin to tackle them. We have developed excellent concepts, such as equity and sustainability. Yet inertia at leadership level, and a world population not fully aware of the scale of the problem (and in many cases not sufficiently empowered to do much about it) means we fail to take the needed timely corrective actions and put the concepts to work.

For humanity, the poverty of a large percentage of the world's population is both a symptom and a cause of the water crisis. Giving the poor better access to better managed water can make a big contribution to poverty eradication. Such better management will enable us to deal with the growing per capita scarcity of water in many parts of the developing world (Plate 2).

Solving the water crisis in its many aspects is but one of the several challenges facing human kind as we confront life in this third millennium and it has to be seen in that context. We have to fit the water crisis into an overall scenario of problem-solving and conflict resolution. As pointed out by the Commission for Sustainable Development in 2002: Poverty eradication, changing unsustainable patterns of production and consumption and protecting and managing the natural resource base of economic and social development are overarching objectives of, and essential requirements for, sustainable development. Yet of all the social and natural resource crises we humans face, the water crisis is the one that lies at the heart of our survival and that of our planet Earth" (http://unesdoc.unesco.org/images/0012/001295/129556e.pdf, p. 4).

We know the problem: It is one of sustainable management. Thus, in the beginning of the twenty-first century there are three main issues concerning water: (1) the provision of sufficient water for a growing and increasingly demanding population; (2) the impact of water development, and of other developments involving hydrological effects, on the environment; and (3) anticipated problems with climatic change and the unreliability of water resources.

So the general targets set by the Water Supply and Sanitation Collaborative Council (WSSCC) for the improvement of human life are:

- To reduce by 2015 the proportion of people without sustainable access to adequate quantities of affordable and safe water by one-half
- To reduce by 2015 the proportion of people without access to hygienic sanitation facilities by one-half
- To provide water, sanitation and hygiene for all by 2025.

1.1 The global water crisis in figures

(based on Water Partners International. *Water facts*) http://water.org/water-crisis/water-facts/water/

The table below enumerates some estimates of the consequences of the global water crisis. The figures given are sometimes different from other figures presented in this paper, due to different literature source.

Health

- 3.575 million people die each year from water-related disease.
- 43% of water-related deaths are due to diarrhoea.

- 84% of water-related deaths are in children ages 0–14.
- 98% of water-related deaths occur in the developing world.
- 884 million people, lack access to safe water supplies, approximately one in eight people.
- The water and sanitation crisis claims more lives through disease than any war claims through guns.
- At any given time, half of the world's hospital beds are occupied by patients suffering from a water-related disease.
- Less than 1% of the world's fresh water (or about 0.007% of all water on earth) is readily accessible for direct human use.
- An American taking a five-minute shower uses more water than the typical person living in a developing country slum uses in a whole day.
- About a third of people without access to an improved water source live on less than US $1 a day. More than two thirds of people without an improved water source live on less than US $2 a day.
- Poor people living in the slums often pay 5–10 times more per litre of water than wealthy people living in the same city.
- Without food a person can live for weeks, but without water you can expect to live only a few days.
- The daily requirement for sanitation, bathing, and cooking needs, as well as for assuring survival, is about 50 litres per person.
- Water projects in developing countries fail at an average rate of 50% or higher.

Sanitation

- Only 62% of the world's population has access to improved sanitation – defined as a sanitation facility that ensures hygienic separation of human excreta from human contact.
- 2.5 billion people lack access to improved sanitation, including 1.2 billion people who have no facilities at all.
- The majority of the illness in the world is caused by faecal matter.
- Lack of sanitation is the world's biggest cause of infection.
- At any one time, more than half of the poor in the developing world are ill from causes related to hygiene, sanitation and water supply.
- 88% of cases of diarrhoea worldwide are attributable to unsafe water, inadequate sanitation or insufficient hygiene.
- Of the 60 million people added to the world's towns and cities every year, most occupy impoverished slums and shanty-towns with no sanitation facilities.

- It is estimated that improved sanitation facilities could reduce diarrhoea-related deaths in young children by more than one-third. If hygiene promotion is added, such as teaching proper hand washing, deaths could be reduced by two thirds. It would also help accelerate economic and social development in countries where sanitation is a major cause of lost work and school days because of illness.

Impact on Children

- Every 15 seconds a child dies from a water-related disease.
- Children in poor environments often carry 1.000 parasitic worms in their bodies at any time.
- 1.4 million children die as a result of diarrhoea each year.
- 90% of all deaths caused by diarrheal diseases are children under 5 years of age, mostly in developing countries.

Impacts on Women

- Millions of women and children spend several hours a day collecting water from distant, often polluted sources.

- A study by the International Water and Sanitation Centre (IRC) of community water and sanitation projects in 88 communities found that projects designed and run with the full participation of women are more sustainable and effective than those that do not. This supports an earlier World Bank study that found that women's participation was strongly associated with water and sanitation project effectiveness.
- Evidence shows that women are responsible for half of the world's food production (as opposed to cash crops) and in most developing countries, rural women produce between 60–80% of the food. Women also have an important role in establishing sustainable use of resources in small-scale fishing communities, and their knowledge is valuable for managing and protecting watersheds and wetlands.

Impacts on Productivity

- On average, every US dollar invested in water and sanitation provides an economic return of eight US dollars.
- An investment of US $11.3 billion per year is needed to meet the drinking water and sanitation target of the Millennium Development Goals, yielding a total payback for US $84 billion a year.

Other estimated economic benefits of investing in drinking-water and sanitation.

- 272 million school attendance days a year.
- 1.5 billion healthy days for children under five years of age.
- Values of deaths averted, based on discounted future earnings, amounting to US $3.6 billion a year.
- Health-care savings of US $7 billion a year for health agencies and US $340 million for individuals.

1.2 Increased global water stress

By the year 2025 more than 2.8 billion people in 48 countries will face water stress. Of these countries, 40 are in West Asia, North Africa or sub-Saharan Africa (Plate 3). Over the next two decades, population increases and growing demands are projected to push all the West Asian countries into water scarcity conditions. By 2050, the number of countries facing water stress or scarcity could rise to 54, with a combined population of four billion people – about 40% of the projected global population of 9.4 billion.

Many African countries, with a population of nearly 200 million people, are facing serious water shortages. By the year 2025, it is estimated that nearly 230 million Africans will be facing water scarcity, and 460 million will live in water-stressed countries.

Today, 31 countries, accounting for less than 8% of the world's population, face chronic freshwater shortages. Among the countries likely to run short of water in the next 25 years are Ethiopia, India, Kenya, Nigeria and Peru. Parts of other large countries (e.g. China) already face chronic water problems.

Bahrain, Kuwait, Saudi Arabia and the United Arab Emirates have resorted to the desalinization of seawater from the Gulf. Bahrain has virtually no freshwater, while three-quarters of Saudi Arabia's freshwater comes from fossil groundwater, which is reportedly being depleted at an average rate of 5.2 km^3 per year (http://maps.grida.no/go/graphic/increased-global-water-stress).

1.3 Global climate change

Water resource managers, who are struggling with present problems, will face even greater challenges when the global climate is changing. If greenhouse gas concentrations keep rising, climatic changes are likely to result. Those changes will potentially have wide-ranging effects on the environment and socio-economic and related sectors such as health, agriculture, forests, water resources, coastal areas and biodiversity (Plate 4).

Fundamentally the greenhouse effect is a beneficial process. It is foremost dependant on the water vapour in the atmosphere causing the global average mean annual temperature to be 14^0C, thus enabling life on earth.

Two third of the solar radiation (short wave) passes through the atmosphere and warms the surface of the earth (Plate 5). The warm surface now emits energy in the form of infrared radiation (long wave) back to the atmosphere. A part of this outgoing radiation is absorbed by the atmosphere (water vapour and greenhouse gases) and re-emitted to the earth's surface. The direct effect is the warming up of the surface and the troposphere.

Due to the increasing concentration of greenhouse gases, especially carbon dioxide (CO_2), this natural greenhouse effect is aggravated and leads to rising temperatures. This effect will have widespread consequences on nearly every sector of human life (Plate 6).

Analysis tells us that a difference of a few degrees in annual average temperature of the earth can lead to massive impacts on glacier extension, sea level, precipitation regimes and distribution, and patterns of biodiversity, and sea level. Some consequences of the rise of sea level also affect Africa at the Nile Delta (Plate 7).

“The different assessments carried out by the Intergovernmental Panel on Climate Change (IPCC) have shown with increasing evidence that the emissions of greenhouse gases released in the atmosphere since the nineteenth century – which will continue for the coming decades, even if the rate is reduced or stabilized – will lead to a ‘global warming’ of the earth over the period 1990–2100, with an expected increase of the average annual temperature in the range of 1.4 ^{0}C to 5.8^{0}C. The projected rate of warming is very likely to be without precedent during at least the last 10.000 years. Among the associated effects are rises in the ocean level (in the range of 0.09 to 0.88 meters for the same period) and, as a consequence of the availability of more energy in the climate system, an intensification of the global hydrological cycle. In some areas, this will lead to changes in the total amount of precipitation, in its seasonal distribution pattern and in its frequency and intensity. Plate 8 shows that in the context of changing pattern of rainfall the decrease of run-off water may put large areas of arable land at risk. Some of the richest arable regions (Europe, United States, parts of Brazil and South Africa) are threatened with a significant reduction of run-off water, resulting in a lack of water for rain-fed agriculture and thus putting millions at risks. Together with changes in vapour-transpiration, these new conditions may directly affect the magnitude and timing of runoff, the intensity of floods and droughts and have significant impacts on regional water resources, affecting both surface water and groundwater supply for domestic and industrial uses, irrigation, hydropower generation, navigation, in-stream ecosystems and water-based recreation. Plate 9 shows some of the projected impacts of climate change.

Hydrological sciences have underscored 'non-linearity' and 'threshold effects' in hydrological processes, which means that the terrestrial component of the hydrological cycle amplifies climate inputs. The regional drought that struck the African Sahel during the 1970s and the 1980s provides illustration of these concepts: while the decrease in precipitation over this region during the two mentioned decades was in the magnitude of 25% compared to the 1950–69 period, the major rivers flowing through the region have experienced reductions in annual flows of a magnitude of 50%, in others words, what can be considered as a minor change in the total or in the temporal pattern of precipitation may nevertheless have tangible effects on water resources.

As a consequence of sea level rise, a calculable effect on water tables is that the interface between freshwater and brackish water will move inland. This may have significant impacts on the development and the life of people in coastal regions and on small islands.

Most numerical simulations have shown that an intensification of the hydrological cycle will not simply result in a smooth drift towards new conditions, but will most probably be associated with an increased variability of rainfall patterns at different time scales (inter annual, seasonal, individual storm event). Thus, climate change will have to be taken into account in managing the temporal variability of water resources, and in managing the risks of water related disasters (floods and droughts).

For water resource managers, the impacts of climate are still considered as minor compared to the problems they are facing with the present climate variability. However, as it is likely that the variability may increase due to climate change, the impacts of the latter might become a real concern for water managers. In fact, coping with present-day climate variability while applying principles of Integrated Water Resources Management (IWRM) that take due account of risk, is certainly the most sound option for coping with climate change in the future" (WWAP, 2003, p. 76).

"The incidence of drought in Africa may have been on the increase in recent decades and there are many Third World countries whose economies will be highly sensitive to climatic shifts predicted for the near future. But ironically parts of the Developed World may have to adapt more under global warming. Resources are likely to change most in some mid-latitude regions as subtropical high-pressure belts shift northwards and many of the sophisticated water supply systems in these regions are attuned to exploit *current* resources to the full.

Predictions of rainfall patterns from different General Circulation Models do not show the same degree of convergence as predicted temperatures, and can vary widely at regional scales. Vapour-transpiration losses, soil moisture and runoff are even more difficult to predict at present.

Recent reviews of General Circulation Models output suggest a 4–12% increase in precipitation and evaporation globally associated with double $C0^2$, but the distribution is likely to be uneven. Reduced runoff and soil moisture could affect many agricultural areas in the northern hemisphere. Of particular concern were early American predictions of reduced rainfall in two of the three major world 'breadbaskets', the American Great Plains Prairies and the Ukraine. Only India and Southeast Asia might benefit, with a more reliable monsoon season. Increased rainfall in some desert areas will be of little practical value. Large increases in precipitation of up to 40% north of 50° N and south of 40° S, predicted by most recent models, could benefit water resources in northwest Europe and the margins of the polar ice sheets.

There is evidence that polar ice has already increased by circa 40.000 km^3 this century. Some researchers calculate that accumulation in Antarctica could reduce sea level *rise* by up to 200 mm. However, the polar high-pressure belt is likely to block the intrusion of snow-laden depressions far into the continental interior and so limit accumulation to the continental margins. At slightly lower latitudes, milder winters would reduce snowfall amounts and snowmelt would come earlier, decreasing melt water flooding and reducing soil moisture levels during the growing season.

Initial attempts have been made recently to put a monetary value on the effects on water resources. One researcher estimated the global "welfare loss in the water sector" at nearly US $47 billion, of which the USA and the EU each accounts for about US $14 billion. These estimates cover only the cost of lost water. However, another one also looked at the costs of increased water pollution in the USA and estimated these alone to amount to US $33 billion under a 4^0C warming" (Jones, 1997, pp. 336–337).

Some predictions for Africa

Africa is made highly vulnerable to environmental changes, and climate change is likely to increase this vulnerability. Plate 10 shows which of the regions of Africa (North Africa, West Africa, Central Africa, East Africa, Southern Africa and the Western Indian Ocean Islands) are most vulnerable to specific impacts of climate change. These impacts include desertification, sea level rise, reduced freshwater availability, cyclones, coastal erosion, deforestation, loss of forest quality, woodland degradation, coral bleaching, the spread of malaria and impacts on food security.

Water resources are inextricably linked with climate, so the prospect of global climate change has serious implications for water resources and regional development. Plate 11 shows the water availability per capita in cubic metres for selected countries in Africa in 1990, with projected data for 2025, whereas Plate 12 shows which African countries will be affected by water stress and water scarcity in the future.

For food production water is essential equally or even more important than nutrients. So its increasing scarcity will have major impacts on farmer productivity. For poor countries with rapid population growth and depletion of groundwater, water-deficit induced food insecurity will be a growing problem. Plate 13 shows that a severe decrease in cereal production will occur in the fringes of the great deserts.

With our climate changing, we have to adapt our ways to a new environment – in most cases warmer and possibly wetter or drier. Projections on the climate in the future provide some guidance for us, but how can we create models for how the human society reacts? Plate 14 presents a rough idea of changes in agricultural output from increased temperatures, precipitation differences and also from carbon fertilization for plants. It can be seen that most African countries will have a decrease of agricultural productivity between 15 and 50%.

Projecting climate is one thing, but agriculture adds multiple more dimensions of complexity – extreme events, crop rotations, crop selection, breeds, irrigation, erosion, soils and much more.

Useful links

on climate change:
http://www.ipcc.ch/
on global water crisis:
http://america.aljazeera.com/opinions/2014/4/water-managementprivatizationworldbankgroupifc.html
on financing global water crisis:
http://america.aljazeera.com/opinions/2014/4/water-managementprivatizationworldbankgroupifc.html
on health:
http://www.who.int/water_sanitation_health/diseases/diseasefact/en/index.html

1.4 Tasks:

- Define the terms: water scarcity, water stress and water vulnerability. Give reasons why the figures are given in per capita per year and what the figures comprise.
- In plate 11 (Water availability in Africa) Namibia is missing. Find out from the internet the ranking of Namibia.
- Describe the impact of climate change for the global food security.
- Compile a list of water and sanitation related diseases and their impacts.
- Make a rough estimate of economic benefits in US $ when investing in water and sanitation.
- Find out from the internet how much money was globally spent on water and sanitation for developing countries in 2008.

2 Science of Water

Before dealing with the management of water resources the properties of water and its supply systems will be dealt with. The text is mainly based on Wright (2003, pp. 279–301).

2.1 General physical and chemical properties of water

The molecule water (H_2O) is an excellent solvent for many ionic compounds. Since water is a very mobile liquid, it makes for instance salt readily available and will deliver wanted and unwanted materials to plants, animals, buildings etc.

Water has the high specific heat capacity of 4.18 J $C^{-1}g^{-1}$. That means that 4.18 J are needed to raise the temperature of 1 g of water for 1 ^{0}C. So the air temperature in the vicinity of big water bodies (lakes or oceans) is only slowly rising in spring and decreasing in autumn[1]. It can also act as an excellent cooling in industry and elsewhere. Its standard enthalpy change of vaporization (water to vapour) is 2.260 kJ kg^{-1}. Therefore the rate of vaporization is not very fast. The standard enthalpy change upon freezing (water to ice), or standard enthalpy change of fusion (ice to water) is 333 kJ kg^{-1}. This helps to protect living organisms from the effects of freezing or melting as a consequence of weather condition.

Water has a maximum density of 1 g cm^{-3} at the temperature of 4 ^{0}C, whereas solid ice has a density of 0.9 g cm^{-3}. This is why ice floats on water. Once a layer of ice forms on the surface of water, because of low thermal conductivity it acts as an insulating layer protecting the lower layers from freezing.

In standing water bodies we find stratification. When the sun heats a water body the surface is warmed first, expands and therefore becomes less dense. This warmer layer is called epilimnion. It is rich in oxygen because it is next to the atmosphere. The lower and cooler layer is called hypolimnion and is poor of oxygen. When organisms die and sink to the bottom they begin to rot. Rotting involves oxidation. So this dead matter removes oxygen from the water, depleting it further. Only anaerobic organisms and methanorgenic and sulphate-reducing bacteria tend to live at the bottom. As decay continues, nutrients build up in the bottom of the water body.

Between the warmer epilimnion and the cooler hypolimnion there is a small layer called thermocline, where rapid temperature change occurs. The degree of mixing between these layers of differing temperatures is very poor.

In the cooler month of autumn the epilimnion cools and the density of water rises. It sinks and more mixing with lower waters takes place. Stratification disappears which is called overturn. As layers mix, chemicals are distributed through the water body so that the upper layers become richer in nutrients. These results in more biological activity and burst of growth of algae, the phytoplankton bloom, can occur. A similar situation occurs during the spring month.

2.1.1 Properties of natural waters

The natural state of water (streams, rivers, lakes and underground water) is never pure, because water has the ability to dissolve a wide range of materials (chapter 2.1.5) so that it contains a variety of soluble inorganic and organic compounds. Additionally water can carry large amounts of insoluble materials that are held in suspension, whose amounts and types vary from place to place. These impurities determine the characteristics of a water body. Depending on their size and the rate of flow suspended solids in a moving water body (rivers) will settle out at various points or be carried for longer distances. After heavy rains the amount of suspended matter will be very high. It is measured in g m^{-3} and the more there is the cloudier or more turbid is the water.

In a flowing water body the degree of mixing is very high. So it will not only be saturated with oxygen but also carry well-mixed nutrients. Small rapidly flowing rivers will nearly always be saturated with oxygen while sluggish rivers may contain spots with oxygen contents well below saturation level. How much oxygen is dissolved is dependent on the temperature of the water. The warmer it is, the less oxygen it can contain.

2.1.2 Water and living organisms

If dissolved or suspended organic matter is present, living organisms can exist. The organic matter can be utilized by them if it is biodegradable (can be decomposed into simpler inorganic substances by micro-organisms). Plants and algae in a water body will initiate food chains and food webs. There should be equilibrium between the amount of living matter produced and the amount of dead decomposing organic matter produced. If this is disturbed then the water body can become either choked with living organisms or devoid of them. The stability of the equilibrium depends upon the range of living organisms present and the ways in which the food chains and webs are interlinked. A cycle of nutrient movement through the water will be established, which exists in a quite delicate and easily disturbed ecological balance.

Beside nutrients a supply of oxygen is needed to maintain aquatic life. It is needed for the respiration of all animals and plants and for the biodegradation of organic matter by aerobic bacteria. The dissolved oxygen comes from two sources: the atmosphere and the photosynthesis of plants. For example, at a temperature of 10 ^{0}C and a pressure of 1 atmosphere a maximum of 11.28 g will dissolve in 1 m^3 of pure water. This maximum is termed saturation concentration. The dissolution of atmospheric oxygen and that generated by photosynthesis replaces any oxygen used up by aerobic processes by living organisms. The minimum amount of oxygen that is required to sustain a variety of organisms is 5 g m^{-3}. Thus at 10 ^{0}C there is only a difference of 6 g m^{-3} before there is a threat to life.

The more hours of daylight (photosynthesis) the higher is the concentration of oxygen. So there is more oxygen in the water at midday than at midnight and more in summer than in winter.

Different aquatic organisms have different abilities to withstand temperature variations. If the temperature of a water body increases, the amount of oxygen will decrease. Additionally increases a higher temperature the metabolism of organisms. So the oxygen demand goes up at the same time as the availability of oxygen goes down. Coarse fish such as perch or roach can live in water with temperatures of up to 30 ^{0}C and oxygen levels of only 3 g m^{-3}. On the other hand game fish like salmon or trout die if the oxygen level falls below 5 g m^{-3} or the temperature moves outside the fairly narrow range of 5–20 ^{0}C.

2.1.3 Acidity and alkalinity

The pH value of (impure) water is a measure of its acidity. Simply speaking the pH is the negative log of the H^+ ion concentration, $[H^+]$ (pH = – log $[H^+]$). In pure water, about one in ten million molecules dissociate into hydronium ions (H_3O^+) and hydroxide ions (OH^-), according to the following equation:

$$2\,H_2O(l) \rightarrow H_3O^+(aq) + OH^-(aq)$$

Because the negative log of $[H^+]$ is used in the pH scale, the pH scale usually has positive values. Thus, the larger the pH, the smaller is the number of $[H^+]$.

Alkalinity is a measure of the ability of a solution to neutralize acids to the equivalence points of carbonates or bicarbonates. A base accepts (removes) hydronium ions (H_3O^+) from the solution, or donates hydroxide ions (OH^-) to the solution. Both actions will lower the concentration of hydronium ions, and thus raise pH. By contrast, an acid donates H_3O^+ ions to the solution or accepts OH^-, thus lowering pH. Pure water has a pH of 7. (This value is correct at 23 ^{0}C and slightly different at other temperatures.)

In water acids and bases are dissolved into ions. Mineral acids such as hydrochloric (HCl), sulphuric (H_2SO_4) and nitric acid (HNO_3) produce high concentrations of hydronium ions in aqueous solutions and are therefore strong acids. The bases sodium hydroxide (NaOH) and potassium hydroxide (KOH) give large numbers of hydroxyl ions in solution and are therefore strong bases. Many acids and bases found in nature are weak acids and bases. Such compounds give low numbers of ions.

2.1.4 Hard and soft water

In hard water Ca^{2+} and Mg^{2+} ions are dissolved. The source of these ions is the erosion of carbonate rocks containing carbon dioxide (Limestone ($CaCO_3$) is more readily attacked than dolomite ($CaCO_3$ * $MgCO_3$). The larger the concentration of these two ions, the harder is the water.

The consequences of the usage of hard water are manifold. Boling of hard water will precipitate the calcium and magnesium carbonates. Thus furring in kettles and boilers (reduced heat conductivity) may occur and in pipes the process may lead eventually to blockages. With hard water it is difficult to produce a good lather with soap, because magnesium and calcium ions form an insoluble slid with the hydrocarbon chain of the soap molecules. A grey-white scum is often seen to collect on the surface of water, which is deposited around the inside surfaces of baths and sinks, and is left on the fibres of washed fabrics. Hardness is also an important factor in the taste of water. Upon a concentration of more than 500 mg dm^{-3} $CaCO_3$ equivalent water starts to taste unpleasant. On the other hand hard water helps to develop strong teeth and bones, and the incidence of heart disease is lower. It can also protect against lead entering solution in lead pipes by coating the inside of pipes with insoluble lead carbonate or sulphate. In order to prevent lead entering drinking water, it has been necessary to increase the hardness of water by, for example, adding lime.

2.1.5 Hydrolysis

Water has the ability to break down even very hard igneous rocks like granite. By the chemical weathering process of hydrolysis the silicate minerals are destroyed. In such reactions, pure water ionizes slightly and reacts with silicate minerals. An example reaction:

$$Mg_2SiO_4 + 4\ H^+ + 4\ OH^- \rightleftharpoons 2\ Mg^{2+} + 4\ OH^- + H_4SiO_4$$

olivine (forsterite) + four ionized water molecules ⇌ ions in solution + silicic acid in solution

This reaction results in complete dissolution of the original mineral, assuming enough water is available to drive the reaction. However, the above reaction is to a degree deceptive because pure water rarely acts as a H^+ donor. Carbon dioxide, though, dissolves readily in water forming a weak acid and H^+ donor.

$$Mg_2SiO_4 + 4\ CO_2 + 4\ H_2O \rightleftharpoons 2\ Mg^{2+} + 4\ HCO_3^- + H_4SiO_4$$

olivine (forsterite) + carbon dioxide + water ⇌ Magnesium and bicarbonate ions in solution + silicic acid in solution. This hydrolysis reaction is much more common. Carbonic acid is consumed by silicate weathering, resulting in more alkaline solutions because of the bicarbonate. This is an important reaction in controlling the amount of CO_2 in the atmosphere and can affect climate.

Aluminosilicates when subjected to the hydrolysis reaction produce a secondary mineral rather than simply releasing cations.

$$2\ KAlSi_3O_8 + 2\ H_2CO_3 + 9\ H_2O \rightleftharpoons Al_2Si_2O_5(OH)_4 + 4\ H_4SiO_4 + 2\ K^+ + 2\ HCO_3^-$$

Orthoclase (aluminosilicate feldspar) + carbonic acid + water ⇌ Kaolinite (a clay mineral) + silicic acid in solution + potassium and bicarbonate ions in solution.

(http://en.wikipedia.org/wiki/Weathering#Hydrolysis)

2.2 Global water

"The overwhelming bulk of water on earth can be used neither by man nor by the majority of terrestrial plants and animals, because it is either too salty or frozen. Even so, the remainder is no mean quantity and it does have the advantage that it is naturally recycled, so that although it is *finite* in quantity it is ultimately *unlimited* in supply. Practical limits to both the quantity and quality are nevertheless imposed by *recycling times* (Plate 15).

The need for conservation and the careful control of exploitation is now almost universally acknowledged. This recognition owes much to fears that resources in general may be running out, to the rise of the environmental movement and to practical experience over recent decades, particularly with catastrophes and failures, both man-made and natural" (Jones, 1997, p. 2).

The total volume of water on the globe amounts to 1.338.000 km^3, but 96.5% of it is saltwater in the oceans and thus unfit for human use. Only 3.5% is freshwater, but the bulk of it is bound in ice, permafrost and snow cover so that in the end only 2.53% can be used by man (Plate 16).

The water cycle consists of precipitation, vapour transport, evaporation, and evapotranspiration from vegetation, infiltration, groundwater flow and runoff. Plate 15 explains the global water cycle, illustrating how nearly 577.000 km^3 of water circulates through the cycle each year. The world's surface water is affected by varying levels of precipitation, evaporation and runoff, in different regions. Water is transported in various forms within the hydrologic cycle. Hydrologists estimate that each year about 502.800 km^3 of water evaporates over the oceans and seas, 90% of which (458.000 km^3) returns directly to the oceans through precipitation, while the remainder (44.800 km^3) falls over land. With vapour-transpiration and evaporation from land and lakes totalling about 74.200 km^3, the total volume in the *terrestrial* hydrologic cycle is about 119.000 km^3. Around 35% of this, or 44.800 km^3, is returned to the oceans as run-off from rivers, groundwater and glaciers. A considerable portion of river flow and groundwater percolation never reaches the ocean, having evaporated in internal runoff areas or inland basins which lack outlets to the ocean. However, some groundwater that bypasses the river systems reaches the oceans. Annually the global hydrologic cycle circulates nearly 577.000 km^3 of water.

The table of estimated residence times shows the approximate times that water resources exist as biospheric water; atmospheric water; river channels; swamps; lakes and reservoirs; soil moisture; ice caps and glaciers; oceans and seas, and groundwater. The estimated residence times range from one week to 10.000 years.

"The water cycle is based on a continuous movement between the surface and the atmosphere because water evaporates from land surfaces and water bodies and transpires also from living plant cells. The water vapour produced is circulated through the atmosphere and falls down eventually as rain or snow. They are thus the source of all drinkable (potable) water. The precipitation can either run off the land into rivers and streams (run-off at heavy storms) or infiltrate into the soil, depending on its porosity and permeability. Under the influence of gravity it will move downwards through porous rock strata, until it reaches an impenetrable layer. Above this it collects and becomes groundwater. Its surface is called water table, which will rise or fall according to the prevailing weather. Since groundwater can spend a lot of time in contact with subterranean rocks it can contain a lot of dissolved material" (Wright, 2003, p. 279).

2.3 Freshwater use

"Our primary source of water is run-off diverted by humans for use in irrigated agriculture, in industry and in homes; for consumption of various kinds; and for waste disposal. It is the water of evapotranspiration that mainly supports forests, rain fed cultivated and grazing land, and a variety of ecosystems. Despite a withdrawal of only 8% of total annual renewable freshwater resources, it has been estimated that 26% of annual evapotranspiration and 54% of accessible runoff is now appropriated by humans. As the per capita use increases due to changes in lifestyle (leisure and domestic practices) and as population increases, the proportion of appropriated water is increasing. This, coupled with spatial and temporal variations in water ability, means that the water to produce food for human consumption, industrial processes and all the other uses is becoming scarce" (WWAP, 2003, p. 10).

The ever rising human demand for water is due to four fundamental pressures: the growing population and urbanization, the demands for greater production from agriculture and industry, and wasteful practices.

The global water usage can be divided into three sectors: agriculture (about 67%), industry (about 20%) and domestic (13%).

The agricultural sector is by far the biggest user of freshwater (Plate 17). Analysis indicates that in the United States agriculture accounts for some 49% of total freshwater use, with 80% of this volume being used for irrigation, whereas in Africa and Asia, an estimated 85–90% of all freshwater is used for agriculture (Plate 18).

According to estimates at the beginning of the 2000s, agriculture accounted for 67% of the world's total freshwater withdrawal, and 86% of its consumption. Plate 19 and 20 show some estimates of how much water is needed to produce a range of agrarian products. It shows for instance that for the production of 1 kg of wheat 900–2.000 litres of water (depending on climate and agricultural practices) are needed. This has led Professor J.A. Allan from King's College London and the School of Oriental and African Studies to develop the concept of virtual water, which measures how much water is embedded in the production of food and consumer goods. For his contributions he was awarded the 2008 Stockholm Water Prize. In his awarding, the Stockholm International Water Institute (SIWI) stated that "Virtual water has major impacts on global trade policy and research, especially in water-scarce regions, and has redefined discourse in water policy and management. By explaining how and why nations such as the US, Argentina and Brazil 'export' billions of litres of water each year, while others like Japan, Egypt and Italy 'import' billions, the virtual water concept has opened the door to more productive water use." In semi-arid and arid areas, knowing the virtual water value of a good or service can be useful towards determining how best to use the scarce water available."

(http://en.wikipedia.org/wiki/Virtual_water)

By 2025, agriculture is expected to increase its water requirements by 1.3 times, industry by 1.5 times, and domestic consumption by 1.8 times (Plate 21). By the year 2000, an estimated 15% of the world's cultivated lands had been irrigated for food crops, accounting for almost half the value of global crop production.

The world's irrigation areas totalled approximately 253 million hectares in 1995. By 2010, they are expected to reach about 290 million hectares, and by 2025 about 330 million hectares. This development will lead to an increased water demand to meet the hunger target by 2015 and to eradicate poverty by 2030 and 2050 respectively (Plate 22).

In the industrial sector, which accounts for about 20% of global freshwater withdrawals, the biggest share of freshwater is stored in reservoirs and dams for electrical power generation and irrigation. However, the volume of water evaporated from reservoirs is estimated to exceed the combined freshwater needs of industry and domestic consumption. This greatly contributes to water losses around the world, especially in hot tropical regions. In the industrial sector 57–69% is used for hydropower and nuclear power generation, 30–40% for industrial processes (Plate 20, lower part), and 0.5–3% for thermal power generation. In the context of power generation nuclear and hydro power are very different. Like fossil fuel power stations, nuclear power stations use water for cooling, although they require nearly 50–100% more than conventional stations and hence need to be sited near a good supply like the sea, a large river or a lake. The cooling process is achieved mainly by evaporation. So the consumptive losses are very high. In contrast, hydropower is the largest gross user in the USA, yet it accounts for only 0.5% of the consumptive use.

Domestic water use is related to the quantity of water available to populations in cities and towns. Analysis indicates that people in developed countries on average consume about 10 times more water daily than those in developing countries. It is estimated that the average person in developed countries uses 500–800 litres per day (300 m^3 per year), compared to 60–150 litres per day (20 m^3 per year) in developing countries.

In large cities with a centralized water supply and an efficient canalization system, domestic consumption does not usually represent more than 5–10% of the total water withdrawal (intake). Water withdrawal in large cities is estimated at 300–600 litres per person per day, while small cities have a water withdrawal of 100–150 litres per day, and consumption can reach 40–60% of the total water intake.

In developing countries in Asia, Africa and Latin America, public water withdrawal represents just 50–100 litres per person per day. In regions with insufficient water resources, this figure may be as low as 20–50 litres per day (http://maps.grida.no/go/graphic/freshwater-use-by-sector-at-the-beginning-of-the-2000s).

2.4 Water pollution

Pollution makes water unfit for its intended usage. The contamination can consist of micro-organisms, chemicals, industrial or other wastes or sewage in amounts likely to cause harm to living organisms. It can also physically and chemically damage industrial plants and equipment.

Normally natural waterways contain micro-organisms, which enable them to undergo self-purification, if organic matter is brought into the water. If, however, the load is too high, then the decomposing process by aerobic bacteria may consume so much of the dissolved oxygen, that it is used up to an extent that no animal or plant life can live in the water and a foul, extremely offensive smell is produced (H_2S). Lakes are particularly vulnerable to this process because of their enclosed nature and the absence of mixing waters. A lake will stay polluted for a long time because there is no flushing-out effect and their volume may be too small to cause effective dilution. Lakes rely mostly on their living organisms for self-purification and they are prone to eutrophication, i.e. nutrients contained in the discharge and run-offs into the lake build up and encourage the growth of algae. When they die, their subsequent decomposition uses up the dissolved oxygen to the detriment of other living organisms.

2.4.1 Sources of water pollution

Plate 23 shows some types of pollution, their sources and what their effects are. The measurement and control of water quality are therefore of crucial importance in the interest of public health and in maintaining the quality of the environment.

The vast majority of pollutants poison aquatic organisms directly, but many others cause indirect harm. In general, freshwater organisms are unaffected by pH changes in the range of pH 5.0 to pH 9.0. The toxicity of many pollutants, however, is pH dependent. So nickel cyanide is 500 times more toxic to fish at pH 7.0 than at pH 8.0, and ammonium ions are ten times more toxic at pH 8.0 than ph 7.0. The hardness of water is related to the pH. In general, the softer the water the more toxic acts any heavy metal ion which is present.

2.4.2 From polluted water to drinking water

Wasting of water, population growth and climate change has led in many regions of the globe to a water shortage. Thus the reuse of polluted water seems to be one mean to overcome the supply crisis. The now Professor Emeritus Takashi Asono (71) has served in a wide variety of international, national, state, and local roles to explore and develop wastewater reuse as part of overall engineered environmental and water resource systems. In 2001 he was awarded the Stockholm Water Prize for his theoretical and practical contributions to wastewater reclamation, recycling and reuse.

Asono has been dealing with the concept "From Toilet to Tap" for many years and is convinced that the technique will be introduced more and more in the future in dry regions. The reclamation plant in Fountain Volley in Los Angeles (California) is the biggest and most modern one in the world. Here the treated waste water is pumped for 45 minutes through a micro-filter system that eliminates bacteria, protozoan and solids. The pores of the filter have a diameter of only 0.2 micrometre, 600 times thinner than a human hair. Now the water has a colour of chamomile tea (some opponents of the system say urine) and is pumped through pipes to the reverse osmosis where it is pressed through a semi-permeable membrane which lets pass only the water molecules but no other substances like uric acid, viruses and toxic substances. Desalination plants work on the same principle and astronauts on their mission drink the same water many times.

To be on the safe side the process is repeated three times in California. In the end 15% of the liquid is enriched with toxic substances that are recycled. The rest of 85% is already drinkable but for security reasons it is additionally treated with UV radiation and hydrogen peroxide.

Although the water is crystal clear and tasteless the acceptance of the treated water by the people of Los Angeles is very low. This seems to be no problem in Windhoek, Namibia, where the New Goreangab Water Reclamation Plant, which started working in 2002, pumps about 21.000 m^3 per day into the supply system (Plate 24). About 30% of the water supply of the City of Windhoek is to be guaranteed by the recycling of sewage water. By a multi-barrier system of process steps including membranes and ozonisation, the sophisticated plant produces potable water from a blend of wastewater treatment effluent and surface water.

(http://www.berlinwasser.com/content/language1/html/593.php)

2.5 Urban water supply and purification of potable water

2.5.1 Sources of drinking water

"Drinking water is normally collected from either underground water or by exploiting surface water. It must be free of pathogens, and toxic and inorganic chemicals, colourless, contain no suspended solids and have an acceptable smell and taste. To protect the delivery system the corrosive nature must also be reduced.

Underground water is readily and cheaply accessed by drilling down to the water table and pumping (Deep-lying pressurized water can also be tapped by the borehole of an artesian well). Plate 25 shows that groundwater is obtained from peri-urban well fields and urban wells, then used and disposed of as wastewater through pluvial drainage, piped sewage and on-site sanitation and industrial effluent disposal. It also shows that wastewater is treated and then reused for irrigation, with excess flows re-entering the aquifers".

(http://maps.grida.no/go/graphic/urban_water_cycle)

If, however, the urban water supply is based on a shallow aquifer the growth of the settlement induces increased groundwater pollution and changes in pluvial drainage, the water table and the well fields (Plate 26).

(http://maps.grida.no/go/graphic/urban_water_supply_and_wastewater_on_a_shallow_aquifer)

"Normally the groundwater is chemically and bacteriologically of good quality, but because of anaerobic conditions it may contain Mg^{2+} and Fe^{2+} salts. These must be removed by aeration to oxidize them to a less soluble higher oxidation state. The anaerobic bacteria must also be destroyed by disinfection.

There are three ways of obtaining surface water: pumping from rivers and lakes; building a barrage across the river and diverting its flow through a canal system; or building a dam across a valley at the lower end of a catchment area. The long term storage of this collected water is via large, open reservoirs or artificial lakes. Ideally, to prevent water shortages, the rate of extraction must be equal to its rate of replenishment. The longer water remains in a lake or reservoir, the cleaner it becomes due to the bacterial breakdown of organic matter, sedimentation and flocculation, and the disinfecting ability of UV-radiation. However, because of stratification the epilimnion may become green coloured because of the development of algal blooms, which makes special treatment necessary.

In the hypolimnion, aerobic bacteria action on the organic material falling from above may cause the formation of Fe^{2+} Mn^{2+}, NH_3, S^{2-} and SiO_2. Denitrification may occur and the presence of sulphide ions is particularly unwanted because it chemically depletes the water of dissolved oxygen, interferes later with any chlorination process, and causes foul smells and taste. Stratified water bodies therefore cause problems of water treatment works. To overcome this, the depth of abstraction may have to be varied or the water mixed by pumping it from the hypolimnion to the epilimnion" (Wright, 2003, p. 322).

2.5.2 Purification

"Before river water is allowed to enter a treatment plant, it must be screed to remove any large floating and suspended object. This is done by rubber booms floating on the surface near the extraction point thus action as a physical barrier, also to floating oil. Further screening is necessary to remove floating and suspended debris that has passed under the booms.

Screened water is then stored to help reduce the number of bacteria present in the water, before "real" purification begins. After storage of seven days the water is cascaded down a series of steps, which enables more oxygen to be dissolved whilst allowing the escape of dissolved gases such as carbon dioxide and hydrogen sulphide as well as volatile organic compounds to the atmosphere. The removal of carbon dioxide from the water disturbs the carbon dioxide-carbonic acid equilibria, and therefore more carbonic acid decomposes to form carbon dioxide and water. This reduces the acidity of the water and hence its corrosive effects.

In the next step the water is purified by four principal processes: sedimentation, filtration, aeration and sterilization by chlorination (Plate 27).

Before sedimentation can occur, all particles must be of the right size to undergo settling. Gravity does not cause the sedimentation of all suspended solids. Some particles are so small that they form a colloidal suspension and the water appears turbid even after prolonged standing. These particles originate from clays, proteins, metal oxides and organic matter. So coagulates are added sometimes to the water. Once coagulation has occurred, the water is gently agitated to enable the particles to grow bigger. This process is called flocculation and, when it is over, the water is allowed to undergo sedimentation. If the water is considered to be too hard, a water softener is added. By it the calcium and magnesium ions that cause the hardness are precipitated as insoluble carbonates. Activated charcoal can also be added to remove unpleasant smells, tastes or colour.

Although filtration removes about 90% of all bacteria, the last process involves disinfecting the water. This is done by adding dichlorine (or ozone) to the water in order to sterilize it and then adding sulphur dioxide to remove any excess of dichlorine once it has done its job of killing harmful pathogens.

Sedimentation removes about 90% of the turbidity of the water. The remaining suspended matter has to be removed by filtration. The water is filtered through sand beds that contain harmless bacteria, which decompose any organic matter to form unobjectionable inorganic compounds. Some filter beds are made of a layer of anthracite or activated charcoal on top of the deep layer of coarse sand.

After filtration the water is again aerated by passing over a cascade. This increases the amount of dissolved oxygen in the water and reduces the amount of dissolved carbon dioxide, thus aiding natural purification of inorganic material by aerobic bacteria.

Dichlorine is a very powerful oxidizing agent. It reacts with many organic compounds and therefore a higher dosage must be used to take this into account. Some of these chlorinated organic compounds are toxic. Dichlorine is ineffective though against viruses. So sometimes sodium chlorate or calcium chlorate is used to supply chlorite anions. Although the sterilization of water at the water works is of paramount importance, it is still necessary to ensure that the potable water continues to be sterile as it enters the distribution system for human use. This is done by the addition of ammonia to the chlorinated water which produces chemicals called chloroamines. They react with water gradually releasing chlorate ions, which continue to act as a bactericide.

Ozone (O_3) is also a very powerful oxidizing agent and will destroy viruses, bacteria, spores and protozoans. The main problem with it is that it rapidly breaks down into dioxygen and therefore has no long-term effects as a disinfectant. Hence, after the addition of ozone it is necessary to chlorinate the water.

Small volumes of water can also be sterilized using ultraviolet radiation, but the water must be free of potentially protective particular matter.

By this stage the water is usually fit for drinking and is stored in water towers or reservoirs. In developing countries, where the sterilization is not always carried out, there is a high child mortality rate as a consequence. In the developed countries safe drinking water is taken for granted. However, the chlorination of water has caused the formation of traces of chlorinated organic compounds and there seems to be a link between these chemicals and cancer of the bladder. However, there is far greater danger from drinking untreated water than that from the slight risk of bladder cancer" (based on Wright, 2003, pp. 326–327).

2.5.3 Desalination – a source of "new" water?

"In environments where freshwater is scarce but salt (or brackish) water is present in abundance (coastal areas in arid regions) there is the potential of converting this water by desalination into freshwater. The supply here will be limited more by technology and costs than by the amount available or by ecological implications.

A variety of techniques are available for the purification of saline or brackish waters. The choice is largely determined by the volumes of freshwater required, the type of salinity and thus the unit costs of processing. For chemical electrolysis the costs in chemicals or electricity are proportional to the salt content of the water, so they are best used for lower levels of dissolved salts, e.g. brackish water. Chemical treatment with water softeners, such as washing soda (sodium carbonate) or sodium polyphosphates like Calgon, which form insoluble complexes, or sodium aluminium silicate (Permuti), which operates by ion exchange, is generally restricted to removing excess calcium and magnesium from alkaline terrestrial water.

Distillation is more universally applicable and is one of the main methods of desalination. But it can require substantial capital and running costs, depending on the method used. Multistage flash distillation is a popular form, which artificially reduces the pressure so that the boiling occurs at 80–85·^{0}C to reduce fuel costs. Vapour compression distillation economizes on fuel and waste water by pumping steam through a mixture of fresh seawater and recycled seawater (brine) that has already passed through the system at least once. Another popular method is reverse osmosis. In this, water is forced through thin filter membranes which have pores designed to allow water molecules to pass through but not the larger dissolved salts and minerals.

There are now over 1.800 desalination plants worldwide. The largest plant in the world at al-Jubail in Saudi-Arabia produces nearly 2.3 million litres a day, mainly for the supply of Riyadh, and was probably the main target for Iraqi oil pollution in the Gulf during the Gulf War on 1990. For all intents and purposes, Saudi Arabia has no rivers, receives less than 100 mm of rainfall a year, and its groundwater is largely connate and in critical decline through overexploitation. It therefore matters little that the oil-fired desalination plants produce water that is more costly than refined petrol.

Even when the plentiful supply of cheap oil is gone, however, the Gulf States will be left with endless sunshine. Solar power could transform the economics of desalination for large areas in the world. The main problem is procuring power in sufficient quantities for large-scale desalination. In its simplest form, it need involve nothing more than a seawater pool covered by a glasshouse that replicates the natural ocean evaporation-rainfall cycle in miniature" (based on Jones, 1997, pp. 320–321).

2.5.4 Typhus

The disease, also called typhoid fever, is still a major problem in tropical and subtropical countries, and in many parts of Southern and Eastern Europe. Typhoid is caused by bacteria called *Salmonella typhii* and is found in the faeces of a person who has the disease. Typhoid is usually spread by the contamination of drinking water with sewage, or by flies carrying the bacteria from infected faeces to food. It can also be transmitted by typhoid carriers who handle food.

Once a person has contracted the disease, the bacteria pass through the wall of the bowel and spread to the lymphatic glands where they multiply. During this period the patient shows no symptoms (incubation period). After about ten days the bacteria begin to enter the bloodstream and the victim now starts to feel ill, with headache and various muscular aches and pains. A fever develops, which rises in a regular fashion until it reaches its peak after a week. The abdomen is uncomfortable and tender, and there is usually constipation. In the second week the victim's condition rapidly deteriorates and constipation gives way to diarrhoea. Mental confusion appears and the victim becomes apathetic with a pinched-looking face, flushed cheeks and dilated pupils. In the third week the illness reaches its peak. The victim may now progressively deteriorate and die. Appropriate treatment which drugs can cut short the illness (based on Wright, 2003, p. 313).

2.5.5 Cholera

Cholera had almost disappeared globally by the mid-1950s, but it reappeared and spread throughout the world during the last few decades. The World Health Organization (WHO) fears that a rapidly changing climate, combined with declining socio-economic conditions in the poorest part of the population, will contribute to an increasing spread of the disease (Plate 28).

In 2008 there was an outbreak of severe cholera in Zimbabwe. Until February 2009 more than 60.000 people had been infected and the number of deaths exceeded 4.000. The spreading of the fatal disease with numbers far beyond normal started from the capital Harare, but meanwhile cholera bacteria had also been detected in the river Limpopo, the border river to South Africa and also in Botswana and Zambia the disease has occurred. The outbreak started in Harare and was due to the total breakdown of the water supply system and the sewage system of the town (Plate 29).

Cholera is a serious and often fatal disease caused by comma-shaped bacteria called *Vibrio cholera*. The main source of infection is water contaminated by human faeces containing the bacteria. Poor water hygiene is a particular contributor to the spread of the disease. Carriers of the disease, who show no symptoms, are of even greater importance than the actual cases of cholera themselves in spreading the disease.

The main feature of the illness is severe diarrhoea due to the irritation of the bowel by a toxin produced by the bacteria. The diarrhoea is so profuse and liquid that it is given the name of "rice water". These stools have to be collected so that the amount of fluid lost by the victim can be measured before the stools are disposed of in a sanitary fashion. Loss of water with contained mineral salts is the main cause of death. Protection against cholera can, to a certain extent, be done by vaccination, but the main method of prevention is in the use of proper sanitation to dispose of human excreta, supported by public health measures and health education (based on Wright, 2003, p. 315).

2.5.6 Nitrate in drinking water

Extensive farming depletes the soil of nitrate (NO_3^{-1}), the main source of nitrogen for plants. Therefore farmers have to apply nitrate fertilizer. Unfortunately, nitrates are amongst the most water-soluble inorganic compounds and can be leached into groundwater and be present in run-offs. If more fertilizer is applied than the plants can use then wells, rivers and other water bodies can become polluted. Nitrate is itself not toxic to humans and other animals. However, it is readily converted into the toxic nitrite ion (NO_2^{-1}) in the digestive system of human infants. It is one of the few chemicals that can cross the human placenta and be absorbed by the foetus. Foetal haemoglobin has a high affinity for nitrite. In the first few months of their lives, human babies are very susceptible to nitrite poisoning. This is because the acidity of their stomachs is not sufficiently high enough to destroy the bacteria found there, which causes the formation of nitrite. The latter ion reacts with haemoglobin to produce methaemoglobin which does not carry dioxygen. The skin turns a bluish colour, particularly around the eyes and mouth. Hence it is called the "blue-baby syndrome". The level of oxygen carried by the blood may be so reduced that the baby may suffocate. In older children and adults nitrite is absorbed and excreted and therefore methaemoglobin is not a problem.

Whereas in developed countries because of high hygiene babies are no longer exposed to this danger in developing countries the problems is still virulent because drinking water is used from wells or open water holes. In the EU drinking water guideline the maxim level for nitrite is 25 mg per litre and in US the level is 10 mg per litre.

Although it is relatively easy to remove or reduce excessive nitrate levels in water, because they are so soluble, the methods of revere osmosis or distillation are not cheap because they are energetically demanding and produce only low yields of water. The simplest and cheapest method is blending with water which has a low nitrate level or is free of nitrate at all (based on Wright, 2003, p. 328).

2.6 Drains, waste water and sewage treatment

2.6.1 Drains

Drains carry away excessive amounts of water from buildings, fields, roofs and paved surfaces. Most people relate the term "drain" to the pipes which carry away foul drainage water from toilets, hand-basins and baths, etc. to the public sewer. If the pipes carry rainwater from roofs and paved areas together with domestic sewage we call it a combined system. This is the case in older sections of urban areas. In newer systems the sanitary sewage is separated from the storm sewage. This arrangement is more efficient because it excludes the very large volume of storm sewage from the treatment plant. It permits flexibility in the operation of the sewage plant and prevents pollution caused by combined sewer overflow, which occurs when the size of the sewer is not sufficient to transport both household and storm water.

After the sewage has left the building, it is carried away by drains into the main sewer. These are in urban areas large pipes or masonry-lined tunnels. The carried organic matter is subject to biodegradation. If the amount of dissolved oxygen is not sufficient, anaerobic processes will take place and hydrogen sulphide (H_2S), a colourless, toxic and flammable gas, which is responsible for the foul odour of rotten eggs, will be generated. This process can be a particular problem in hot climates because of the reduced solubility of oxygen in water of higher temperatures and the more rapid biological action.

Nearly all drainage systems rely on gravity flow and only partially filled pipes. The only exceptions are surface water drains, which are assumed to be full when the water flow is at its peak. Foul drains and sewers slope downwards towards the treatment plants or pumping stations, and the sewage flows in the bottom of the pipe rather than filling it completely. It is necessary to design a draining and sewage system that allows a rate of flow that enables water to sweep the solids along the pipes and thus be self-cleansing. Sometimes, when the treatment work is at a higher point than the source of the sewage, it is necessary to pump the effluent. Such a pumped system is known as a rising main.

99.9% of the waste water or sewage is water. Only 0.1% is solids, which pollute it. 70% are of organic origin (25% carbohydrates, 10% fats and 65% proteins) and 30% are inorganic substances like grit, metals and salts.

Because of the unpredictability of sewage flow rates, one of the problems with the sewage system is estimating the load it is capable of taking. One estimate is to use the **D**ry **W**eather **F**low (DWF). It is the base flow rate through the sewers at times of low rainfall (after a period of seven days with less than 0.25 mm of rain has fallen on any one day).It should be estimated twice a year, once in the dry season and once in the wet season.

The DWF is given by

DWF = PQ + I + E

P = Population served

Q = Mean daily domestic waste water generated (m^3 day^{-1})

I = Mean rate of infiltration

E = Mean flow of industrial effluent discharge (m^3 day^{-1})

The composition of infiltration depends on the nature of groundwater that seeps into the sewer. Storm-water sewage can contain significant concentration of bacteria, trace elements, oil and organic chemicals.

Sewage treatment works cope with DWFs from 0–3. If prolonged rain occurs, then DWFs for sewage in excess of 6 are achieved, and the sewage may be released into receiving tanks without further treatments because it is highly diluted.

The functions of sewage treatment are to reduce the total biodegradable material, including suspended solids, to acceptable levels as measured by BOD (**B**iochemical **O**xygen **D**emand, see 5.2.1) to remove toxic material and to eliminate pathogenic bacteria.

2.6.2 Waste water and sewage treatment

In a municipal water treatment plant there are normally three stages of treatment applied. In the first step (mechanical) the fairly solid items like rags, paper or wood are removed by screens of vertical steel bars, from which the material is scrapped off manually or mechanically. The waste water then passes through some kind of grinder, where leaves and other organic materials are reduced in size so that efficient treatment and removal can occur in subsequent processes.

In the first settling tank inorganic matter like sand, grit and gravel is allowed to settle out. In a second tank the organic materials and finer particles are allowed to settle out and form a liquid sludge. Any scum that forms is removed by a device that skims the surface of the water. The process of sedimentation removes about 60% of the suspended solids, and because this contains oxidisable material it lowers the BOD by about 30%. In small treatment plants the settling takes place in septic tanks. Sometimes certain chemicals are added to coagulate or flocculate the solids to one another and precipitate. Flocculation and coagulation can lead to the removal of suspended solids in excess of 70%. Another method is flotation, by which air is blown into the water. The bubbles lift the suspended solids to the surface, from where they are removed by skimming. This process can remove more than 75% of the solids. By the end of the primary treatment the effluent contains something like 100 g m^{-3} of suspended solids and 150–200 g m^{-3} of BOD.

In the secondary treatment (biological oxidation) the remaining organic matter is broken down to a suitable BOD and suspended solid level which allows the discharge of the effluent to rivers and lakes.

In nature the waste disposal is carried out by aerobic bacteria, who convert organic matter into substances like carbon dioxide, water, nitrates and phosphates as well as new organic materials. This process is executed the better the more dissolved oxygen is present. The underlying idea in a treatment plant is to accelerate and improve this process by bringing as much oxygen into contact with the bacteria as possible.

There are two ways of organising this process. The first method is a "biological filter", where the micro-organisms grow on a bed of loose or porous material like blast furnace slag, gravel or crushed rocks. The waste water is spayed on the surface of this bed and trickles down over a gelatinous film of micro-organisms (bacteria, fungi, algae, protozoa and micro and macro invertebrates) coated on the support material. The organic matter in the waste water is absorbed by the microbiological film and converted into carbon dioxide and water. This slowly carried out trickling process can remove about 70% of the BOD of the effluent and 99% of the pathogenic bacteria.

In the second method ("active sludge process") oxygen is brought to the micro-organisms by compressed air or by mechanical agitation by propellers. The oxygen in the air "feeds" the aerobic bacteria already present in the effluent enabling them to utilise the organic material to form new cells. The resulting suspension is called the activated sludge. The particles, known as "floc", are composed of millions of actively growing bacteria bound together by gelatinous slime. Organic matter is absorbed by the floc and converted to aerobic products. The reduction of BOD fluctuates between 60 and 85%. At the end of the secondary process the effluent contains a maximum of 30 g m^{-3} of suspended solid and a BOD of 20 g m^{-3}. If however the river to which the effluent is being discharged is being used as a water supply, then the water must contain a maximum of 10 g m^{-3} of suspended solid, a BOD of 10 g m^{-3} and ammonia at 10 g m^{-3}. When such a high standard is required, then a tertiary stage of treatment will be included.

In this tertiary stage solids with diameters larger than 0.045 mm can be removed by micro-strainers composed of rotary screens with a very fine mesh. Another method is the use of stabilisation ponds or lagoons, being 0.6 to 1.5 m in depth and a surface area of several acres. Here at the bottom anaerobic conditions prevail, but the region near the surface is aerobic, allowing the oxidation of dissolved and colloidal organic matter. A reduction of BOD of 75–85% can be obtained.

Effluents can also be passed through rapid gravity sand filters. In these solid matter is trapped in the bed and is subsequently removed by backwashing.

Sometimes, more advanced treatment is necessary. Processes are available to remove more than 99% of suspended solids and BOD. Processes such as reverse osmosis and electrodialysis reduce dissolved solids.

If the effluents contain too many nutrients they can cause eutrophication in the river into which they are discharged. So sometimes the process of denitrification is necessary to be applied. Urea nitrogen starts already in the sewer to decompose into ammonium (Organic N + H_2O > NH_4^+ + OH^-). This ammonium is not decomposed but nitrified over nitrite to nitrate. This is carried out in the tertiary stage when the effluent is passed through artificially generated areas, some of them rich in oxygen and the other free of oxygen. In the oxygen rich zones the ammonium is converted into nitrite (2 NH^{4+} + $3O_2$ > 2 NO_2 +2 H_2O + 4 H^+) and in the next step into nitrate (2 NO_2 + 1 O_2 >2 NO_3^-). In the oxygen free zones carbonate decomposing bacteria take the oxygen from the nitrate (5 C + 4 H^+ + 4 NO_3 > 5 CO_2 + 2 H_2O + N_2). The remaining nitrogen passes off as a gas into the atmosphere. In a similar process also the phosphates, which may also cause eutrophication, are decomposed.

2.6.3 Sludge

The sludge from the primary and secondary treatments is a foul-smelling thick liquid containing large quantities of water. It is pumped into a closed tank or digester and stored at 35 ^{0}C for about three weeks. Inside the digester, microbiological processes occur, which convert the complex organic chemicals present in the sludge to methane (CH_4), carbon dioxide and an inoffensive black, creamy material that smells of tar. Digestion reduces the organic material to between 45 and 60% and also destroys pathogens. The methane gas is collected and used to heat the digester or drive gas motors. The sludge contains too much water. So in the second step it is dewatered to reduce it in mass and volume, and prevent further decomposition and foul smells. The sludge is dried in open beds (older plants and rural areas) or dewatered by pressure filtering (newer plants).

The ultimate solid sludge can be disposed of in a number of ways. It can be incinerated, which reduces the volume and destroys toxic organic compounds but leaves toxic inorganic materials in the ash. Another way is dumping it in ground depressions called sludge lagoons, which can cause unpleasant smells. It can also be mixed with household refuse and composted to produce organic manure. When sludge is mixed with soil the main problem is the presence of pathogens (Salmonella bacteria), fungi, protozoa and parasites (tapeworm and roundworm eggs). Hence there are strict rules when sludge is applied to agricultural land. For example, 90 days must elapse before livestock can use the land, and salad crops must not the grown on treated land for one year. Higher concentrations of heavy metals can also be present in sewage sludge (e.g. 7.2 mg of copper per kg of dried sludge).

2.6.4 Reed beds

In smaller communities reed beds can be used to provide a complete waste water treatment based on natural biological processes (Plate 30). Most solids are composted and used as fertilizers, while the reeds and other plants are selected to provide high uptake of both nutrients and pathogens.

Further readings (*comments* from Wright, 2003, pp. 303–304 and 331).

Andrews, J.E., Brimlecombe, P. Jickells, T.D. and Liss, P.S. (1996). *An Introduction to Environmental Chemistry.* Blackwells Science, Oxford.

The chemistry of water and its physical properties have to be searched for! There is an excellent, well-illustrated and explained section though on the oceans, which forms about one-fifth of this book.

Chapman, D. (Ed.) (1996). *Water Quality Assessment: A Guide to the use of Biota, Sediments and Water in Environmental Monitoring*. Spon Press, London.

An essential guide to the design and practicalities of monitoring the quality of fresh water.

Harrison, R.M. (Ed.) (2001). *Pollution, Causes, Effects and Control.* 4th Ed. Royal Society of Chemistry, Cambridge.

Recently revised and therefore an up-to-date account of pollution in general. In particular the chapters on the chemical pollution of freshwater and marine environments, drinking water standards, the biology of water pollution and the treatment of sewage will supplement and extend this chapter!

Hester, R.E. & Harrison, R.M. (Eds.) (2000). *Chemistry in the Marine Environment*. Royal Society of Chemistry, Cambridge.

This book covers a wide range of topics including the pollution of the oceans and its usefulness, e.g. as a source of pharmaceuticals. It has an international approach, and is an interesting account of the influences of chemical reactions on the seas and oceans.

Howard, A.G. (1998). *Aquatic Environmental Chemistry. Oxford Science Publications*, Oxford University Press, Oxford.

One of the Oxford Chemistry Primers and therefore a very cheap and short read! A straight forward account of topics such as acidity of water, metal complexes in solution, oxidation and reduction, etc.

Laws, E.A. (2000). *Aquatic Pollution.* John Wiley, New York.

An expensive but easy-to-read book! It covers pollution in lakes, rivers, streams, underground aquifers and the oceans. Amongst the topics covered are the polluting effects of urban runoff, acid rain and sewage disposal. Numerous case studies are also included.

Mason, C.F. (1996). *Biology of Freshwater Pollution.* 3rd Ed. Longmans, London.

This is a very well-written and comprehensive account of this subject. It includes some very interesting case studies. The forth edition is about to be published.

The Open University (1993). *T237, Water Quality, Analysis and Management, Units 5–6; Water Supply and Sewage Treatment, Unit 7: Environmental Control and Public Health*. Open University, Milton Keynes.

Both these booklets may be a little long in the tooth but they still provide excellent reading in the areas of water quality, water supply and sewage treatment, with particular reference to the UK. A minimal amount of chemical knowledge is required to understand the content.

2.7 Tasks:

- Explain the consequences of the thermal properties of water.
- Find out from the internet what pH value certain substances like battery acid, household bleach, seawater, distilled water, vinegar, baking soda or lemon juice have.
- Explain the relevance of oxygen in water bodies and in what ways water is enriched by it.
- Explain the relevance of hard water.
- Explain the term 'virtual water' to the class with different examples and consequences.
- Prepare for a presentation in class: What are the impacts of acid rain on soils and plant production?
- Prepare for a presentation in class: What is the source of drinking water in your home town or village and how is the water prepared for human consumption?

3 Water Governance and Water Policy Issues

There is currently a consensus, that water is globally in crisis, with the crisis appearing to be more a crisis of governance than a crisis of resources. This chapter, based mainly on WWAP, 2003, pp. 370–384), focuses on how societies are attempting to govern water in more effective ways. It also contains a discussion on water governance, some of its components and how it can improve water management and service delivery.

3.1 Water Governance

3.1.1 What is Governance?

Governance refers to relationships that can be manifested in various types of partnerships and networks. A number of different actors with different objectives are involved, such as government and civil society institutions and transnational and national private sector interests. An important shift in governance thinking is that development is now increasingly seen as a task that involves society as a whole and not the exclusive domain of governments.

The notion of water governance and its meanings are still evolving and there is no agreed definition. Its ethical implications and political dimensions are all under discussion. Different people use the notion differently, relating it to different cultural contexts. Some may see governance as essentially preoccupied with questions of financial accountability and administrative efficiency. Others may focus on broader political concerns related to democracy, human rights and participatory processes. There are those who look at governance with a focus on the relationship between the political-administrative and the ecological systems. Other approaches see governance entirely in terms of management, and the operation and maintenance of infrastructure and services. The United Nations Development Programme (UNDP) defines governance as the exercise of economic, political and administrative authority to manage a country's affairs at all levels. It comprises the mechanisms, processes and institutions through which citizens and groups articulate their interests, exercise their legal rights, meet their obligations and mediate their differences.

In this particular context, governance refers essentially to the manner in which power and authority are exercised and distributed in society, how decisions are made and to what extent citizens can participate in decision-making processes. As such, it relates to the broader social system of governing, as opposed to the narrower perspective of government as the main decision-making political entity. Governance of water is perceived in its broadest sense as comprising all social, political and economic organizations and institutions, and their relationships, insofar as these are related to water development and management.

Governance is concerned with how institutions rule and how regulations affect political action and the prospect of solving given societal problems, such as efficient and equitable allocation of water resources. The rules may be formal (codified and legally adopted) or informal (traditionally, locally agreed and non-codified). Sound and effective water governance systems are crucial to pursuing various sustainable water development and management goals.

In essence, water governance refers to the range of political, social, economic and administrative systems that are in place to develop and manage water resources and the delivery of water services, at different levels of society.

Water governance issues are also dependent on properly functioning legal and judicial systems and electoral processes. For example, legislative bodies made up of freely and fairly elected members and representing different parties are important to popular participation and accountability. It is essential that legal and judicial systems protect the rule of law and human rights. Open electoral processes help build political legitimacy. Water reforms that, for example, include decentralization and increased democratization may require constitutional, legal and administrative reforms that enhance the legitimacy and authority of the judiciary and legislative bodies and executing agencies.

Although water governance and holistic and integrated approaches to water resources management feature strongly in the international water agenda, in many countries water governance is in a state of confusion. The specific water governance issues vary. In some countries there is a total lack of water institutions, and others display fragmented institutional structures (sector-by-sector approach) and overlapping and/or conflicting decision-making structures. In many places conflicting upstream and downstream interests regarding riparian rights and access to water resources are pressing issues that need immediate attention; in many other cases there are strong tendencies to divert public resources for personal gain, or unpredictability in the use of laws and regulations and licensing practices, which impede markets and voluntary action and encourage corruption and other forms of rent-seeking behaviour.

Over the past decades, there has been increasing competition for the available water resources, and increasing water pollution. Consequently, water shortages, water quality degradation and destruction of the aquatic ecosystem are seriously affecting prospects for economic and social development, political stability, as well as ecosystem integrity. In developing countries, scarcity and degradation of water resources may have a severely limiting impact on development options, especially for poor people. In order to meet basic human and ecological needs and services, societies need to address and solve several serious water challenges and must come to terms with dwindling water resources, their uneven geographic and seasonal distribution, and inadequate and inequitable allocation of water services.

The water crisis is essentially a crisis of governance and societies are facing a number of social, economic and political challenges on how to govern water more effectively. The way in which societies organise their water resource affairs is critical for promoting and supporting sustainable development as an integral part of a poverty-focused development strategy. Sustainable development challenges are, at their core, a question of both governance and of how societies can balance economic and social development with ecosystem integrity. Sound and effective governance of water resources and related services are paramount to facilitating and supporting an enabling environment for Integrated Water Resources Management (IWRM). If we do not change the way in which water is governed, negative development impacts will be even more widely felt. It is also important to note that much wider governance issues and policies outside the water sector affect water resource issues. In effect, the challenges facing the sector are systemic in nature and inextricably linked to broader social, political and economic issues of water governance. For example, agricultural and industrial policies may have substantial impacts on the water sector.

3.1.2 Water Governance and the International Water Agenda

The world has changed since Agenda 21 was endorsed in Rio. The end of the Cold War has opened up borders, and globalization and economic and political liberalization have become socio-economic forces that all countries must deal with in order to reap their benefits or avoid their negative impacts. Current understanding is that water governance is a complex issue and very variable. Those who govern must be able to function in situations of rapid change, and often need to become agents for positive change. They also have to deal with competing demands for the resource. There is an ever-growing disparity between those who adapt quickly and easily and those who do not, created in part by the complexity, unpredictability and pace of events in our world. Weaknesses in governance systems are one of the major reasons behind the difficulties encountered in both following a more robust sustainable development pathway and balancing socio-economic needs with environmental sustainability. There is thus a strong need for improved institutions and social arrangements.

Agenda 21 sets out a number of challenges for various areas of sustainable development and, in general, there have been huge difficulties converting principles into concrete actions. Although governance of water was not explicit as a programme area in Chapter 18 of Agenda 21, it was represented within most programme areas for water. It envisaged, inter alia:

- National comprehensive policies for water resources management, which are holistic, integrated and environmentally sound;
- Institutional strengthening and reform in conjunction with reform of water laws; and
- Integrated Water Resource Management (IWRM) based on dynamic, interactive, iterative and multi-sectoral approaches. Its evolution would embrace spatial and temporal integration and all water users, and would be integral to socio-economic planning.

Agenda 21 set a specific target: that by 2000, national action programmes, appropriate institutional structures and legal instruments would be implemented, with water use attaining sustainable patterns. This target remains unfulfilled. It was also stated that sub-sectoral targets of all freshwater programme areas would be achieved by 2025. National reports to the Commission on Sustainable Development were anticipated in order to report on progress towards target implementation, but few national reports contain any such information: a global or regional overview of the formulation of national water policies has therefore yet to emerge. Nevertheless, monitoring progress in relation to water governance is an essential tool for informed decision-making and development of future water governance requirements. Currently, there are very few indicators that can be applied and it is essential to develop the appropriate tools and mechanisms for collecting data at the national level.

Based on experience since Rio, some contextual aspects are important in understanding progress related to more effective water governance. One is the preoccupation that many governments have shown about debt and deficit reduction. During the past decade, these governments have significantly reduced their expenditures on environment-related infrastructure and services, which has generally had a serious negative impact on agencies responsible for water. Many more governments have been steadily backing away from concern for, or commitment to, environmental issues, and instead have emphasized strategies for economic growth based on a neo-liberal ideology and strategy. As a result of a newly emerging political economy in many countries, governments have devolved responsibilities for water and other services to lower levels of government that frequently have not had the human and institutional capacities or financial resources to maintain levels of services. Additionally, governments have been commercializing or privatizing such services. Increasingly, modified management processes should reflect a 'business model' in which efficiency, results-based management and tangible products have been emphasized, and less interest has been shown in providing systematic and transparent consultation processes with the public regarding policy development and implementation.

Since Rio, significant international water goals relating to governance have been set. The Second World Water Forum in The Hague in 2000 identified water governance as one of the highest priorities for action and expressed the need to govern water wisely through the involvement of the public and in the interests of all stakeholders. At the United Nations (UN) Millennium Assembly in 2000, heads of state emphasized conservation and stewardship in protecting our common environment and focused in particular on preventing unsustainable exploitation of water resources through the development of water management strategies at all levels, promoting equitable access and adequate supplies.

Although water-related objectives in Agenda 21 remain unfulfilled, progress has been made in the areas of water governance and management. There now exists a much better global awareness and understanding of the role water plays in ecosystem conservation and the overall cultural, social and economic value of water. The increasing focus on water governance, IWRM and demand-driven approaches marks an important shift in how water is being governed in terms of equitable distribution and efficiency.

In general, progress has been made in the following three areas.

- The increasing recognition of water governance and required reforms of policies and institutions as the key to sustainable water development, of which the adoption of appropriate legislation, policies and institutions is only a part of the governance issue: it is the way in which enhanced institutions and policies are being established and implemented that matters. The existence of sufficient rules and regulations means little if they cannot be effectively enforced, due to power politics, vested interests and lack of funds, or the public's absence from the decision-making process.

- Reform of water institutions and policies is now taking place in many countries to address incoherent water property rights, fragmented institutional structures, inadequate policies, lack of incentives for increased partnerships and participation and various other aspects of water governance. However, progress has so far been too slow and too limited.
- Integrated approaches are widely accepted as the main vehicle or instrument to manage water in more effective ways, and the international community has made considerable efforts and progress in increasing awareness of water resources and their management. However, their implementation remains incomplete in both developed and developing countries.

3.1.3 Some criteria for effective water governance

Governance affects economic, social and environmental outcomes. Water resource institutions regulate who gets what, when they will get it and how much of it they will get. Adequate governance can decrease political and social risks, as well as institutional failures and rigidity. It can also improve capacities to cope with shared problems. Research suggests that there is a strong causal relationship between improved governance and improved development outcomes such as higher per capita incomes, lower infant mortality and higher literacy.

Defining the various components required for effective water governance is a complicated task. In general, we are more familiar with failures than with effective water governance. What makes governance effective can differ from context to context and depends on cultural, economic, social and political settings. More effective governance systems·need to be designed and created to deal with governance shortcomings and to increase the development potential of civil society agencies, local communities and the private sector.

The water governance issues that need to be addressed and reflected in water policy are:

- Basic principles such as equity and efficiency in water distribution and allocation, water administration based on catchments, the need for holistic and integrated management approaches, the need to balance water use between socio-economic uses and uses to maintain ecosystem integrity, etc.
- Clarification of the roles of the government, civil society and the private sector and their responsibilities regarding ownership, management and administration of water resources. Under this heading the following issues will be included:
    - absence of or conflicting water rights legislation;
    - lack of effective mechanisms for intersectoral dialogue;
    - lack of economic incentives;
    - fragmentation of water management and administration;
    - lack of mechanisms for the participation of the community or other stakeholders;
    - the role of women in water management;
    - the effects of vested interest;
    - the absence of water quantity and quality standards; and
    - the absence of mechanisms for coordination and conflict resolution.
- Issues related to IWRM, including
    - inappropriate price regulation and subsidies to resource users and polluters;
    - inappropriate tax incentives and credits;
    - overregulation or underregulation;
    - bureaucratic obstacles or inertia and corruption;
    - conflicting or absent regulatory regimes;
    - mechanisms to incorporate upstream and downstream externalities (environmental, economic and social) in water-planning processes; and
    - mechanisms to resolve disputes.

Effective governance of water resources requires the combined commitment and effort of governments and various civil society actors, particularly at local/community levels, as well as the private sector. Policies must deliver what is needed on the basis of clear objectives and informed decision-making, which should occur at the appropriate level. Policies should also provide clear economic and social gains for society as a whole. Given the complexities of water use within society, managing it effectively and equitably entails ensuring that the disparate voices are heard and engaged in decisions concerning the waters in which they have an interest. Water governance can be said to be effective when there is equitable, environmentally sustainable and efficient use of water resources and its benefits. Such efficient use includes minimizing transaction costs and making the best use of a resource. Although there is no single model for effective governance, the following basic attributes are likely to represent some of its features.

- Participation: all citizens, both men and women, should have a voice – directly or through intermediate organizations representing their interests – throughout processes of policy and decision-making. Broad participation hinges upon national and local governments following an inclusive approach.
- Transparency: information should flow freely within a society. The various processes and decisions should be transparent and open for scrutiny by the public.
- Equity: all groups in society, both men and women, should have opportunities to improve their well-being.
- Accountability: governments, the private sector and civil society organizations should be accountable to the public or the interests they are representing.
- Coherency: the increasing complexity of water resource issues, appropriate policies and actions must be taken into account so that they become coherent, consistent and easily understood.
- Responsiveness: institutions and processes should serve all stakeholders and respond properly to changes in demand and preferences, or other new circumstances.
- Integrative: water governance should enhance and promote integrated and holistic approaches.
- Ethical considerations: water governance has to be based on the ethical principles of the societies in which it functions, for example by respecting traditional water rights.

These attributes are examples and represent ideal situations, which may not all be found in any single country. Through wide participation and consensus-building, societies should aim at identifying those attributes and actions that are most relevant to them. In this regard, inclusive dialogues at national and local levels are important to identify the appropriate challenges and actions for a given context.

3.1.4 Who owns the water?

Property laws often determine who owns or has the right to control, regulate and access water resources. Water rights are often complicated by the variable nature of the resource. Additionally, there are economic, social and environmental values attached to water rights, and any effective water governance structure will need to address this complexity.

There is increasing pressure to recognize and formalize water rights. This is happening in many countries, although it raises complex questions about the multiplicity of claims and water uses, and it may not be sufficient to secure equitable access to water resources. The process of formalization is all too often biased in favour of the rich and powerful who may abuse the system. In many developing countries, local regulations, customary laws and traditional rights assign rights and responsibilities that differ from state regulations. It is therefore important for formal rights to consider traditional practices.

For formal and informal rights to be meaningful, it is essential that they retain the capacity to protect against competing water users. Due to the nature of water resources, illegal abstractions are generally easy and commonplace. They can be difficult to resolve since the transaction costs for controlling and excluding non-members or owners, particularly in irrigated agriculture, can be very high. Excessive illegal use threatens to break down property rights and established institutions, as well as depleting water resources.

Water can be seen as a 'common pool' resource system. All water use creates positive or negative externalities (social, economic and/or environmental). The effective governance of water requires that water rights and obligations be clearly defined.

Property rights

- Open access property: There is no defined group of users or owners and the water resource is open to anyone.
- Common property: The group in charge of the resource, such as a local community or a particular user group has a right to exclude non-members from uses and benefits. Members of the management group have both rights and obligations with respect to use and maintenance of the water resource.
- State property: Water users and citizens in general have an obligation to observe use and access rules determined by the controlling government agencies.
- Private property: Within the existing institutional framework the owner has the right to decide on water access and uses. Those without rights or financial means to acquire water are excluded from consumption.

Such rights and obligations stipulate who is entitled to what quantity and quality of water, and when they are entitled to it. Water entitlements may also include obligations, such as respecting the rights of downstream water users and the discharge of wastewater.

Although the state will normally legislate on the issues of property rights, many of the current problems of water governance derive from hierarchical and centralized control by the state and its inability to 'provide sufficient water-related services or to enforce regulations. It is often held that the local community, together with water users' organizations, can govern common resources in equitable and efficient ways.

Although rights may be defined on paper, water resources may in practice be considered free-for-all. In many instances, particularly in agriculture, water rights are closely linked to land rights: any reform in water rights has therefore also to address land rights and vice versa. This is being addressed in South Africa's water policy reform (see below: Water reform in South Africa) where land and water rights are being disconnected and the riparian principle may thus not necessarily apply.

Advocates of free market policies are likely to favour private and transferable water rights and pricing that reflects the growing scarcity of the resource. They suggest that this will lead to efficient and equitable allocation of resources and will provide the greatest incentives to avoid wasteful practices. Private property rights imply that the owner can exclude those without rights or those who cannot afford the good. A legitimate concern with privatization and increased commercialization is that such a policy may exclude poorer segments of society from reasonable access to water.

3.1.5 Whose water governance?

It is important to consider to what extent the processes of institutional reform and devolution of water rights serve society, both in its entirety and its component groups. Currently, poor people in both rural and urban areas tend to be disadvantaged in accessing water and sanitation services and in accessing water for food production. If the water resource is managed primarily through private markets, only those having property or sufficient income may have easy access. If public authorities manage water, it is still not certain that poor, isolated or socially immobilized elements will gain improved access. Consensus on public policies in governing water is a problematic issue and raises many questions. Any water governance reform should aim for social and political stability. Mechanisms to compensate those members of society who lose out in the short term may be difficult to establish, or may be omitted if they are few and not politically strong. However, robust and flexible governance structures should be able to cope with such problems.

3.1.6 Water Governance and Water Management

Governance and management are interdependent. Effective governance systems should enable the more practical management tools to be applied correctly. Public-private partnerships, public participation, economic, regulatory or other instruments will not be effective unless the political will exists and broader administrative systems are in place. For example, the polluter pays principle is a management tool specifically designed to decrease water pollution. However, before such a principle can be enforced, it is essential that appropriate rules and regulations, clear mandates for different agencies and transparent financial arrangements be implemented and communicated.

3.1.7 An integrated approach

There is a wide acceptance of Integrated Water Resource Management (IWRM) as the appropriate management tool for sustainable use of our water resources and for improved delivery of water services (see chapter 5.1). IWRM promotes participatory approaches, demand and catchment-area management, partnerships, subsidiarity and decentralization, the need to strike a gender balance, the environmental, economic and social value of water and basin or catchment management. It replaces the traditional, fragmented sectoral approach to water management that has led to poor services and unsustainable resource use.

IWRM is based on the understanding that water resources are an integral component of the ecosystem, a natural resource and a social and economic good. Physical processes, such as the naturally occurring interplay between the hydrological cycle, land, flora and fauna, take place in an integrated manner. The challenge is to create governance systems, institutions and management instruments that take into account and reflect such physical complexities in planning, decision-making and implementation processes, while at the same time balancing them with social, economic and environmental needs and objectives.

The Global Water Partnership Technical Committee has proposed a simple framework as the starting point for IWRM. Concurrent development and strengthening of three elements is needed: an enabling environment, appropriate institutional roles and practical management instruments.

1. The enabling environment comprises national, provincial and local policies and legislation. These constitute the 'rules of the game', which allow all stakeholders to play their respective roles. The 'rules' should promote both top-down and bottom-up participation of all stakeholders, from the national level down to the village or municipality, or from the level of a catchment or watershed up to the river basin level.
   The government's role should be that of activator and facilitator, rather than top-down manager. Important aspects of the government's role include formulating national water policies and legislation, enacting and enforcing the legislation, and encouraging and scrutinizing the private sector.
2. In the area of governance and institutional roles, development, financial and human resources, traditional norms and other circumstances will play a large part in determining what is most appropriate. Nevertheless, institutional development is critical everywhere to the formulation and implementation of IWRM policies. Clear demarcation of responsibilities between actors, separation of regulation from service provision functions, adequate coordination mechanisms, filling jurisdictional gaps and eliminating overlaps and matching responsibilities to authority and to capacities for action are all parts of institutional development.

3. Finally, practical management instruments should be developed to help water managers. The art of IWRM lies in selecting, adjusting and applying the right mix of these tools for a given situation. Five categories deserve special attention.
   - Water resource assessment: comprising data collection networks, environmental impact assessment techniques and risk management tools, e.g. for floods and droughts.
   - Communication and information: raising awareness is often a potent instrument for improving management, particularly when accompanied by opportunities for informed stakeholder participation.
   - Tools for water allocation and conflict resolution: allocation could be done through a mix of regulatory and market instruments based on valuation of costs and benefits; and conflict resolution tools could provide guidance in issues of upstream versus downstream, sector versus sector and human versus nature.
   - Regulatory instruments: including direct controls such as land use plans and utility regulation, as well as economic instruments (prices, tariffs, subsidies and others) and encouragement of self-regulation, for example by transparent benchmarking.
   - Technology: both new and traditional technologies might provide scope for progress, within the water sector as well as in others that affect water demand.

Integrated management will need to tackle sectoral agencies protecting their traditional roles and responsibilities as well as the problems of overlapping or conflicting legal mandates and responsibilities. The limited array of senior and powerful advocates for the concept of IWRM make it difficult to alter the well-entrenched existing water governance systems, which tend to reflect sectoral approaches

As water-related services are extended to promote public health and food production, uncoordinated institutions can be confusing and lead to water resource depletion. In the Zambian village of Mbala, people received no less than three different pieces of advice from government agencies on how to protect a local water source: to uproot trees, to plant trees around the water source, and to uproot trees and replant them with orange trees to protect the water source.

It is equally alarming that in many countries, a large number of water supply and sanitation projects and water management polices continue to be developed in isolation from each other.

During the last decade many country initiatives have been taken, ranging from relatively simple changes (creation of interagency coordinating groups) to fundamental reallocations of power and changes in basic values or principles. Some examples of implementation of integrated approaches, although limited, can be found in new water laws that encourage cross-sectoral management in South Africa and Zimbabwe. These latter reforms show many similarities in issues of ownership, catchment-based management and the need to obtain a permit for any water use.

3.1.8 Water reform in South Africa

The political changes in South Africa and the emergence of a democratic system have allowed for reform of the water sector as regards policy, organizational structure, water rights and legislation. This water reform is often cited as a very comprehensive and innovative approach to water management.

The new water law sets out to meet the objective of managing water quantity and quality to achieve optimum long-term environmentally sustainable social and economic benefits for society, while ensuring that all people have access to sufficient water. Water is considered a national resource vested in the state. The law provides for nineteen catchment management agencies, which have to prepare a management plan, issue water licences, actively promote community participation and perform other functions for implementation of the water law.

In many areas, water services have expanded rapidly. However, in some cases decentralization of service provision and responsibilities for some other areas of the water law has been difficult due to limited human and institutional capacities as well as a shortage of financial resources.

Improving water governance will help to address government, market and system failures. In Latin America there has recently been a move to address aspects of market failure. For example, the Chilean water reforms have placed major emphasis on the correct pricing of water to reflect opportunity costs over and above the tariff. Similar attempts are underway in Costa Rica and Ecuador where downstream users pay the watershed owners and managers for watershed services. The Chilean experience is instructive but the context may be location-specific, since there was a major commitment to developing the entire economy based on an export-oriented open economy. There have been many frictions due to such changes; issues of openness, transparency, participation and ecosystem concerns are now being tackled.

The water reform work in Chile is a case in point of the need to sequence reforms to meet the most urgent requirements, and, along with the example of South Africa, illustrates that water reform is often triggered from outside the water sector (for example, by political and economic liberalization). Experience in the United States suggests that reduced water demand appears to be largely due to reductions in water use subsequent to changes in the energy and agricultural sectors as well as enforcement of federal instream water requirements for ecosystem maintenance.

3.1.9 Decentralisation and participation

Effective water governance requires changes in attitudes and behaviour among individuals, institutions, professionals, decision-makers – in short, among all involved. Participation by the public or stakeholders is an important tool in implementing such changes as it facilitates more informed decision-making and eases conflict resolution. It can also guarantee that voices of relatively powerless groups, such as women and indigenous people, are heard. Participation offers people the opportunity to meet their responsibilities, as well as the opportunity to claim their rights.

Key aspects of sustainability include empowerment of local people, self-reliance and social justice. These reflect concern about principles of equity, accountability and transparency. One way to incorporate these principles into real-life management is to move away from conventional forms of water governance, which have usually been dominated by a top-down approach, and professional experts in the government and private sector and move towards the bottom-up approach, which combines the experience, knowledge and understanding of various local groups and people.

An important lesson during the 1990s was recognizing the benefits of combining expert knowledge with local knowledge. The self-help Orangi Pilot Project in Karachi/Pakistan, which provided low-cost sanitation to the urban poor, is a good example of the bottom-up approach. The entire project was managed and financed by the local population, clearly illustrating that water governance is an important issue even at local levels.

Local participation can also be a powerful tool for conflict resolution. An enlightening case is provided by the Taiz region in Yemen, where social and political conflicts, arising from competing demands on scarce water resources, have started to be resolved by engaging local stakeholders in a continuous dialogue. However, the anticipated end result of this particular case has still to be achieved.

The actual progress in participatory approaches has been modest and uneven. Many governments have a very instrumental view of local communities and related community-based organizations, and their active involvement is normally sought only for implementation of water projects. Participation in a truer sense would entail involvement throughout the whole policy or project cycle. Progress has also been uneven in overcoming the gender gap. Increased attention to gender can enhance project effectiveness as well as provide support for equity issues: it is encouraging that in some places such as Burkina Faso and Bangladesh, thinking and experience have moved beyond women and development to gender and development. In effect, in Burkina Faso, women and men each have their own forms of organization with their own rights to water and land for agriculture: the women in the river valleys, the men on higher ground. When the state took over the land for irrigation, it only gave out plots and water rights to male heads of households and created only male water users' groups. The women lost their production and harvest rights, their traditional organization went unrecognized and they lost their motivation for agriculture. When the government realized this, new plots were also given out to the women and productivity, as well as operation and maintenance of the watercourses, improved.

In Bangladesh, with an abundance of groundwater, large-scale farmers were the first to benefit from state subsidies to install deep wells with mechanized pumps. When shallow wells and smaller pumps became available, this irrigation technology was placed within the reach of the smaller-scale farmers. Out of necessity, they used water more efficiently than the large-scale farmers, and so accumulated a surplus of water that they sold to landless farmers and women, who united and bought pumps to sell water for agriculture. In Bangladesh agriculture, men have access to water technology and land; it is they who mobilize labour, arrange inputs and have the ultimate say over the harvest. Continuing exclusion of women from the developments in water technology has widened the gap. But as water vendors, women have found other opportunities to benefit from the new technology.

Institutional reforms have, at least in part, been justified by the principle of subsidiarity (management at the lowest appropriate level). Many national and state governments have delegated responsibility for water and other environmental services to lower levels of existing government, to new institutions created specifically to take on responsibilities at lower tiers of governments. Not all delegation has been within-government: the new Water Law of Zimbabwe, for example, delegates catchment management responsibilities and day-to-day duties of water rights allocation and administration to stakeholder-elected catchment councils. Each catchment council is composed of sub-catchment councils, composed of local water user groups and associations (see chapter 8.2: Case study: Cuvelai Basin in Namibia). However, recent political instability in Zimbabwe is seriously threatening attempts to reform the water sector.

The catchment is increasingly accepted as the appropriate scale for water resource management. However, for it to be more useful would require overcoming certain obstacles. Strong sectoral or local interests may secure water first. River basins do not always match existing administrative boundaries, which can make it more difficult for riparians to solve common problems. Many local communities and civil society organizations are facing problems in mobilizing resources and the required human and institutional capacities. It is important that decentralization of water responsibilities to local communities or new catchment-based organizations be done in a transparent and participatory way to prevent powerful local groups from claiming the entire water resource, further marginalizing poor people, women and other politically weak groups.

It is further necessary that local catchment-based management groups respect the rights of other basin users downstream and, where appropriate, international river basin agreements (see chapter 3.2).

3.1.10 Public-private partnerships

The ways in which various government agencies, civil society organizations, private firms and the market relate to each other is crucial for effective public-private partnerships. Governance draws explicit attention to these relationships. Partnership formation can bring about substantial benefits. In cases where less public funding is available for water-related initiatives, partners outside government have sometimes contributed, through money or voluntary action, to expediting activities that would otherwise have been difficult to support. In this manner, partnership arrangements have shown that they can help to maintain or to improve water services.

The Ministerial Declaration at Bonn, 2001, encouraged private sector participation. It also noted that this does not imply private ownership of water resources and that water service providers should be subject to effective regulation and monitoring. Private sector involvement in water may take many forms and is not new. At the most basic level, water service providers have always bought in goods and services from the private sector, and governments have enlisted the private sector to assist in assessing and monitoring water resources, for example in groundwater investigations. In recent years, the trend has been to give the private sector a larger role in managing, operating and maintaining water and wastewater systems. These may be broadly divided into the following:

- Divestiture of assets: this model has been used in England and Wales. The private sector owns the infrastructure and is responsible for planning and financing its development, as well as for its operation and maintenance. The driver for privatization of the water industry in England and Wales was the need for investment, and the key to its implementation, a strong regulatory framework. The water and wastewater companies are regulated by an economic regulator, the Office of Water Services, which has limited prices, the Environment Agency, which controls water abstractions and wastewater discharges, and the Drinking Water Inspectorate, which controls the quality of water supplied.

- Concessions: these are granted for the management, operation and development of systems for a limited period (usually about twenty-five years), but ownership of the infrastructure remains with the government. This is the dominant system in France, where there is no regulator, but the interests of consumers are represented by the contract between the service provider and the local government, which owns the assets. Shorter contracts with minimal investment by the operator (Ieases) are sometimes employed.
- Build-Operate-Transfer and the Build-Own-Operate-Transfer schemes: these involve the private sector in the financing, construction and operation of works. They are usually used for treatment plants and the private investor makes a return on his investment from the revenue for water sold or fees for treated wastewater. The private sector is again controlled through the terms of the contract by a local government or a public utility.
- Service contracts: many utilities use service contracts, that is, they will buy in some goods and services from the private sector. In recent years, some utilities have contracted out substantial parts of their operations, e.g. billing and revenue collection, which would have previously been regarded as a responsibility of the public utility itself.

Pressure from international funding agencies has led to the increased involvement of the private sector in developing countries, largely through concession contracts for the major European companies in the field. In Macao, privatization resulted in an improved level of service. In Buenos Aires, private sector involvement has resulted in increased coverage of services and more reliable water supplies. However, it has been criticized because of lack of transparency in the renegotiating of contracts and tariff increases and decisions to disconnect customers whose payments are late. In all cases involving concession contracts and private sector involvement, success appears to rely on the presence of effective regulation by central or local government agencies. A problem in many developing countries is the lack of capacity and experience to develop an adequate regulatory system.

There is considerable potential for increased private intervention in the near future in providing services to more affluent urban areas of developing countries. However, participation in the extension of service to the urban and rural poor remains more problematic, as this hinges on pricing and cross-subsidy policies that would enable private utilities to generate a fair return on their investments.

A further problem in developing countries is the lack of the necessary skills within the private sector to operate, maintain and develop water and wastewater systems. In this case, private sector participation often implies foreign companies taking over utilities. However, the use of smaller service contracts for specific activities could employ indigenous private companies, thus encouraging the development of greater skills within these companies and enabling local governments to gain more experience in preparing and managing contracts.

The rights to abstract water and discharge wastewater are important to all service providers and are normally controlled by public authorities. However, some economists argue that active trading in water rights promotes water use efficiency as market mechanisms allocate water to the highest valued use. Trading of water rights takes place in parts of some developed countries, such as the United States and Australia.

An alternative to government provision of services to rural and poor urban communities is community-based service delivery. It is often claimed that various civil society organizations are capable of delivering services more effectively than government agencies. Community-based organizations, water users' associations and non-governmental organizations (NGOs) can play important roles, independently or in partnership with government agencies. In addition to delivering services, they can act as a link between state and community, be directly responsible for natural resource management, or act as a 'watchdog'. Much of the competence of civil society organizations is found in their knowledge about and links in the local context, which are important in choosing appropriate solutions. Local knowledge can form a basis for flexible, innovative and dynamic institutional frameworks for sustainable water development. However, many civil society organizations have limited funds and membership, and rely on voluntary work and charismatic leadership. In many cases, the NGOs and other civil society organizations have been inconsistent in their work and have faced difficulties in maintaining and expanding their activities. As previously mentioned, government agencies tend to perceive civil society organizations in a rather narrow instrumental manner and their involvement is normally sought only for project implementation.

Partnership practices have illustrated that there is no blueprint to determine the appropriate model to use. It is obvious that many different kinds of partnerships are needed, ranging from personal or informal to voluntary or legally binding arrangements. They may be short-term and project-specific or long-term and broad in scope. They may involve sharing of work or financial costs, or the sharing only of information. Experience suggests that key ingredients in successful partnerships are a shared vision, compatibility, equitable representation, legitimacy, communication, adaptability, mutual trust and understanding, perseverance, fixed formal or informal rules and transparency. In many parts of the world there is a huge distrust between the state, civil society and the market, which does not render the formation of partnerships any easier.

3.1.11 Water governance and financing

In terms of financing, governance is essentially about creating a favourable environment to increase water investments and to ensure that investment is used correctly. Governance is also concerned with how capital is being spent and how more can be done with existing resources, or even with less. The economic rationale behind governance is that effective water governance is supposed to lower transaction costs by preventing corruption and increasing financial efficiency. A fundamental insight is that countries cannot 'construct' themselves out of water problems and capital-intensive infrastructure development must go hand-in-hand with developments in governance of water financing.

It is evident that the water sector is underfinanced and governments have not reached the financial targets set out in Chapter 18 of Agenda 21. However, the limited funds in many water development endeavours should not paralyse action. Currently, the main cost for water-related services in developing countries is carried by governments through taxation and service charges and, to a lesser degree, by donor assistance. The private sector is only modestly involved in water-related services. Governments of developing countries have not been able to raise adequate funds through taxation of the application of water tariffs for enhanced cost recovery. A recent report on financing water development in Africa pointed to some specific sources for additional funding

Financing development in Africa

- Water should be explicitly included in Poverty Reduction Strategy Papers.
- In most African countries, water management is dispersed between other sectors (agriculture, health, energy, etc.) and is not the responsibility of a specific ministry or authority.
- A fixed percentage of African government budgets (for example 5%) could be devoted to water resources development and management.
- Bilateral and multilateral aid could be earmarked as matching funds to African governments' budgetary commitments.
- Urban revenue could be transferred for rural water supply development and human and institutional capacity-building efforts.

- Private finance and public-private partnerships may be best suitable for urban areas. The role of private sector involvement in the African water sector is subject to debate.
- No amount of financial resources can solve Africa's water challenges without firm commitment by its political leaders and decision-makers. Efficient utilization of financial resources can only be achieved when a basic system of effective governance, including transparency, accountability and subsidiarity, is in place to guide public functions.

But, most importantly, the report acknowledged the interdependence between effective water governance, increased funding and efficient utilization of existing resources. The challenging task of raising additional funds should also render decision-makers aware of the need to complement capital-intensive investments with alternative low-cost technology, especially in the sanitation sector.

High levels of corruption and other financial mismanagement reduce the rate of economic growth. Corruption has a pervasive and troubling impact on poor people since it distorts allocation of water resources and related services in favour of the wealthy and powerful. Thus, poor people will receive a lower level of services and infrastructure investment will be biased against projects that serve the poor. The introduction of more effective governance systems with a strong autonomous regulatory authority and transparent and accountable processes would attract new financing. Improving capacity to prepare and manage contracts would also reduce bad utility practices, both public and private.

Throughout the past decade, many developing countries have sought to reduce debts and deficits. This has resulted in large reductions in infrastructure and services expenditure, with serious negative impacts on agencies responsible for water. Policy objective of debt and deficit reduction have led to significant withdrawal of human and financial resources in supporting environmental services, including water. However, the Heavily Indebted Poor Countries initiative is attempting to reverse this trend. Debt relief is being linked to poverty reduction and, therefore, not only are more funds being made available for the provision of basic services, but countries are being actively encouraged to spend more on these. It may be expected that this will lead to an expansion of funds for water supplies and sanitation services for the poor in both rural and urban areas.

The heavy dependence on public funding and unclear financing mechanisms, institutions and policies are some of the investment characteristics in many developing countries. These issues have to be addressed together with the need for increased financing. The government plays an important role in providing incentives to private finance by establishing clear regulatory and institutional frameworks. Governments should also ensure that poor people are served and can afford water-related services. Countries' economies and prospects for economic growth remain highly dependent on water and other natural resources. There is a growing need to adequately reflect the use of water and other natural resources in national income accounts. Additionally, there is an increasing demand for policies and institutional frameworks that can correct market failures and the economic and social undervaluation of water resources.

3.1.12 Conclusions

The water crisis is essentially about how we as a society and as individuals perceive and govern water resources and services. Although progress in water governance and related management areas has been incredibly slow and uneven, there are encouraging signs that water governance reform is taking place in many countries, promoting and facilitating coherent policy frameworks and institutional integration instead of fragmentation, partnerships and participation.

Water governance will be improved by raising the political will to overcome obstacles and implement water-related commitments made at Rio and afterwards. Although water reforms are evolving in many countries, much remains to be done to achieve the objectives of integrated approaches, sustainable development of water resources and the delivery of adequate water services.

Water resource issues are complex and transcend the water sector itself: indeed, there is an urgent need to broaden the horizon of water issues outside of the water sector. Macro-economic development, population growth and other demographic changes have greater impacts on water demands than water policy. This emphasizes the importance for water professionals to increase their understanding of broader social, economic and political context, while politicians and other key decision-makers need to be better informed about water resource issues. Otherwise water will continue to be an area for political rhetoric and lofty promises instead of implementation of sorely needed actions.

3.1.13 Institutions and conferences

The Water Supply and Sanitation Collaborative Council (WSSCC) is a global multi-stakeholder partnership organisation that works to improve the lives of poor people. WSSCC enhances collaboration among sector agencies and professionals around sanitation and water supply and contributes to the broader goals of poverty eradication, health and environmental improvement, gender equality and long-term social and economic development. The activities undertaken by WSSCC were recognized in the United Nations General Assembly resolution A/RES/45/181 of 21 December 1990. WSSCC is hosted by the World Health Organization (WHO). WSSCC's network of national WASH Coalitions and individual members give it the legitimacy and flexibility to work effectively at the grassroots level. Through Networking & Knowledge Management, Advocacy & Communications and the Global Sanitation Fund, WSSCC is at the forefront of knowledge, debate and influence on water, sanitation and hygiene (WASH) for all.
(http://www.wsscc.org/)

The World Water Assessment Program (WWAP), founded in 2000, is the flagship program of UN-Water. Housed in UNESCO, WWAP monitors freshwater issues in order to provide recommendations, develop case studies, enhance assessment capacity at a national level and inform the decision-making process. Its primary product, the World Water Development Report (WWDR), is a periodic, comprehensive review providing an authoritative picture of the state of the world's freshwater resources.

The following table shows the most important conferences that had been held on water issues:

1972–2009: from Stockholm to Turkey

Dates	Events	Outcomes	Quotations
1972	**UN Conference on the Human Environment. Stockholm** Main issues: preservation and enhancement of the human environment	Declaration of the UN Conference on the Human Environment	'A point has been reached in history when we must shape our actions throughout the world with a more prudent care for their environmental consequences.' (6. Declaration of the UN Conference on the Human Environment)
1977	**UN Conference on Water. Mar del Plata** Main issues: assessment of water resources, water use and efficiency	Mar del Plata Action Plan	'…relatively little importance has been attached to water resources systematic measurement. The processing and compilation of data have, been seriously neglected.' (Recommendation A: Assessment of water resources, Mar del Plata Plan)
1981-1990	**International Drinking Water and Sanitation Decade**		'The goal of the Decade was that, by the end of 1990, all people should possess an adequate supply and satisfactory means of excrete and sullage disposal. This was indeed an ambitious target as it has been estimated that it would involved the provision of water and sanitation services to over 650,000 people per day for the entire ten year period. Although major effort made by government and international organizations to meet this target, it was not achieved.' (Chogull, C; Francys, R.; Cotton, A. 1993. Planning for and Sanitation.)
1990	**Global Consultation on Safe Water and Sanitation for the 1990s. New Delhi** Main issues: safe drinking water, environmental sanitation	New Delhi Statement: 'Some for all rather than more for some'	'Safe water and proper means of waste disposal…must be at the centre of integral water resources management' (Environment and health, New Delhi Statement)
1990	**World Summit for Children. New York** Main issues: health, food supply	World Declaration on the Survival, Protection and Development of Children	We will promote the provision of clean water in all communities for all their children, as well as universal access to sanitation.' (18. World Declaration on the Survival, Protection and Development of Children)
	Beginning of the International Decade for Natural Disaster Reduction (1990–2000)	Recognition of increases general vulnerability of people and property to natural disasters	'to reduce through concerted international action, especially in developing countries, the loss of life, property damage and social and economic disruption caused by natural disasters…' (Resolution 44/236 of the UN General Assembly)

1992	**International Conference on Water and the Environment, Dublin** Main issues: economic value of water, women, poverty, resolving conflicts, natural disasters, awareness	Dublin statement on Water and Sustainable Development	Principle 1: 'Fresh water is a finite and vulnerable resource, essential to sustain life, development and the environment' Principle 2: 'Water development and management should be based on a participatory approach, involving users, planners and policy-makers at all levels' Principle 3: 'Women play a central part in the provision, management and safeguarding of water' Principle 4: 'Water has an economic value in all its competing uses and should be recognized as an economic good' (Guiding principles. The Dublin Statement on Water and Sustainable Development)
1992	**UN Conference on Environment and Development (UNCED Earth Summit), Rio de Janeiro** Main issues: cooperation and participation, water economics, drinking water and sanitation, human settlements, sustainable development, food production, climate change	Rio Declaration on Environment and Development Agenda 21	'…establishing a new and equitable global partnership through the creation of new levels of cooperation among States, key sector societies and people' (Rio Declaration) 'The holistic management of freshwater…and the integration of sectoral water plans and programs within the framework of national economic and social policy are of paramount importance for action in the 1990s and beyond.' (Section 2, Chapter 18, Agenda 21)
1994	**Ministerial Conference on Drinking Water Supply and Environmental Sanitation, Noordwijk** Main issues: drinking water supply and sanitation		'To assign high priority to programs designed to provide basic sanitation and excreta disposal systems to urban and rural areas.' (Action Program)
1994	**UN International Conference on Population and Development. Cairo**	Program of Action	'To ensure that population, environmental and poverty eradication factors are integrated in sustainable development policies, plans and programs.' (Chapter III – Interrelationships between population, sustained economic growth and sustainable development, C-Population and Environment, Program of Action)

1995	**World Summit for Social Development. Copenhagen** Main issues: poverty, water supply and sanitation	Copenhagen Declaration on Social Development	'To focus our efforts and policies to address the root causes of poverty and to provide for the basic needs of all. These efforts should include the provision of…safe drinking water and sanitation.' (Chapter I – Resolutions adopted by the Summit, Commitment 2.b. Copenhagen Declaration)
1995	**UN Fourth World Conference on Women, Beijing** Main issues: gender issues, water supply and sanitation	Beijing Declaration and Platform for Action	'Ensure the availability of and universal access to safe drinking water and sanitation and put in place effective public distribution systems as soon as possible.' (106 x, Beijing Declaration)
1996	**UN Conference on Human Settlements (Habitat II), Istanbul** Sustainable human settlements development in an urbanizing world	The Habitat Agenda	'We shall also promote healthy living environments, especially through the provision of adequate quantities of safe water and effective management of waste.' (10. The Habitat Agenda, Istanbul Declaration on Human Settlements)
1996	**World Food Summit, Rome** Main issues: food, health, water and sanitation	Rome Declaration on World Food Security	'…to combat environmental threats to food security, in particular, drought and desertification…restore and rehabilitate the natural resource base, including water and watersheds, in depleted and overexploited areas to achieve greater production.' (Plan of Action, Objective 3.2, Rome Declaration)
1997	**First World Water Forum, Marrakech** Main issues: water and sanitation, management of shared waters, preserving ecosystems, gender equity, efficient use of water	Marrakech Declaration	'to recognize the basic human needs to have access to clean water and sanitation, to establish an effective mechanism for management of shared waters, to support and preserve ecosystems, to encourage the efficient use of water.' (Marrakech Declaration)
1998	**International Conference on Water and Sustainable Development, Paris**	Paris Declaration on Water and sustainable Development	'to improve co-ordination between UN Agencies and Programs and other international organizations, to ensure periodic consideration within the UN system… [To] emphasize the need for continuous political commitment and broad-based public support to ensure the achievement of sustainable development, management and protection, and equitable use of freshwater resources, and the importance of civil society to support this commitment.' (Paris Declaration)

2000	**Second World Water Forum, The Hague** Main issues: water for people, water for food, water and nature, water in rivers, sovereignty, inter basin transfer, water education	World Water Vision: Making Water Everybody's Business	• Involve all stakeholders in integrated management; • Move to full-cost pricing of water services; • Increase public funding for research and innovation; • Increase cooperation in international water basins; • Massively increase investments in water' (Vision Statement and Key Messages, World Water Vision)
	Ministerial Declaration 7 challenges: Meeting basic needs, Securing the food supply, Protecting ecosystems, Sharing water resources, Managing risks, Valuing water, Governing water wisely	Ministerial Conference on Water Security in the 21st Century	'We will continue to support the UN system to re-assess periodically the state of freshwater resources and related ecosystems, to assist countries where appropriate, to develop systems to measure progress towards the realization of targets and to report in the biennial World Water Development Report as part of the overall monitoring of Agenda 21.' (7. B, Ministerial Declaration)
		UN Millennium Declaration	'We resolve…to halve, by the year 2015…the proportion of people who are unable to reach or to afford safe drinking water.' (19, UN Millennium Declaration)
End of the International Decade for Natural Disaster Reduction (1990–2000)			
2001	**International Conference on Freshwater, Bonn** Water – key to sustainable development	Ministerial Declaration	'Combating poverty is the main challenge for achieving equitable and sustainable development, and water plays a vital role in relation to human health, livelihood, economic growth as well as sustaining ecosystems.' (Ministerial Declaration)
	Main issues: governance, mobilizing financial resources, capacity-building, sharing knowledge	Recommendations for action	'The conference recommends priority actions under the following three headings: • Governance • Mobilising financial resources • Capacity building and sharing knowledge' (Bonn Recommendations for Action)
2002	**World Summit on Sustainable Development. Rio+10. Johannesburg**	Johannesburg Declaration on Sustainable Development	'We recognize that poverty eradication, changing consumption and production patterns, and protecting and managing the natural resource base for economic and social development are overarching objectives of, and essential requirements for sustainable development.' (Para. 11, Declaration on Sustainable Development)

		Plan of Implementation	'The provision of clean drinking water and adequate sanitation is necessary to protect human health and the environment. In this respect, we agree to halve, by the year 2015, the proportion of people who are unable to reach or to afford safe drinking water (as outlined in the Millennium Declaration)I and the proportion of people who do not have access to basic sanitation.' (II. 7, Plan of Implementation) 'Develop integrated water resources management and water efficiency plans by 2005, with support to developing countries, through actions at all levels to: a) Develop and implement national/regional strategies, plans and programs with regard to integrated river basin management, b) Employ the full range of policy instruments, including regulation, monitoring, voluntary measures, market and information-based tools. c) Improve the efficient use of water resources.' (IV. 24, Plan of Implementation)I
2003	**International Year of Freshwater**		'Water is likely to become a growing source of tension and fierce competition between nations, if present trends continue, but it can also be a catalyst for co-operation. The International Year of Freshwater can play a vital role in generating the action needed – not only by governments but also by civil society, communities, the business sector and individuals all over the world.' (UN Secretary-General, Kofi Annan)
2003	**3rd World Water Forum, Kyoto**	Ministerial Declaration Governance, integrated water resources management, gender, pro-poor policies, financing, cooperation, capacity-building, water use efficiency, water pollution prevention, disaster mitigation 1st edition of United Nations World Water Development Report[2]	'We recognize that good governance, capacity building and financing are of the utmost importance to succeed in our efforts.' (Ministerial Declaration)
Beginning of the International Decade for Action 'Water for life' (2005–2015)			

2006	**4th World Water Forum, Mexico**	Ministerial Declaration Water for growth and development, Implementing Integrated Water resources Management (IWRM), water supply and sanitation for all, water management for food and the environment, risk management, responsibility of Governments, increased financial commitments. 2nd edition of the United Nations World Water Development Report[3]	'Reaffirm the critical importance of water, in particular freshwater, for all aspects on sustainable Development.' (*Ministerial Declaration*)
2009	**5th World Water Forum Istanbul, Turkey**		Bridging Divides for Water

(http://www.unesco.org/water/wwap/milestones/) and (World Water Assessment Programme, 2009a, p. 304).

Further readings

http://unesdoc.unesco.org/images/0012/001295/129556e.pdf

3.2 Hydropolitics

It has been predicted that access to water will create severe conflict between countries. In Africa, central Asia, west Asia and the Americas, some countries are already arguing fiercely over access to rivers and inland seas, and confrontations could arise as water shortages grow. Countries currently or potentially involved in international disputes over access to river water and aquifers include: – Turkey, Syria and Iraq (the Tigris and Euphrates rivers); – Israel, Jordan, Syria and Palestine (the Jordan River and the aquifers of the Golan Heights); – India and Pakistan (the Punjab rivers); – India and Bangladesh (the Ganges and Brahmaputra rivers); – China, Indochina and Thailand (the Mekong River); – Tajikistan, Kyrghyzstan and Uzbekistan (the Oxus and Jaxartes rivers); – Ethiopia, Sudan and East African riparian countries, including Kenya, Tanzania, Rwanda, Burundi, Uganda and Egypt (the Nile River). All these countries are known to be experiencing water scarcity or water stress per capita because they are using their water resources excessively (based on UNDP/GRID-Arendal 2009. *Tigris and Euphrates rivers fragmentation.* from http://maps.grida.no/go/graphic/tigris-and-euphrates-rivers-fragmentation)

History shows that conflicts over water often emerge and give rise to political tensions, but that most disputes are resolved peacefully. However, the absence of conflict is, at best, only a partial indicator of the depth of cooperation. Measuring the level of conflict between governments over water is inherently difficult as water is seldom a stand-alone foreign policy issue. Oregon State University has attempted to compile data covering every reported interaction over water going back 50 years. What is striking in these data is that there have been only 37 cases of reported violence between states over water (30 of them in the Middle East). Over the same period more than 200 water treaties were negotiated between countries. In all, 1.228 cooperative events were recorded, compared with 507 conflict events, more than two-thirds of which involved only low-level verbal hostility (Plate 31).

Most of the conflict events were related to changes in the volume of water flow and the creation of new infrastructure, which could affect future timing and volume of water flow. Looking back over the past half-century, perhaps the most extraordinary water governance outcome has been the level of conflict resolution and the durability of water governance institutions. The Permanent Indus Water Commission, which oversees a treaty on water sharing and a mechanism for dispute resolution, survived and functioned during two major wars between India and Pakistan. (based on UNDP/GRID-Arendal 2009. *Water – Cooperation or Conflict?* from http://www.grida.no/publications/vg/water2/page/3264.aspx).

3.2.1 Water utilisation in international rivers

International rivers are defined as drainage basins shared by two or more states or constitute the boundary between them. They are formed by hydrographical components such as rivers, lakes, canals and groundwater constituting, by virtue of their physical relationship, a unified whole, where any use affecting waters in one part of the system may affect waters in another part.

There are over 200 international rivers, but only 140 of these rivers have river basins sufficiently large in size for use and development. There are forty-three international rivers in the Americas, twenty in Europe, twenty-seven in Africa and fifty in Asia.

Basin-wide planning is needed because of the physical unity of a river basin where intervention in one area is going to influence other parts of the basin. The hydrology of a river does not change when an international frontier runs across or along it – only the politics change. Demands on the water resource are different among basin countries owing to many factors including population growth, economic development, cultural practices, foreign policy objectives and the availability and accessibility of other domestic water resources. Thus international rules are needed to regulate the different demands. The following text, based on Kliot (1994, pp. 2–10), describes some legal principle that have evolved over the past years.

Planning and utilization of rivers

Two basic concepts which have evolved during the first half of this century concern the purposes and the planning of water projects. Any water project must first be defined as a single-purpose development project or a multipurpose project. Most of the major water projects are multipurpose, a fact which imposes on planners the major task of co-ordinating the various and possibly conflicting numbers of targets for water resource development. International rivers have always been used for navigation, irrigation and as hydropower sources for flour-milling, mining and metallurgy. They have also served as sources of drinking water and for recreational purposes. The basic idea behind multipurpose planning is that as many water uses as possible should be included in any water project.

Planning, the second concept concerning water resource development, can be unified planning, co-ordinated planning or the most desired form of planning method – integrated planning. Integrated planning is crucial in international river basins because jurisdictional divisions are imposed on the physical and hydrological unity of river basins. Integrated planning operates in two ways: (a) between countries within an international river basin and (b) between projects within a country. The need for integrated river basin development arises from the relationship between the availability of water and its possible uses in the various sectors of a drainage area. It is now recognized that individual water projects, whether single purpose or multipurpose, cannot, as a rule, be undertaken with optimum benefit for the people affected before establishing the broad outlines of a plan for the entire drainage area. Integrated river basin development involves the coordinated development of the various projects in relation to all the reasonable possibilities of the basin. These may include irrigation and drainage, electric power production, navigation, flood control, watershed treatment, industrial and domestic use of water, recreation and wild life conservation.

When considering the broad possibilities for water use it is important to distinguish between consumptive and non-consumptive uses. Consumptive uses are those in which the water is wholly or largely used up. Irrigation and domestic uses are consumptive uses but even here some of the water can be re-cycled and re-used. Navigation represents a non-consumptive use and another example is provided by the utilisation of water for the generation of hydro power, since the physical quantity of the water used in the production of hydroelectricity remains undiminished. Some of the non-consumptive uses, however, may cause deterioration in water quality and water contamination has become a source of major concern all over the world.

The most desirable method for international water basin management is multipurpose integrated river basin development. Most integrated basin development has occurred on rivers which flow wholly within a single state: thus, in the former Soviet Union, the Volga-Kama, Don-Dnepier and Syr-Darya systems have been the subjects of basin-wide development; in the USA the concept has been extended to include an entire region under the Tennessee River Valley Authority. To a lesser extent multiple-purpose development has occurred on a unilateral basis on those portions of international streams located within the boundaries of a particular state. For example, projects on the Tigris-Euphrates have been executed by and for the sole benefits of Iraq respectively. This generalization, however, is no longer accurate for the Tigris-Euphrates system since it is at present used by all its co-riparians: Syria, Turkey and Iraq.

Integrated river basin development seldom takes place in international water basins because the co-riparians compete with each other and adopt methods of consumptive water utilization which curtail or eliminate other riparian rights to the river's waters. Hence, conflict over water resources is almost inevitable. Possible conflict may arise as a result of various uses: navigation versus irrigation or sanitary uses versus navigation. In the Middle East the irrigation needs of one country often clash with the irrigation needs of another. Ordinarily, conflicts over such consumptive uses are less likely to be resolved than conflict over non-consumptive uses.

Water use in international rivers

To the extent that the use of waters of an international water-course system in the territory of one system state affects the use of waters of that course system in the territory of another water-course state, the waters are considered a shared natural resource.

The UN Water Conference at Mar del Plata, Argentina (1977), clearly declared that: 'In relation to the use, management and development of shared (international) water resources, national policies should take into consideration the right of each state sharing the resources to equitably utilize such resources as the means to promote bonds of solidarity and cooperation'.

The major problem in the management of international rivers is the sovereignty of the states which share the river basin. Co-operation in the development of an integrated river basin is a challenge to the state's proclaimed sovereignty over its resources. States must feel that they will be compensated economically and politically by the other riparians for their readiness to co-operate and share water resources.

Four major legal principles concerning the sovereignty of the states over water resources have evolved over the years.

1. The principle of *absolute territorial sovereignty* (Harmon Doctrine)

According to this concept, a state has the right to use the fluvial waters which lie within its territory without any limitation whatsoever, regardless of the effects of this utilization on other states. This theory is known as the Harmon Doctrine after J. Harmon, Attorney General of the USA, who expounded it in 1895 during a dispute with Mexico over the utilization of the waters of the Rio Grande.

The doctrine has often been adopted by the upper riparian states which claim that a state, being fully sovereign over its own territory, may act within that territory as it sees fit no matter what the consequences to co-riparians may be. Generally, upstream position confers marked power advantages. Diversion, overuse, contamination and flow delay are tactics available for use in accordance with one's (superior) position. There is a general agreement nowadays that the Harmon Doctrine was not an expression of international river law. Rather, it was an assertion that, since no rules of international law governed the usage of water, states were free to do as they wished. This doctrine, which contradicts the international law, was rejected by the USA a few times after it was used.

2. The principle of absolute territorial integrity

Lower riparians often favour the principles of *absolute territorial integrity* by which no state may utilize the waters of an international river in a way which might cause any detrimental effects on co-riparian territory. This means that states must conduct themselves within the limits of their territories in such a way as not to alter the natural regime of the river when it runs through the territory of another state. This principle was advocated by Egypt at the Nile Commission in 1925 but Egypt later retreated from this position.

The doctrine is often tied to *prior appropriation* of water, in which existing water rights of lower riparians must first be respected and satisfied before any other claims can be met. At present existing use is one of the factors which need to be taken into account when determining what the just and equitable sharing of the benefits of an international river basin is. Existing uses of the water by one country may also exceed the reasonable share to which that country may equitably be entitled. Prior appropriation may simply reflect the fact that one area was favoured by its previous European masters over another area.

Intermediate theories

The Harmon Doctrine and the theory of absolute territorial integrity constitute two extreme positions. Between them there are other concepts which are more pragmatic, which state that use of the water of international rivers is subject to various restrictions which may favour the other riparian states (doctrines 3 and 4). All these intermediate theories were evolved out of the conviction that no state should harm the water utilization of another state.

3. Condominium or common jurisdiction of all riparians

The condominium or common jurisdiction of all riparians over the whole international river or river system aims at limiting a state's freedom of action over the utilization of international rivers. The application of this principle would mean that a state would need to obtain prior consent from co-riparians for all projects concerned with the utilization of the waters. According to this system, based on the community theory, the emphasis is placed on the mutual development of a river's waters by all riparian states.

International law has recognized that a river is the property of the community of all riparian states. This has been followed by recognition of the existence of certain limitations to territorial sovereignty in favour of the international community in general.

Many treaties which regulate the use of boundary waters are based on the acceptance of this principle. The principle as such (though without any formal agreement) has been acknowledged for example by Israel and the Arab states in their conflict over the Jordan River. The Permanent Court of International Justice has confirmed the principle of limited sovereignty in its adjudications over the case of the River Oder and in the case of Lake Lanoux arbitration between France and Spain.

4. The principle of equitable utilization

Finally, there is the principle of equitable utilization, which permits use of a river's waters to the extent that this does no harm to other riparian countries. This principle has become the most widely advocated by the international legal community, as evidenced by treaties, judicial decisions, academic research and international bodies. The best expression of the principle of equitable utilization can be found in the *Helsinki Rules* drawn up by the non-governmental International Law Association (lLA) in 1966, and they have become the accepted legal foundation for utilisation of international rivers.

Law experts have made in 1992 a more detailed division of the above general principles of international law concerning international rivers and defined the following seven doctrines:

1. the doctrine of riparian rights
2. the prior appropriation doctrine
3. the theory of absolute territorial sovereignty

4. the theory of absolute territorial integrity
5. the theory of equitable apportionment
6. the theory of limited territorial sovereignty
7. the theory of equitable utilization

Another international organization working on a set of rules for sharing international water resources is the ILC, a UN affiliated body. Since 1971 this organisation has been developing the Law of the Non-Navigational Uses of International Watercourses, and by 1992 some thirty-two articles had been formulated and approved.

Article 6 of the ILC set of rules firmly states that equitable and reasonable utilization of participation in international river basins is the only principle accepted in the body of international law. The Helsinki Rules concerning international river basins were compiled in 1966, based on the principle of equitable distribution. In subsequent years this body compiled rules about flooding and marine pollution of land origin (New York, 1972); about cost allotment for the conservation of navigable rivers (New Delhi, 1974); about the administration of international water resources and protection of waterworks in the case of war (Madrid, 1976); about the pollution of basins (Montreal, 1982); and about underground water (Seoul, 1986). The Committee on International Water Resources (which organized the work of the various conferences listed above) terminated its activity in 1988.

The Helsinki Rules on the Uses of the Waters of International Rivers contain six chapters. The first chapter is a general chapter which defines the term 'international drainage basin'. Chapter 2, which has five articles, deals with the equitable utilization of the waters of international drainage basins; Chapter 3, which contains three articles, formulates rules concerning pollution. Chapter 4 presents nine articles concerning navigation in international river basins. The remaining two chapters concern timber floating (Chapter 5) and procedures for the prevention and settlement of disputes (Chapter 6).

The ILC Law of the Non-Navigational Uses of International Watercourses contains thirty-two articles. Articles 1–4 are general articles which provide the basic definitions. Article 5 deals with equitable and reasonable utilization of watercourse systems. Article 6 presents the factors relevant to equitable and reasonable utilization. Article 7 specifies the obligation not to cause harm. Articles 8 and 9 deal with the general obligation of co-riparians to co-operate and exchange data and information. Articles 10–23 provide a whole framework for co-operation among co-riparians when they plan to develop international water courses.

Chapter 2 of the Helsinki Rules begins with Article IV which states that each basin state is entitled to a reasonable and equitable share of the benefits deriving from the use of the waters of an international drainage basin. Article V contains the following eleven relevant factors involved in the equitable utilization of international river basins:

a) the geography of the basin including, in particular, the size of the drainage area in the territory of each basin state;
b) the hydrology of the basin including, in particular, the contribution of water by each state;
c) the climate affecting the basin;
d) the past utilization of the waters of the basin including, in particular, existing utilization;
e) the economic and social needs of each basin state;
f) the population dependent on the waters of the basin in each state;
g) the comparative costs of alternative means of satisfying the economic and social needs of each basin state;
h) the availability of other resources;
i) the avoidance of unnecessary waste in the utilization of waters of the basin;
j) the practicability of compensation to one or more of the co-basin states as a means of negotiating settlements over conflicts among users;
k) the degree to which the needs of a basin state may be satisfied without causing substantial injury to another basin state.

Rules concerning international aquifers were formulated at the Seoul meeting of the ILA. The rules called for the prevention of pollution of international groundwater, the exchange of relevant information concerning the aquifer and integrated management 'including conjunctive use with surface waters, of their international groundwater'. But there is no suggestion of how these waters should be divided among the co-riparians.

The relevant articles of the ILC Rules which are compatible with the above Helsinki Rules are Articles 5 and 6. Article 5 calls for equitable and reasonable utilization and participation in the international river basin. Article 6 specifies the factors relevant to the equitable and reasonable utilization of international rivers:

a) geographic, hydrographic, hydrological, climatic and other natural factors;
b) the social and economic needs of the water course states concerned;
c) the effects of the use or uses of an international water course (system) caused by one water-course state to other water-course states;
d) the existing uses of the international water course (system);
e) conservation, protection, development and economy of use of the water resources of the international water course (system) and the costs of measures taken to effect the above;
f) the availability of alternatives, of corresponding value, for a particular planned or existing use.

It is extremely important to note that neither the Helsinki Rules nor the ILC Rules are legally binding, but the principle of equitable utilization of international river basins has become that most widely advocated by the international legal community. On the basis of state practice almost all scholars and researchers who have studied this question maintain that equitable utilization is a norm of international law. However, as yet, there have been only a few adjudications over international water disputes and thus few opportunities to apply the doctrine in a practical setting.

Many treaties and 'state practices' reflect the adoption of the Helsinki Rules or ILC Rules. Thus the responsibility to supply prior information about plans to use the water of international rivers was demonstrated in the arbitration process concerning Lake Lanoux between Spain and France and in the Treaty of the Rio de la Plata. The agreement reached between the USA and Mexico for the protection and improvement of the environment in the border area which regulates the issue of trans-boundary pollution is an example of the adoption of Helsinki Rule V or ILC Rules which advocate avoidance of any detrimental change in the quality of water in international rivers. A similar principle has been applied by the International Commission for the Protection of the Rhine against pollution.

The principle of respecting existing water utilization when new projects are developed was adopted in the case of the Helmand River which was the focus of a dispute between Afghanistan and Iran and in the case of the River Roji, which is shared by Italy and France. The 1963 agreement over the River Niger provided support for the norm of legitimate utilization of an international river and its tributaries by each riparian state. The use made by the eleven co-riparians in respect of the portion of the River Niger base lying in their respective territories was recognized and this principle was also adopted by South American countries. This principle is consistent with the Helsinki Rules (Article V (a)) and ILC Rules (Article 6 (d)).

In the Columbia River Treaty, Canada agreed to permit the USA to use large areas of Canadian territory for storing water for flood control. In return, the USA agreed to pay for this use with both hydroelectric power and money. This solution is also consistent with Articles V (i) and V (j) of the Helsinki Rules which refer to the principles of avoiding the unnecessary waste of water and the practicability of compensation for co-basin states. The co-operative investigation program in the Lower Mekong River and the common committee for the co-riparians to the Senegal River which oblige members to submit projects to it are other examples. In Europe, co-operation over the Rhine and Danube mainly concerns matters of navigation and hydroelectric power; consumptive use and pollution are seen as secondary.

Thus, whereas the Helsinki Rules do not have formal legal status they serve as guidelines for state practice in various parts of the world. Moreover, there are legal interpretations of these regulations. For example, there is agreement that while the cornerstone of equitable utilization is equality of right, this is not synonymous with the equal division of waters. Equitable utilization is concerned with the economic and social needs of the co-riparians, and the water should be distributed in such a manner as to satisfy needs to the greatest extent possible and provide maximal benefits for each co-riparian. Equitable utilization minimizes the damage one state might cause another but it cannot always prevent it entirely. Such utilization also indicates that, although the right to equitable utilization is recognized only in so far as it relates to the beneficial use of the water, underdeveloped states which are incapable of meeting the efficiency standards for the utilization of irrigation waters will not be deprived of their water, provided that no user is wilfully wasteful or inefficient.

A special problem is presented by the principle of prior appropriation or the 'natural' or 'historic' right of a state to utilize water. Under international law, it is clear that existing uses have preferential status over projected uses in matters of equitable utilization. The practice of states, however, has not reflected approval of the primacy of the doctrine of prior appropriation to the exclusion of other factors. The right of prior or existing use was recognized in the Nile Commission discussions (1929), but the existing treaties refer to protecting 'existing' uses rather than 'prior' uses. Where the conflict is over respective existing uses, the comparative period of use is disregarded and the 'existing use' factor is neutralized, thus eliminating its important role in equitable utilization.

Another problem presented by the existing norms for equitable utilization is raised by the notion of 'preferential use', namely preference given to a particular use within an international river over other different and perhaps conflicting uses. This derives its significance from a time when navigation was considered supreme to any other use. At present, however, no use or category of uses is entitled to any preference over any other use or category of uses. This is clearly expressed in the Helsinki Rules, but there seems to be a tendency among governments and courts to give drinking and other domestic uses preference over other uses. One can thus see the complexities of weighing the various needs of co-riparians to an international basin. In 1986, the ILA adopted three complementary rules to the Helsinki Rules. Article 1 called states to prevent acts or omissions within one's territory that would cause substantial injury to any co-basin states. Article 2 called for co-ordination in connection with water utilization and Article 3 called for providing notice on any water projects to all the co-riparians. The Seoul Conference also defined, for the first time, international groundwater aquifers and called for the prevention of pollution of such aquifers, formulated the necessity to consult and exchange relevant information concerning utilization of such water, and called for a common management of such groundwater.

Three other legal and customary principles which have developed in relation to international rivers also assist in sharing water more equitably. The first is the principle of mutual benefits. An upstream country may be reluctant to go ahead with its projects unless it can be assured of receiving some compensation for the unexploited water resource it might send downstream. The benefits, which might be economic or political, must be clearly described in quantitative and qualitative terms to all riparian states, in order for them to agree to co-operate. Reciprocity of benefits distributed is needed in order to gain the co-operation of all riparian states. The second principle is the principle of linkage. Agreement with a neighbour state about an international river project that the neighbour might want may be used to gain concessions for other bilateral issues such as favourable trade arrangements or support for some multilateral policy. Linkages between policy areas are typical of countries with high levels of conflict. Finally, the third and last factor which shapes water utilization is the attitude a state adopts in legal matters and, more particularly, to international law concerning international rivers. The image a country wishes to project can also be important and so the desire to pursue a good neighbour policy, to be a model of cooperative international behaviour, will influence a country's willingness to co-operate with its riparian neighbours.

The legal norms and customary international law which has been presented in such detail here conceal the important but sorry fact that conflicts over the precious waters of international rivers are common phenomena, as can be seen in the case of the Jordan Basin.

Examples of current and potential surface water conflicts involve the Nile, Senegal, Niger, Zambezi and Orange Rivers in Africa and the Jordan River in the Middle East. Others are the construction of the Atatürk Dam in Turkey and its far-reaching consequences for the Euphrates flow in Iraq.

Finally three types of conflicts are distinguished, which can be usefully applied to identify the current conflicts over water resources:

a) Cognitive conflicts represent our disagreements about the 'facts'. These lead to debates over the extent and availability of resources because of differences about factual data – something increased knowledge and research were supposed to help prevent.
b) Stakeholder conflicts reflect the patterns of power distribution, the historical coalitions of social power or, more broadly, the 'parties at interest'. Such conflicts exemplify the question of 'who is at stake' and refer not only to the obvious national entities but also to regional, community, local and other sub-national interest groups.
c) Ideological conflicts are really the ultimate expression of values and priorities. They reflect not only different models of social development (e.g. conservation versus exploitation) but more subtle orientations towards the present and the future.

The Arab world

"One of the focal points of quarrels over scarce water lies in the Arab world. One-quarter of it has no surface water, yet it has the fastest growing population outside tropical Africa. Population in the Middle East could increase by 34 million over the next 30 years and water demand is likely to rise to 470 billion m^3 per year, 132 billion more than the total available even with dramatic conservation measures. Worse still, most of the significant water resources are shared between Arab and non-Arab nations that have a history of enmity.

Local rainfall is both sparse and highly variable. Cairo has a mean annual rainfall of 22 mm, which ranges from 1.5 to 64 mm, yet at least 400 mm is needed for successful cropping. The Arabian Peninsula is most vulnerable of all, with less than 100 mm per year and no major rivers. Saudi Arabia has only one-third of the estimated minimum rainfall resources needed for producing successful crops. It has become the seventh largest grain exporter only by 'mining' its aquifers, which will become exhausted in 20–100 years. Despite this paucity of freshwater resources, however, at least Saudi Arabia and the Gulf states are not (as yet) dependent on international water sources, and they do have coastlines and cheap oil to power desalination plants. Iraq, Jordan and Egypt are in more difficult positions" (Jones, 1997, p. 330).

3.2.2 Case study: The Jordan Basin

Water has an unusual strategic significance for Israel, because high levels of immigration, especially from the former Soviet Union, increased its population by 25% in the early 1990s, and securing its water resources continues to be an important element in military and political decisions. The struggle for water in this basin has been going on for a long time and was one of the reasons for the wars Israel was waging against its Arab neighbours.

On the Jordan Basin the complex ramifications of water claims with political and historical issues can be exemplified very well. Thus the case study, which is mainly based on Sabbagh (1999) and Dombrowsky (2001), will describe all dimensions in great detail. The text will be restricted mainly to Israel and the Kingdom of Jordan. Lebanon and Syria is not primarily dependant on Jordan water but the Kingdom of Jordan is. Although the largest part of it is situated in greater distance to the Jordan Basin, the river nevertheless plays an important role for this country, as the vast majority of its population lives rather close to the western border, which for the most part is identical with the watercourse.

Political development

The conflict began with the immigration of the Jews to Palestine in the beginning of the 20th century. After World War I and the decline of colonial powers the Zion movement demanded on the Paris peace conference 1919 an own state in the Middle East which comprised the whole Jordan basin, but the British Mandatory Territory was divided into Transjordania and Palestine. By this act the Jordan became an international boundary. In a next step Palestine was to be separated into an Arabian and a Jewish part. In 1947 this separation was carried out.

After the withdrawal of the British in 1948 the National Jewish Council declared the independent state of Israel, which has not been recognized by the Arabs up to now. In the so called Independence War in 1948 Israel enlarged her territory. The West Jordan land (CIS-Jordania) fell to Jordan and the Gaza-strip fell to Egypt. The former international city of Jerusalem was occupied by Israel and has been under Israel administration ever since.

In the so called Six-day War beginning on 5th June 1967 Israel was attacking Egypt. Five days later Syria was also attacked and the Golan Heights were occupied (Plate 32). At the end of the war Israel had occupied the West Jordan land (the Arab territory of Palestine), the Gaza strip and the Golan Heights. Israel had now control over the whole Jordan basin.

Rivers and lakes in the Jordan Basin

The Jordan River is, together with its headstreams and tributaries, the predominant water resource in the region. Stretching 360 km from the source of the Hasbani on the Anti-Lebanon Mountains in Southern Lebanon to its outlet into the Dead Sea, the Jordan River has a catchment area of approx. 18.300 km².

The Jordan River is fed by three major headstreams of which the most important one is the Dan. It has its source in northernmost Israel and contributes an average of 250 Mio. m^3 per year to the river system. The tributaries Hasbani and Banias deliver another 125 Mio. m^3/a each, but unlike the Dan River, these two streams do not rise on official Israeli territory, as the Hasbani has its source in southern Lebanon, and the Banias originates on the Golan Heights, a mountain range originally belonging to Syria, but occupied by Israel during the Six-Days-War and eventually annexed in 1981.

After further smaller tributaries and wadis from the Golan have added up to 300 Mio. m^3/a the Jordan crosses the Hulah Basin, a former swamp area, before flowing through Lake Genezareth (also called Lake Tiberias or Sea of Galilee). The largest fresh water lake in the region is situated 210 m below sea level and is up to 55 m deep. But although the theoretical input from the north is considerably high, due to its surface of 170 km^2 being exposed to a semi-arid climate, the high evaporation limits the annual amount of renewable water to about 510 Mio. m^3/a.

South of this lake the Yarmuk River coming from the east joins the Jordan. Its theoretical annual amount of water is subject to considerable deviations – the average amount lies between 400 and 500 Mio. m^3/a, and maxima of up to 600 Mio. m^3/a have been recorded. Its annual contribution is not only unreliable, but the amount is also highly varying over the year. Three quarters of its waters flows in only five months, with 25% in February alone.

Further south, only minor rivers (most notably the Zarqa, coming from Jordania) and wadis feed the Jordan River, adding approx. 300 Mio. m^3/a in total.

So, all in all, up to almost 1.500 Mio. m^3/a of usable water could reach the Dead Sea under natural conditions each year. But due to the heavy usage of Jordan water by all of the riparians, only an estimated amount of between 250 and 300 Mio. m^3/a (a mere fifth!) effectively drains into the salt lake at the lowest point of the earth's land mass.

Precipitation

Whereas elsewhere in the humid climate in Central Europe rain provides a reliable source for fresh water this is not the case in this region. The Jordan Basin is situated in a part of the world that is exposed to a semi-arid to arid climate with high seasonal, annual and spatial variations. This is due to the shifting of the Inner-Tropical Convergence Zone, which pushes the humid westerly winds further north and creates high pressure cells for most of the year, therefore restricting most of the annual rainfall to the winter months. In addition to a distinctive seasonal variation the annual variation can be up to 50%. But even more crucial for the region is the overall amount of precipitation. Even the Israeli maxima in western Galilee (around Mount Carmel and Mount Meron) do not exceed Central European standards. Only the mountainous regions of south-western Syria and eastern Lebanon surpass 1.000 mm/a, and in the Jordan trench the mean values are considerably lower: the highest precipitation is gauged in Hulah Valley with 525 mm. Southwards, the amounts decline radically, from 400 mm at Lake Genezareth over 200 mm in the Jordan Valley down to 100 mm around the Dead Sea and to only 50 mm at Eilat by the Red Sea.

Aquifers

All of the major aquifers that are decisive for the storage of ground water in the region are situated in disputed areas (Plate 33). The most important one is the Mountain Aquifer in the West Bank. Split up in three parts (the Western, the Eastern, and the North-Eastern), it has an annual yield potential of 679 Mio. m^3/a of renewable fresh water, thus being one of the most significant sources in the Jordan Basin.

Situated close to the Mediterranean Sea is the Coastal Aquifer, which is politically separated into the Israeli and the Gaza Aquifer. The much larger part is lying in Israel, providing about 240 Mio. m^3/a, more than four times as much as the potential in the Gaza strip with 55 Mio. m^3/a. Due to their allocation close to the Mediterranean Sea, however, the overexploitation of these ground water resources leads to an increased intrusion of brine (salty water), making the fresh water practically useless.

Claims of the riparians on the water resources

The water resources in this part of the Middle East are less than opulent, but only if they are related to the number of people that depend on this resource the dimension of the problem becomes explicit. Although less than 10 million people are living in Israel and the occupied territories, the population density reaches the highest values found in Europe. With 303 people per km^2 in mainland Israel and 509 people/km^2 in the occupied territories and even 2.824 people/km^2 (!) in the Gaza Strip, it becomes obvious that the existence of so many people in a region with scarce natural fresh water resources and low precipitation must result in a severe water shortage.

Compared to the riparians of the middle and lower Jordan Basin their northern and eastern neighbours are far better off. Researchers have defined water scarcity when there are less than 1.700 m^3/a available per person. So Syria already suffers from water scarcity, and Israel, Jordan and Palestine are even far below the critical limit of 1.000 m^3/a, that marks the dividing line between water scarcity and acute water stress. This extreme discrepancy between supply and demand elucidates the urge of the affected nations to get hold of as much fresh water sources as possible in order to provide their populations with this essential resource.

Extractions from the Jordan Basin

The extensive usage of fresh water from the Jordan Basin by the Israelis began in the 1960s. Since then, Israel has been taking up to 330 Mio. m^3/a from Lake Genezareth and is pumping it to all parts of the country via the National Water Carrier (NWC) (Plate 32). The planning of this national water pipe commenced in 1953 and the construction was completed eleven years later, in 1964. Connecting older pipe networks like the Yarkon-Negev-System, starting near Tel Aviv, with other regional systems, the overall length of the NWC adds up to 130 km and consists of open canals and smaller tunnels in the north, before turning into a completely subterranean pipe further south.

Due to the necessity of pumping this giant amount of water over the ridge of the Jordan Trench and the Carmel Mountains all the way to the coastal plain, the NWC makes up for 12% of Israel's annual electricity consumption.

In the Kingdom of Jordan the King Abdullah Canal (also known as East Ghor Canal) which is running southwards parallel to the river Jordan (Plate 32) draws 140 Mio. m^3/a from the Yarmuk River over a distance of 70 km southwards to the Dead Sea, thus supplying the most populated western regions of the country with fresh water, but also the other riparians make use of the Yarmuk River. As a matter of fact, Syria with 170 Mio. m^3/a even exceeds the Jordanian withdrawal, while Israel is taking another 100 Mio. m^3/a.

Usage of the aquifers

The Mountain Aquifer contains the most important ground water supplies of the region. Although Israel's national authority over Judea and Samaria is disputed, Israel is the largest consumer of fresh water from that area. With 483 Mio. m^3/a it uses 72% of the Mountain Aquifer's annual renewable resources, representing 30% of Israel total annual demand of water. After the Palestinians have pumped their annual share of 121 Mio. m^3/a (18%) from the ground, only 10% of the total renewable water remains unused.

The utilisation of the Coastal Aquifer, however, is even more exhaustive. Israel extracts the complete annual safe yield of the Israeli part of the aquifer, 240 Mio. m^3/a. In the Palestinian Gaza Strip the situation is even worse, as 108 Mio. m^3/a are extracted from the ground, although the aquifer can only renew 55 Mio. m^3/a each year. The overdraft by 100% hence eats into the fossil, non-renewable ground water, a limited, irreplaceable source that will not be available anymore in the nearer future.

Out of all these aquifers Israel is taking 200–300 Mio. m^3 per year more than are renewed every year. The consequence is a permanent falling of the groundwater table. Up to now there has been accumulated a water deficit of 1–2 billion m^3/a.

The Palestinians underline their right for "territorial sovereignty" and demand not only their user rights but also compensation for the years when Israel has "stolen" their water, whereas Israel is stressing the appropriation right (first user right) because the Zionistic settler had been the first to use the water.

Agriculture

Although the climate in the Middle East is semi-arid or even arid, the riparians of the Jordan River are not deterred from carrying out agriculture in areas where the natural provision of water (ground water and precipitation) is not sufficient for rain fed agriculture. Therefore they have to use a great deal of their precious water resources for irrigation.

As the modern and highly efficient drip irrigation is practically standard in Israel, a decrease of the share of the agriculture of the total water consumption was achieved during the last decades. The yield could even be increased while the demand per hectare sank by 33%, from 8.700 down to 5.800 m^3. Thus Israel cannot be accused of wasting water; it is one of the most efficient water users in the world. At least one-quarter of Israel‘s water is reused and it aims to recycle 80%. By 2010, Israel hopes to recycle 430 million m^3 per year. Its National Water Commission has unrivalled legal control over water abstraction and use. Its irrigation systems are already the most efficient in Asia, yet Israel is still aiming to recycle 35% of irrigation water. Some orchards are traditionally watered by ‘dew farming‘, with rocks piled around the trees to cool and cause condensation at night. Even so, the higher level of economic development in Israel means that its per capita consumption is 300 litres a day against Jordan’s 80.

Jordan’s higher share of water needed for farming is due to the low application of efficient irrigation methods, whereas in the Palestinian Authority Territories irrigated agriculture less practised, mainly due to the political situation.

Although agriculture consumes a great share of the countries’ water resources, it is economically hardly relevant. A mere 4% of the Israel GDP is gained in the agricultural sector by merely 2.2% of the nation’s workforce, while in the Kingdom of Jordan 2% of the GDP is gained by agriculture, in which 5.5% of the people are engaged. Only in the less developed territories under Palestinian Authority the portion of people working in agriculture is with 12.75% considerably higher. In these territories agriculture makes up for 18% of the GDP.

So why is a scarce resource like water "wasted" for a more or less irrelevant part of the national economy? There are several reasons. Even though the overall amount of people employed in the agricultural sector is only minor, those jobs are nevertheless welcome. But much more important are ideological reasons. Both Israel and Jordan strive for a certain degree of autarky on the field of food production to secure a sufficient provision of their people during times of crisis. Still, while Israel manages to produce on average three quarters of her national demand, Jordan's rate of self-sufficiency is much lower, especially when it comes to wheat, of which between 85% and 95% has to be imported. In order to make farming affordable the water tariffs are highly subsidised, keeping the price of water below US $0.2–0.3 per m³.

Another reason why Israel is devoting such an amount of financial and water resources to this uneconomical business sector lies in the Zionist ideology of the state. From the beginning of the mass immigration in the late 19th century, agrarian values (illustrated by David Ben-Gurion's image of the "blossoming desert" that Israel was to become) and the image of the "Chalutz", the agrarian pioneer, played a central role in the growth of the Jewish community in Kibbutzim and Moshavim, agrarian collectives and cooperatives in Palestine and in the founding of the state Israel a few decades later. And even though its economic importance has drastically declined, the social prestige of farming is still rather pronounced.

Water conflicts since the founding of Israel

After the Israeli-Arabian fighting following the foundation of Israel in 1948, the Middle East was repeatedly the theatre of fierce confrontation between the Jewish state and its Arab neighbours, often caused by the opposing claims over the scarce water resources of the region and a lacking willingness of cooperation.

The first armed clashes happened between Israel and Syria on account of Israel's plans to utilise the swamp area in Hulah-Valley, situated in the Demilitarised Zone, in 1951. This Israeli territory had been occupied by Syria in the war of 1948, but was later cleared of all armed forces. When Israel started to drain the Hulah swamps in order to gain cultivable land and water to be conducted to other parts of the country, the Syrian government harshly protested against the civilian usage of this area, a subject that had not been treated in the ceasefire agreement. After weeks of verbal quarrels, Syria eventually became ballistic, causing an Israeli air strike on a Syrian post on April 5th as a countermove. Alerted by this escalation the United Nations intervened and reached a settlement allowing Israel to resume the project with the exception of a planned dam, provided that the property of Arabian residents remained untouched.

In September 1953, shortly after the Jordanian government got the UNRWA'S (United Nations Relief and Works Agency for Palestine Refugees) agreement to put the Bunger Plan into practice, which proposed the construction of a reservoir with a capacity of 480 Mio. m^3 in the Yarmuk River and a withdrawal from the river into the planned East Ghor Canal, Israel continued its efforts to gain water sources in the north by starting off the B'not Ya'akov Project. A pump station near that bridge over the Jordan River was to be built in order to draw 435 Mio. m^3/a from the stream to be piped all over the country. Due to pressure by the UN and especially the United States, the project was cancelled after less than two months.

In October 1953, in an effort to end the disputes over the water resources, the US American diplomat Eric Johnson was sent to the Middle East to negotiate an agreement on the utilisation of the fresh water resources of the Jordan Basin between the opponents.

During the following two years each side presented their demands, reacting to the US American "Main Plan", which soon proved to be irreconcilable. Apart from a lack of basic consensus on the frame principles of the draft regulations – the Arab nations demanded strict "in-basin use", restricting Israel to only use the water in her own territory and opposed Israel's proposal to use Lake Genezareth as a reservoir – the distribution of the water was the hardest problem to solve.

The "Unified Plan" was Johnston's final try to settle the conflict. In this, he adopted the annual yields proposed for Lebanon and Syria in the Arabian Plan, partly at the expense of the Kingdom of Jordan, but did not make concessions to Israel in this question. On the other hand, Israel would be allowed to use this water outside the Jordan Basin and Lake Genezareth as a reservoir. Additionally the USA promised to finance the construction of a smaller Yarmuk dam in Jordania. A supranational control commission was also to be established.

After the Technical Committee, consisting of delegates from all countries involved, agreed to a "draft memorandum", a promising agreement seemed to have been reached, and the Israeli government and parliament soon approved the plan. But in October 1955, the Council of the Arab League decided not to confirm it, to some extend because it would have meant to recognise the existence of Israel as a state. And after the nationalisation of the Suez Canal and the following blockade of all southbound Israeli ships by Egypt, the outbreak of the Suez-Sinai War in the autumn of 1956 put an end to all final efforts to implement the plan as a whole, although Israel and Jordania at least silently kept to the proposed yield amounts more or less in the following years.

Aggravation of the conflict prior to the Six-Day War

When the planning of Israel's National Water Carrier became public in 1959, the Arab nations sharply protested against this major interference in the water resources of the Jordan Basin. Especially that water was to be piped over the watershed was an intolerable situation for them. As all appeals to the UN remained unanswered, the region was on the brink of war. But the danger of a major armed conflict soon collapsed, as none of Arab countries was fit to risk a military confrontation with Israel's army. To undermine the National Water Carrier project the Arab League decided to divert the headstreams of the Jordan River, thus cutting off Israel from a large share of its water supply. The plan outlined the construction of three canals:

- a northern diversion from the Hasbani and one of his tributaries into the Lebanese Litani (on the scale of 40–60 Mio. m^3/a)
- a southern diversion from the Hasbani and two more tributaries into the Banias (20–30 Mio. m^3/a)
- a diversion from the Banias into a tributary of the Yarmuk and further on into the East Ghor Canal (110 Mio. m^3/a).

The result would have been a reduction of the water flow of the Upper Jordan River by 35% and effectively halving the projected support for the Negev Desert of 320 Mio. m^3/a.

Armed confrontation related to the water issue commenced again in 1964, when Syrian border guards shot at Israeli caterpillars working on security infrastructure nearby the source of the River Dan close to the frontier. Israel answered with a warning bombardment of Syrian facilities near the planned site of the diversion of the Banias. At the same time Israel had also to cope with a rise of Palestinian terrorist attacks, sabotaging the country's water networks. A year later, when the work on the diversion canals had started, Israel soon took up the bombings again, destroying a great deal of Syrian construction equipment after an Israeli border patrol had been fired at from Syria.

These kind of hostilities happened repeatedly during the following months, considerably delaying the diversion project. Although not under fire, Lebanon even gave up on the canals from the Hasbani, officially due to a shortage of financial means, but also because of lack of sufficient air defence in the case of an Israeli attack. The Syrian efforts came to an end as well in the summer of 1966 after a sweeping air strike of the Zahal River.

With the victory in the Six-Days-War (1967), in the following year Israel's "hydro-strategic situation" was massively improved. With the occupation of the Golan Heights and Judea and Samaria = Westbank the country gained control over the Banias and most of the Hasbani River, parts of the north banks of the Yarmuk and the complete Mountain Aquifer. Furthermore, the Jordanian Mukheiba Dam had been destroyed, and other Jordanian dam projects postponed. Therefore it is hardly surprising that, after this turning point, a regional water agreement was not initiated until the beginning of the Israeli-Palestinian peace process in the middle of the 1990s.

Water issues in Israel and Jordan

While the water situation in the state of Israel definitely does not look too rosy, especially as 30% of its present potential is situated in the areas held since the Six-Day War, and further 30% come from sources like Lake Genezareth and the Jordan River of which the usage is still not supra-nationally agreed, the problems in the two occupied territories are very different in nature.

The Gaza Strip suffers from very scarce water resources. It has got a predominately semi-arid to arid climate with only 200-400 mm of precipitation per year, and is therefore practically entirely dependent on its ground water reserves. As mentioned above the Gaza Aquifer has a renewable capacity of only 55 Mio. m^3/a, but the actual withdrawal has increased up to 110 Mio. m^3/a. This usage of fossil, non-renewable ground water has caused the water table to drop by more than 20 cm per year, increasingly impeding the extraction of fresh water from underground and enabling the intrusion of brine from the nearby Mediterranean. Apart from the pollution by salt water, untreated wastewater is another source of contamination while modern sewage systems in this extremely densely populated area are still under construction.

The West Bank faces a fundamentally different situation. With the Mountain Aquifer's 679 Mio. m^3/a of renewable water and an average precipitation of over 600 mm, the West Bank's 1.4 million inhabitants are considerably better off than the people in the Gaza Strip. The crucial issue here is the distribution between the Arabic and the Jewish settlers. As since 1967 Israel controls Judea and Samaria, the Israeli settlers are systematically favoured when it comes to water rights. While only 140.000 Jews face 1.3 Mio. Arabian Palestinians, the Israeli side gets more than four times as much water from the aquifer (483 Mio. m^3/a) compared to 118 Mio. m^3/a (Plate 33). The result is that each Palestinian uses 60 l/d while a Jewish settler, many of them of European and especially US American origin and therefore used to green gardens, uses up 350 l/d.

The Kingdom of Jordan even combines the two aforementioned problems. For more than ten years the country has been overexploiting its natural resources, presently by about 60 Mio. m^3/a, even though the private consumption of water is harshly regulated and in some regions limited to access just once or twice a week. But not all parts of the society suffer equally. While the average consumption per capita is 70 l/d, the posh residential areas of the capital Amman use even more than the lawn-loving Jewish Settlers in the West Bank, 400 l per day and capita, especially for private swimming pools.

An additional problem in both the occupied territories and the Kingdom of Jordan is the poor condition of the water infrastructure. The cities in the West Bank lose more than 50% of their water through seepage because of rotten supply networks. In Jordanian cities seepage losses come to 39% and in the agricultural sector up to 58%. With help of sufficient financial means the potential savings after modernisations are obvious.

Supranational agreements

As Syria and Lebanon have not yet given up their boycott of all multilateral negotiations, a comprehensive agreement on the water issue between all riparians of the Jordan Basin is still to be reached. But on the bilateral level some progress has been made.

The first major breakthrough in the question of water usage was the Israeli-Jordanian Peace Treaty of October 26th, 1994. Article 6 calls for a permanent solution of the water conflict by settling on the recognition of the "legitimate water allocation" of both parties and concerted efforts on the development of additional resources. Further details have been elaborated in Annex II: As the two countries have mostly settled on the present usage, Jordan was able to include a limitation of Israel's extraction from the Yarmuk River of 25 Mio. m^3/a. To balance the seasonal fluctuation of the supply from the Yarmuk, Israel will store an additional 20 Mio. m^3/a during the winter high water to be used by Jordan in the summer. Furthermore is Israel to deliver 9 Mio. m^3/a of desalinated water and 50 Mio. m^3/a from sources yet to be defined to Jordan. A co-operation in the fields of the exploration of new resources and the protection of the water quality is also outlined. Whether all these aims can be put into action, is, however, dubious. Due to the regular droughts in recent years, Israel could not always meet the demands prescribed in the treaty. Because of the draught in 1999, only half of the additional 50 Mio. m^3/a of fresh water could be placed at Jordan's disposal.

A similar final agreement between Israel and the Palestinian National Authority is still to be reached. But with the outbreak of the second Intifada in the autumn of 2000 and the ensuing standstill of the peace talks, a permanent settling has faded out of sight for the time being. A temporary treaty however exists: The "Interim Agreement between the State of Israel and the Palestinian Authority on the West Bank and the Gaza Strip" was signed in Washington on September 28th, 1995. While not being dealt with in the main text, the question of water rights is handled in Article 40 of Appendix 1, in which Israel, for the first time, "recognizes the Palestinian water right in the West Bank". On the other hand Israel was entitled to make use of the resources of the Mountain Aquifer as well as the water of the Jordan River. The annual yield of 679 Mio. m^3/a from the wells and springs in Judea and Samaria was to be divided between Israelis and Palestinians as follows: 483 Mio. m^3/a for Israeli users (340 Mio. m^3/a from the Western Aquifer alone) and 118 Mio. m^3/a for Palestinians, with 78 Mio. m^3/a remaining quantities to be developed from the Eastern Aquifer, more or less codifying the present distribution. Additionally the Palestinians' water supply should be increased by provision from Israel, the drilling of additional wells, and the improvement of the water infrastructure in the occupied territories. As agreed with the Kingdom of Jordan, a Joined Water Committee was to control the enforcement of the arrangements.

Based on the Helsinki rules and the ILC rules Kliot has proposed a relative ranking of the Jordan basin co-riparians:

Features	Lebanon	Syria	Jordan	Israel
Country share in area of drainage basin	4	1	2	3
Country's water contribution	4	1	3	2
Climate	4	2	1	3
Patterns of utilisation				
Past	4	2	1	3
Present	3	2	1	1
Social indicators				
Life expectancy	1	1	2	3
Infant mortality	3	2	1	4
Economic indicators				
Per capita GNP (US $)		3	2	4
Total debt		2	1	2
Total population (1990)	4	1	3	2
Average annual population growth	4	1	2	3
Cereal import	4	2	3	1

(Kliot, 1994, p. 263)

"The relative ranking of the co-riparians reveals Lebanon's marginal place in this basin, and her need will certainly not receive any priority in the future. Jordan ranks high on many of the indicators and, relatively speaking, should receive large amounts of water from the basin, according to the principle of equity. Syria is second to Jordan in its relative ranking in the basin, a fact which should entitle her to large amounts of water. Israel, according to her ranking on most of the above features, is placed third for equitable water allocation" (Kliot, 1994, p. 263).

Possible solutions for the future

In order to achieve a sustainable utilisation of the water resources in the Jordan Basin joint efforts are necessary to develop new ways of satisfying all demands. As the uneconomic agriculture sector proved to be the biggest consumer of the scarce resource, the import of grain and other basic foods (so called 'virtual water') will have to be increased. The modernisation of the water infrastructure will also help to restrict the waste by seepage and negligence. With the help of "Save Water" programmes, the City of Jerusalem managed to lower the consumption per capita by 14% between 1989 and 1991, and in the industrial sector a decrease in the use of fresh water of 40–90% is possible by sewage treatment, re-use, and modernised production methods. But as the population of this part of the world is rapidly increasing (Israel by 2.4%, Jordan by 4% per year), it is inevitable to think about further measures to provide more water than there is naturally.

A practically infinitive source of water is the ocean. In order to make the salt water from the Mediterranean or the Red Sea usable for consumption and irrigation it needs to be desalinated. This could either be done by the classical reverse osmosis directly on the coast, or by using the hydrostatical pressure differential in canals leading down to the Dead Sea. This procedure could lower the price per m^3 to the level of the water classically desalinated. The price could be even more reduced if Israel allowed the Kingdom of Jordan to use more water from the Jordan Basin, and as compensation, is financing the desalination on the Mediterranean coast.

The transport of water from Turkey over the Mediterranean Sea to Israel by tankers would considerably exceed the costs of desalinated water. Another suggestion was the import of freshwater from Turkey in large vinyl bags pulled by tuck boats, a method that has not been technically proved yet. Even more expensive would be the piping of water from bigger rivers in Turkey (Peace Pipeline), and besides the costs the political situation in the areas the pipeline would have to cross is not safe enough to make this method sufficiently promising.

The basis for a sustainable solution of the region's water troubles would be a lasting peace between Israel and its neighbours and a settling of the political quarrels between the Arab states. Until the more prominent obstacles for the reconciliation (territorial, religious and refugee questions) have been regulated, the scarcity of the vital resource water will continue to be an everyday's threat to all the inhabitants of the involved countries.

3.2.3 Case study: The Tigris and Euphrates Basin

The headwaters of the two great rivers of ancient Mesopotamia lie in modern-day Turkey (Plate 34). Iraq and Syria both depend heavily on storm and meltwater runoff from the mountains of eastern Turkey. Yet this is also the main area of water surplus for Turkey. Turkey built on the upper Euphrates several large dams to use the water for the Southeast or Greater Anatolia Project (GAP) in the 1960s, aiming to develop up to 26 billion kW of hydro-power, equivalent to about 60% of national requirements, and to irrigate up to 1.6 million ha, capable of growing half the national production of rice and vegetables and allowing the introduction of a commercial cotton crop. Turkey aims to make the area the 'bread basket of the Middle East' by 2010.

Wary of political ramifications, the World Bank and the major sources of foreign aid refused to finance the scheme. Three decades later, the scheme is still little more than half complete, and technical problems have been caused by poor management of soil erosion on the new arable land. The Kaban (Keban) Dam accumulated 2 Mio. m^3 of sediment in its first 10 years. Even so, the three main dams hold the equivalent of 3 years discharge for the Euphrates. On occasion, flow has ceased entirely, and the economic and environmental impacts are matched by strong political antagonism.

International politics are further aggravated by the fact that southeast Anatolia is the homeland of the Kurds, who seek independence and wish to join with the Kurdish peoples of eastern Syria and northern Iraq. Tens of thousands of Kurds have already been displaced by the scheme, and more will be displaced and dispossessed when the scheme extends to the Tigris, giving the PKK terrorists further motivation. Syria and Iraq continued to lobby the Arab League states to unite against Turkey on the GAP issue. In retaliation both states have supported also the minority Kurdish Workers Party PKK in its struggle against the Turkish government, prompting Turkey to threaten to cut off the flow of water to Syria and Iraq on more than one occasion.

Control of water resources has always been a major source of political power in the Middle East. The Allies considered asking Turkey to cut off supplies to Iraq during the Gulf War in 1991, but this would have affected Syria as well. Turkey did just this in 1990, when the Ataturk Dam, the fifth largest rock-filled dam in the world, was completed. Syria and Iraq laid plans for joint military retaliation. Flow was restored a month later after a secret agreement in which Syria asked for a guaranteed minimum flow of 500 m^3 per second and Turkey asked for Syria to control and return Kurdish rebels. Some 15 years earlier, Iraq had threatened military action against Syria over the Assad (Tabka) Reservoir. Designed to irrigate 640.000 ha of near desert, Syria regarded it as vital to its national economy, but Iraq accused it of threatening the livelihood of 3 million Iraqi peasant farmers.

In the mid-1980s, Turkey publicized plans for a 'Peace Pipeline', running from Turkey through Syria and Jordan, ostensibly to earn money for the GAP by exporting water up to 3.000 km to the Arabian Peninsula. Covertly the scheme would have extended Turkish political influence throughout all of Iraq's western and southern neighbours, while pointedly cutting off Iraq. None of the states could accept the political implications. If politics were not an issue, however, this could have been a viable solution to many of the region's problems. The pipeline could have transferred up to 8 billion m^3 per year and Saudi Arabia could have obtained water at one-third of the cost of desalination.

With or without the pipeline, the impact upon the Euphrates River in Iraq is dire. Turkey has argued that the flow regulation assists Syria and Iraq by evening out seasonal flows, which used to range from 7.000 m^3/s during snowmelt from March to May down to 100 m^3/s in the dry season. But this is outweighed by a drastic reduction in annual discharge. Since 1990, discharge in the Euphrates entering Syria has decreased by 50%. Discharge entering Iraq is down nearly 80%, as a result of Syria's own al-Thawrah (Tabka) dam and other schemes. Furthermore, Syria and Iraq have complained of poorer water quality due to less dilution of sewage and other pollutants and return waters for irrigated land with higher salinity.

The Marsh Arabs and the military use of water

The Shi'ite Muslims who occupy the marshlands around the confluence of the Tigris and Euphrates suffered near-genocide from the strategy of the Iraqi military dictatorship, which was compounding the effects of the GAP on water levels. In the 1970s, about 220.000 Marsh Arabs occupied these unique marsh-lands. Now perhaps only 10.000 remain, trying to maintain their 5.000 year-old lifestyle based on fishing and reed production. The rest have emigrated or died. Their livelihood is being destroyed by the systematic draining of the marshes, 60% of which have entirely disappeared.

Saddam Hussein's government maintained this was part of a long-term plan for agricultural improvement, which has become more vital since the UN sanctions had been imposed following the Gulf War. The plan's prime aim was to use the water to rehabilitate millions of hectares of former irrigated land destroyed by salinisation by flushing out the salts. The problem is severe, 80% of all the land that has been irrigated in the Tigris-Euphrates basin is now suffering salinisation and 33% has been totally abandoned. The Marshes scheme began in 1984. The Third or Leader River was completed in December 1992 and aimed to cleanse 1.5 million ha of salinated land. Tunnels have been constructed under the marshes to keep the saline return water separate.

There are serious doubts that the scheme is technically adequate for its overt purpose, but graver fears that the side-effects will be very damaging. Although some international consultants believe the rehabilitation could be successful, the World Conservation Union predicts that most of the drained area will become desert within 10–20 years and claims it is the worst ecological disaster of modern times. Much of the local topsoil has been used to build the dikes and the newly exposed land is already suffering salinisation. A unique local ecology is being destroyed. The Indian porcupine, smooth-coated otter and grey wolf are already extinct and many species that evolved in the local habitat, like the Basrah reed warbler, are threatened. But the ecological impact will be much wider. The marshes were a winter haven for two-thirds of all the wildfowl in the Middle East as well as for many others from as far away as western Siberia. The effects on discharges, shown on computer models developed at the University of Exeter, predict that up to 40% of Kuwait's shrimp stocks will be destroyed through loss of spawning grounds.

Whatever the agricultural merits, the military value of the scheme is not in doubt. After the failed Shi'ite uprising following President Bush's exaltation to revolt in 1991 and the Allied imposition of a no-fly zone in August 1992, the Iraqi army could only proceed with the elimination of the Shi'ites by ground operations. The marshes provided an impenetrable refuge, but operations began with poisoning the water. Subsequent draining has enabled artillery to be moved in. During 1992 and 1993, 40 rivers that used to flow into the al-Amarah Marsh were diverted and the Mother of All Battles Project completed the Fourth River (based on Jones, 1997, pp. 330–332).

3.2.4 Case study: The Nile Basin

Plate 35 shows that the Nile basin is one of the 13 major river basins in Africa: the Senegal, Volta, Niger, Lake Chad, Nile, Lake Turkana, Juba Shibeli, Ogooue, Congo, Zambezi, Okavango, Limpopo and Orange River basins. It is shared by ten countries (Burundi, Democratic Republic of Congo, Egypt, Eritrea, Ethiopia, Kenya, Rwanda, Sudan, Tanzania and Uganda) with a combined population of about 300 million, about 160 million of whom live within the boundaries of the Nile Basin. The ten countries that share the Nile waters include some of the world's poorest, with annual per capital income of less than US $250.

Egypt and Sudan, situated in arid respectively semiarid region, are heavily dependent on the Nile water for irrigation to feed their growing populations and Egypt has been using already over 90% of the water, but now the other riparian states also demand water for their projects.

Thus the Middle East Media Research Institute. Inquiry and Analysis Series – No. 165 February 27, 2004. (cited in http://www.water.org/FileUploads/WPHighCurricFULL.pdf pages 75–78) wrote about the growing conflicts:

Rising Tensions over the Nile River Basin

The Nile River is the longest river in the world. From its major source, Lake Victoria in east central Africa, the White Nile flows generally north through Uganda and into Sudan where it meets the Blue Nile in Khartoum, which rises in the Ethiopian highlands. The Nile traverses almost 6.700 kilometres from its farthest sources of the headwaters of the Kagera River in Burundi and Rwanda to its delta in Egypt on the Mediterranean Sea (Plate 36).

In recent months, tensions have been rising over the waters of the Nile. In preparation for the African summit meeting of African heads of state to be held in Libya next week, the ministers of water representing the riparian countries have decided to put the subject of the 1929 Nile Water Agreement on the summit's agenda.

President Hosni Mubarak chaired a cabinet meeting in Cairo to discuss the issues. The communiqué issued after the meeting did not say what Egypt would do in the face of a persistent demand for reallocating the Nile waters, and whether Mubarak himself would attend the summit meeting. It vaguely referred to Egypt's readiness to provide training, technical assistance, "and help in procuring funding for projects that benefit all the countries of the Basin, in the framework of respecting the shares established by the existing agreement". A couple of days earlier, the Egyptian government daily Al-Gomhouriya wrote that the demands by some of the Nile Basin countries for reallocating water shares is a matter of concern to Egypt which requires quick intervention to kill any initiative that would reduce the water supply to Egypt.

The following is an overview of tensions regarding the Nile River:

The Nile Water Agreement of 1929

The Nile Waters Agreement (NWA) over the allocation of its waters between Egypt and Great Britain (which represented Uganda, Kenya, Tanganyika [now Tanzania] and the Sudan) was concluded on November 7, 1929 in Cairo by an exchange of letters between the Egyptian Prime Minister and the British High Commissioner in Egypt. The agreement allocated 48 billion cubic meters per year to Egypt as its acquired right and 4 billion cubic meters per year to the Sudan. These allocations were later increased to 55.5 billion cu. meters and 18 billion cu., respectively, under a 1959 bilateral agreement between these two countries that allowed for the construction of the Aswan Dam. Apart from Ethiopia, which had a government in place, the NWA was made before the other Nile Basin countries gained their independence. The agreement stated that no works would be undertaken on the Nile, its tributaries, and the Lake Basin that would reduce the volume of the water reaching Egypt. It also gave Egypt the right to "inspect and investigate" the whole length of the Nile to the remote sources of its tributaries in the Basin.

This right "to inspect and investigate," which was tantamount to a veto power over any water or power project, has in recent years become moot, as all the former colonies on the Nile Basin have become independent nations and are not likely to readily agree to such encroachment on their sovereignty by Egypt. Indeed, some of them have begun to nibble on the NWA by initiating water projects that threaten to reduce the volume of water available to Egypt. Egypt considers any change in the agreement as a strategic threat and has repeatedly threatened to use all means at its disposal to prevent the violations of the agreement. The other Nile Basin African countries consider the agreement as a relic of a colonial era which no longer reflects their needs and aspirations and hence it should be annulled. Countering this argument, Sherif Al-Mousa, head of the Middle East Program at the American University in Cairo, argues that the Nile water agreement should be treated the same way as the boundaries of most Nile Basin countries which were established by colonial powers, and are recognized under international law.

The Pressures for Change

Population pressures, frequent draughts, and increasing soil salinity have intensified the demands by the Nile Basin countries to renegotiate the 1929 agreement. Not deterred by Egyptian reluctance to negotiate the 1929 agreement, or even Egyptian threats, and constrained by financial hardships, some Nile Basin countries are determined to implement projects that would tap into the sources of the Nile.

The 1959 agreement between Egypt and Sudan, which increased the water allocations to themselves while completely ignoring the interests of the other riparian countries such as Tanzania, Kenya and Ethiopia has, in retrospect, weakened the Egyptian argument about inviolability of the NWA.

The Nile Basin Initiative

To reduce the potential for conflict, and with the help of the World Bank, the Nile Basin Initiative was launched in 1999 as a transitional arrangement until a permanent framework is in place. It is guided by a shared vision "to achieve sustainable socio-economic development through the equitable utilization of, and benefit from, the common Nile Basin water resources." The Nile Basin Initiative notwithstanding, member countries are forging ahead with their own projects and challenges. Droughts are difficult to forecast, even in the beginning of the crop season. Building dams to store water is not unlike a bank savings account, to be used at a time of need. While Egypt has secured its agriculture with the building of the Aswan Dam, it has been reluctant, if not belligerent, when other countries on the Nile Basin sought similar solutions.

Ethiopia Asserts Rights to the Blue Nile

The Ethiopian Minister of Water Resources announced his country's intentions to develop close to 200.000 hectares of land through irrigation projects and construction of two dams in the Blue Nile Sub-basin. He further stated that these projects would be the first phase of forty-six projects which Ethiopia proposed to execute along with ten joint projects which Egypt and Sudan proposed. The Egyptian Ambassador to Ethiopia confirmed.

Egypt's commitment is to the utilization of the Nile waters for the benefit of all riparian countries. However, the Egyptian commitment was conditional. All projects must benefit both upstream and downstream countries, provided these projects do not lead to a reduction of the waters reaching Egypt.

The Ethiopian Minister of Water Resources retorted that the agreement to participate in the Nile Basin Initiative reserves Ethiopia's right to implement any project in the Blue Nile Sub-basin unilaterally, at any given time. He charged that the 1959 agreement between Egypt and Sudan impedes sustainable development in the basin and called for its nullification.

From the Egyptian perspective, any change in the volume of its water could have devastating effects on Egypt. The vast majority of Egyptians live in a valley which is about 4% of the Egyptian territory, and 95% of Egypt's water resources are derived from the Nile.

Tanzania Challenges Egypt

In early February 2004, Tanzania launched a project to draw water from Lake Victoria to supply the Shinyanga region. The project calls for the construction of about a 100 mile long inland pipeline at an initial cost of US $27.6 million, to be constructed by a Chinese engineering company. To mitigate the anticipated Egyptian reaction, Tanzania announced that the pipeline was designed to provide drinking water to its thirsty population rather than irrigate agricultural land. Tanzania's population of 35 million has suffered from frequent droughts, desertification, and soil erosion. In fact, Tanzania was the first riparian country which, upon its independence in 1961, declared the 1929 agreement invalid.

Nevertheless, Egypt expressed its irritation with the Tanzanian project, arguing that under the 1929 agreement it has the right to veto any project – agricultural, industrial, or power – that could threaten its vital interests in guaranteeing its annual share of the river waters. While Egypt is handling the issue diplomatically, Egyptian officials stressed that "the diplomatic dialogue does not mean that Cairo does not consider any number of other options, if necessary." In diplomatic parlance, "other options" do not exclude the use of force. Tanzania has not budged. The Deputy Permanent Secretary in the Tanzanian Ministry of Water and Livestock Development said that Tanzania's sentiments about the legality of the water agreement are well known. He emphasized that "other countries also believe that the treaties [NWA] were illegal but they are to cooperate in negotiations, although they are not restricted from using the waters of the Nile."

Another Challenge from Kenya

Similarly, in response to a threat from Kenya that it was considering withdrawing from the 1929 agreement, the Egyptian Minister of Irrigation and Water Resources Mahmoud Abu Zeid said: "Egypt considers the withdrawal of Kenya from this agreement as tantamount to official declaration of war [emphasis added] and a threat to its vital interests and national security." A Kenyan weekly quoted the Egyptian minister declaring in Addis Ababa that Kenya could be subject to sanctions by Egypt and the other eight members of the Nile River Basin Agreement. He said Kenya's position violates international law and customs "and we will not agree to it."

The Kenyan deputy foreign minister M. Watangola repeated his country's demand for a revision of this historic agreement because Kenya was not consulted prior to its being signed. He said eight Kenyan rivers flow into Lake Victoria, which is the main source of the Nile waters.

Water for Oil

A senior Kenyan parliamentarian suggested that the Nile water should be sold to Egypt and Sudan for oil. He said that the time has come to replace the Nile agreement with a new agreement to allow the members to benefit from the Nile's waters. He added: "We have presented our natural resources to Egypt and Sudan free without them doing anything in return. We need to sell to them as they sell to us." The Egyptian treated the idea as "stupid" because the two countries have vested rights, rather than customers who would buy the water.

Egypt Accuses Hidden Fingers

In addition to Tanzania and Kenya, Ethiopia and Uganda are also demanding the abrogation of the 1929 agreement and a bigger share of the Nile waters. Egypt accuses "hidden fingers known to the Egyptian side [which] are openly inciting the traditional allies of Egypt in the Nile Basin to annul the agreement, arguing that it is incompatible with the population and political developments that have transpired in the last 75 years." The anonymous senior Egyptian official who has made the allegation about the "hidden fingers" stressed that any change in the agreement was inconceivable and warned that "any infringement of the agreement would suggest that the African countries do not respect regional obligations."

Egypt's Alternatives

To deal with the threat to its vital oil supply Egypt has four alternatives. Some are not mutually exclusive:

- Resort to the use of force
- Reduce waste through improved irrigation system
- Price water at market rates
- Maintain the status quo as long as feasible

According to a study by the World Bank, 96.44% of the economically active population in Egypt is engaged in agriculture. It is the highest percentage in the Middle East, with Morocco in second place with 92.61% of active population in agriculture. By contrast, the corresponding ratios for Tunisia and Lebanon are 60.87 and 10.35%, respectively. As a result, much of the water is used in agriculture, which contributes proportionately a small percentage to GDP. In Egypt, 88% of the water is consumed in agriculture which, as a sector, contributes only 14% to GDP, while 8% of water used in industry contributes 34% of GDP. The report suggests that "from a narrow macroeconomic perspective, rationale of justifying the allocation of water to agriculture over industrial and other sectors is weak."

Price Water at Market Rates

While the region remains one of the most water-scarce regions in the world, the cost of water for irrigation is set at below cost recovery levels. Egyptian agriculture is entirely dependent on irrigated land. The government provides irrigation water free, except of cost recovery of on-farm investment projects. Annual irrigation subsidies are estimated at US $5 billion. In Egypt, irrigation subsidies are often rationalized as a means of offsetting low farm prices controlled to keep down urban food prices. Water pricing and subsidies are such that they lead to waste in agriculture and provide little incentive for conservation techniques.

Maintain the Status Quo

Egypt's third option is to seek a status quo while tolerating some changes on the margin. To do so, Egypt must continue to maintain a pro-American and pro-Western orientation to discourage them and organizations controlled by them, such as the World Bank, from financing costly water projects such as dams or power projects in any of the riparian countries, which they themselves cannot finance through internally generated resources.

Resort to the Use of Force

The last and least likely alternative is to resort to the use of force to uphold Egypt's right to exercise the veto power on activities that it deems dangerous to its national interests. Egypt's sabre rattling cannot be taken too seriously, certainly not by the African countries themselves. Indeed, as one Egypt daily pointed out, "the harsh language adopted by Abou Zeid…might not be working…". Not only does Egypt lack the military capacity to strike at countries two thousand miles outside its borders, but it will be hard pressed to justify a military action to enforce the provision of a 75-year old agreement concluded to satisfy colonialist considerations and priorities but dissatisfy the needs of the countries upstream. A Kenyan father of two, who owns eight ponds for fish farming, was quoted as saying: "If the Egyptians try to invade Kenya for the sake of its water we are ready to die for our rights. Kenya must forget the Nile agreement and return to the commercial consumption of the Lake Victoria Lake."

On the last issue Jones (1997, pp. 333–336) is adding some more remarks:
"The Nile River system is a major water resource that is suffering from a combination of political and economic pressures. The experience of the last 30 years has demonstrated that the resource cannot reliably meet even current levels of demand, and demand is rising rapidly with the 'demographic explosion', both in Egypt and the headwater states. The downstream user, Egypt, derives over 90% of its water supply from the river, but the 1959 Nile Waters Agreement binds only Egypt and Sudan.

After the Peace Treaty with Israel following the Camp David accord in 1979, the Egyptian government was keen to use Nile water to reclaim land from the Sinai Desert and even to accede to Israel's request for 1% of the flow of the Nile to be diverted into the Negev. Even though President Sadat had proposed that this could be extend Lebanon and Jordan and form the basis for regional cooperation, a deal to share the Nile with Israel caused widespread concern in Egypt and was stopped by threats to President Sadat's life. Turkey was soon to offer its alternative.

Even without this diversion, Egypt is already exceeding the consumption of 55.5 billion m^3 per year agreed under the 1959 treaty. lt regularly borrows from Sudan and is still planning more irrigation. The tables show the proportion of water producers and water consumer in the Nile Basin:

Country	Producers	Consumers
Egypt	0	80%
Sudan	1%	18,5%
Ethiopia	85%	1%
Equatorial states	14%	0,5%

and the supply and demand for Nile water in 2000:

	Egypt	Sudan	Ethiopia	Equatorial states	Whole basin
Supply in billion m^3	62,4	18,5	69,0	29,6	172,6
Demand in billion m^3	63,7–69,2	22,4–24,04	2,0	5,0	108,2
Balance	-1,3 to 6,8	-2,76 to 3,24	67,0	24,6	64,4

(both tables from Kliot, 1994, p. 72)

Ironically, civil unrest in Ethiopia, Uganda and Sudan has delayed their national plans to use more Nile water, but as these national problems are solved upstream demands will increase and so will the potential for international conflict. As its neighbours assert their rights to the water resources in their own territories, Egypt is becoming more wary. Ethiopia has extensive plans to dam the Blue Nile, the source of three-quarters of the discharge in the Egyptian Nile, to help reconstruct its post-Civil War economy. Sudan‘s plans to drain the Sudd Marshes with the Jonglei Canal (Plate 36) have been delayed for a decade by civil war. The plan would reduce the major evapotranspiration losses and so increase water resources for new irrigation projects in southern Sudan.

Some Egyptian hydro-geologists even fear that Colonel Gaddafi‘s ‘Great Man-Made River‘ in Libya could reduce the Nile‘s discharge. The Man-Made River is a pipeline fed by 120 wells in the Kufrah aquifer and capable of carrying 2 million m^3 per day 1.900 km northwards to serve the arid but populated Mediterranean coastlands. The aquifer extends into the Nile basin and could draw off water from the river.

As the shortage of water intensifies in Egypt, so water quality and environmental problems increase. The sustainability of recycling irrigation water through the aquifer is causing particular concern, since without sufficient local rainfall to flush them through, fertilizers are accumulating, especially nitrates. Small wonder that Egypt is reportedly training military units for jungle warfare on the upper Nile and desert warfare in Libya in order to protect its water interests. The UN Secretary-General, Boutros Boutros-Ghali, has emphasized the need for a regional agreement: “In the next few years the demographic explosion in Egypt, in Kenya and in Uganda will lead to all those countries using more water; unless we can agree on the management of water resources we may have international or inter-African disputes”.

Further readings

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Park, J., Conca, K. and Finger, M. (2008). *The crisis of global environmental governance: towards a new political economy of sustainability.* London: Routledge.

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Useful Web Sites

Global Water Partnership (GWP): http://www.gwpforum.org/servlet/PSP

A working partnership among all those involved in water management.

http://www.cgiar.org/

Deals with issues related to water management and food security: water for agriculture; groundwater; poverty; rural developments; policy and institutions; health and environment.

United Nations Development Programme (UNDP): http://www.undp.org/

UN's global development network, advocating for change and connecting countries to knowledge, experience and resources to help people build a better life.

World Bank, Law Library: http://www.doingbusiness.org/LawLibrary/

Organised database of links and tools on international organizations, laws, treaties and laws of nations with links to their constitutions, legislation.

On Helsinki rule see
http://webworld.unesco.org/water/wwap/pccp/cd/pdf/educational_tools/course_modules/reference_documents/internationalregionconventions/helsinkirules.pdf

3.3 Tasks:

- Write an assignment of about 1.200 words on water governance and water policy issues and discuss the following points:
  - What were the problems and consequences that have led to the introduction of integrated water resource management?
  - What are the functions of water governance in its broadest sense and the necessary preconditions for good governance?
  - What are the consequences of the neo-liberal ideology and water strategy?
- Divide your class in two groups and defend the pros and cons of public-private-partnership. Use also http://www.eoearth.org/article/Water_governance for arguments.
- When were the topics "Integrated water resource management", "children" and "women" on the international agendas for the first time?

- Divide your class in five groups. You are the water ministers of Egypt, Ethiopia, Sudan, Tanzania and Kenya. In your conference you have to defend the interest of your country. Base your arguments on the Helsinki rules and search in the internet for further figures of demand and consumption of the Nile waters to back up your arguments.
- Explain what pressure intensified the demand for the Nile Basin countries to re-negotiate the 1929 agreement.
- Explain which issue, regarding the Nile, was put on the African summit agenda in February of 2004.
- Present to the class the Orangi Pilot Project in Karachi/Pakistan.
- Present to the class the financial targets set out in Chapter 18 of Agenda 21.
- Collect data from the internet for Turkey, Iraq and Syria and compile a table for the relative ranking of the countries like that one shown for the Jordan basin.

4 Water, Sustainability and Development

4.1 General definition of sustainability

The term "sustainability" was first coined in 1713 by the German nobleman, Hans Carl von Carlowitz. He had observed that in the state of Saxony the forests were being cleared excessively for smelting of iron and for mining. He therefore proposed that only as many trees should be felled as are being replanted, so that the forest could regenerate.

"In modern times the term 'sustainable' was first used in a publication of the Club of Rome (Dennis Meadows, 1972. *The limits of Growth*). Since the 1980s, the idea of human sustainability has become increasingly associated with the integration of economic, social and environmental spheres. In 1989, the World Commission on Environment and Development (Brundtland Commission) articulated what has now become a widely accepted definition of sustainability: "[to meet] the needs of the present without compromising the ability of future generations to meet their own needs" (Services are here taken to include the protection of ecosystems). For the UNESCO sustainability with reference to water resources means: "a set of activities that ensures that the value of the services provided by a given water resource system will satisfy present objectives of society without compromising the ability of the system to satisfy the objectives of future generations" (Jones, 1997, p. 320).

4.2 Sustainable development and its applications to rural water supply in developing countries

In many developing countries the management of water supply systems is often poor, resulting in interruptions in the provision of services and sometimes in the complete collapse of systems. When the latter happens, users may be forced to resort to traditional water sources which may be contaminated (Plate 37).

Sustainability with regard to rural water supply has been defined by Perry-Jones:

> "A water supply system is sustainable, when it provides an efficient and reliable service at a level which is desirable and which can be financed or co-financed by the users but without feasible external support and technical assistance. It can be seen as a service that regularly and reliably provides enough water of an acceptable standard for at least domestic use. Breakdowns are rare and repairs can be managed within 48 hours, and local financing covers at least the regular cost of operation, maintenance (O&M) and repairs" (Perry-Jones et al. 2001, S. 8).

In spite of the US $80 billion which has been spent annually on the water and sanitation sector the situation has deteriorated. There are still millions of people in the developing countries without sufficient water supply and proper sanitation. The problem is not the money but the utilisation of it:

> "We have enough money to solve the global water crisis, but we are spending the money on the wrong projects. Instead of spending an additional US $ 80 – US $ 100 billion per year as some policy makers believe us necessary, a small increase of US $ 10 - US $ 20 billion, provided the money is spent on community-scale projects, should be enough to extend water access to those who currently do not have it. […] the heart of the problem is not how much we are spending, but what we are spending it on. Instead of our current bias towards large, centralized water projects, we must invest aggressively in community-scale water projects that bring basic water and sanitation services to those who need it most" (Gleick, 1999, p. 488).

4.2.1 Case study: Rural water supply in the Karonga district in North Malawi

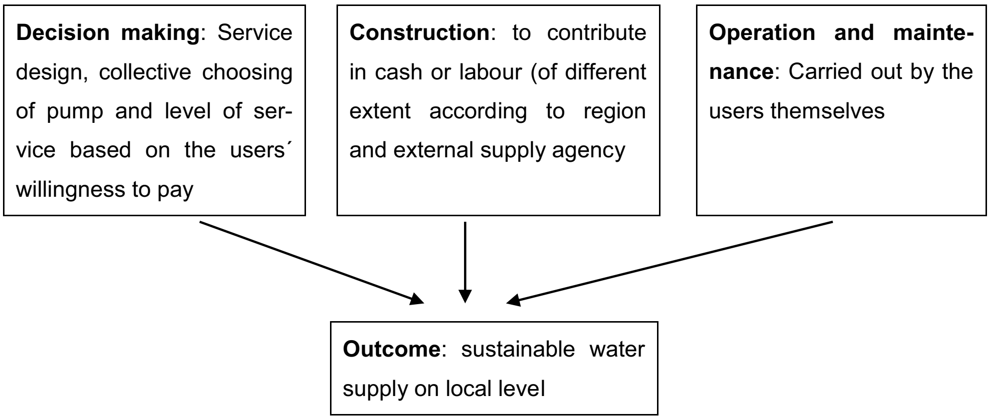
The topic of sustainable development and its applications to rural water supply in developing countries shall be demonstrated by an example from Malawi, where Siekmann (2009) has carried out research. She came to the result that the water supply system in the rural areas cannot be called sustainable in the above mentioned sense and she interviewed the user groups to find out what from their perspectives the reasons for this situation were.

In Malawi only 32% of the rural population has access to safe water (Plate 38). These figures reflect most probably only installed water points, but they do not give an answer to the important question of how many of these water points are really functioning. Surveys from Water AID have shown that in Malawi 40% of all installed improved wells, pumps or standpipes are damaged or broken and cannot be used (Plate 39).

To improve the water supply situation the Government of Malawi was following the Demand Responsive Approach (DRA):

> "A demand responsive approach (DRA) was planned to be used in implementing community capacity to effectively plan, manage and use sustainable water and sanitation facilities and to enhance public sector capacity to facilitate community management of water supply and sanitation services" (Government of Malawi, Ministry of Water Development 2004, S. 4).

The DRA replaced the older Supply Driven Approach and was seen as a prerequisite for success when the following aspects were evenly taken into consideration:



Its main aspects were that the communities can only demand those facilities that they are able and willing to finance and maintain:

> "The rural program will provide improved services on response to local proposals after negotiation of agreement for the building and operation of the demanded system. The principle to be applied for cost sharing will be to restrict Government of Malawi (GOM) financial support to a level equal to the per capita capital costs of a basic minimum service level. All other costs will be borne by the users of the proposed improvement, including capital and O&M in excess of GOM support. These mechanism will help ensure that demand drives the choice of levels of service and that the scheme is perceived as sufficiently valuable to the users for them to be willing to incur the essential recurrent costs, or the additional capital costs of more elaborate supply schemes than the minimum national standard" (Government of Malawi, Ministry of Water Development 2004, S. 8).

With regard to sustainability and the DRA Sugden, a Water Aid Country Representative from Malawi has published some interesting aspects:

> "Sustainability has become one of the most overused and abused words in development vocabulary. Many organisations working in the rural water sector claim to be providing sustainable water points, but it is questionable whether they actually are. The water and sanitation sector suffers from unsustainable projects that fail into disrepair. Organisations often make too many assumptions and have unrealistic expectations of what community maintenance systems can deliver. Five days' training in community based management and a shop in the nearest town selling spare parts do not guarantee sustainability. Challenges still outweigh solutions and, as such, it may be time to re-think the approach.

Perhaps a better way to achieve the Millennium Development Goals is to do nothing for the next ten years and then in 2013 invest huge sums of money drilling boreholes in the poorest countries of the world. In this way there is a better chance that the facilities will still be operational in 2015 and that the millennium goal will be achieved. While this is of course a nonsensical argument, it highlights why sustainability is so important. There is little point in working to halve the proportion of people without access to safe water by 2015, if by 2016 all the services that have been installed are broken.

In most new rural water supply projects hand pumps are chosen as the preferred technology. However, the life expectancy of an Afridev hand pump is estimated at 10–14 years. When considered, this means that not only will massive investment be needed to provide water points to those currently unserved, but it will also need massive investment and capacity to replace the ones that have reached the end of their natural lives. It is a sobering thought that every hand pump installed since 2000 will need to be replaced before 2015 in order to reach the Millennium Development Goals.

One of the keys to achieve the millennium goals must therefore lie in the ability of communities, or organisations, to keep their water facilities operational. As such an indicator that reflects the likely sustainability of supplies seems crucial when planning future projects.

Much work has been carried out on improving and standardising hand pumps and this has no doubt led to improvements in the number of breakdowns and the ease with which they can be repaired. Adopting a demand- rather than supply driven policy may also have an impact on sustainability, but the accompanying Demand Responsive Approach (DRA) still seems to be source of much confusion as the following interviews show:

"What is understood by Demand Responsive Approach (DRA)?"

As part of a survey in Malawi, all the leading implementers of rural water projects were asked what they understood by DRA. The most common reply was simplistic and incorrect, along the lines of: "The communities make a demand, we respond".

The Director of Water Services at the Ministry of Water Development replied "It means different things to different people at different times". While this is no doubt a correct answer, it is not one that gives a great deal of guidance.

In addition an officer on the World Bank funded National Water Development Project replied "That's a difficult question".

(http://www.wateraid.org/documents/plugin_documents/indicatorswatermalawia.pdf)

By now is has become evident that the management of water points is the most crucial issue. To ensure that operation and maintenance is carried out properly the external support agency DANIDA, which had until 2000 installed the pumps in Karonga, had decreed that in every community a water point committee (wcp) had to be formed. It consists of 10 persons with at least five women (according to the Dublin Principles: Principle 3: 'Women play a central part in the provision, management and safeguarding of water'). The positions and responsibilities are:

Position	Roles and responsibilities
Chairperson and Vice Chairperson	Encourage participation by wpc meeting discussions. Ensure that members participate in the activities concerning the water point. Assist in making meeting agenda. Leading and summarising discussions. Make regular visits to inspect the condition of the water point. Ensure that the community is informed of all activities taking place. Make regular contacts with local leaders and extension workers to report progress and any problems.
Secretary and Vice Secretary	Keep and maintain the committee records. Make meeting arrangements. Write the agenda and minutes for meetings. Read minutes at meetings. Deal with correspondence. Assist the chairperson in organising meetings.
Treasurer and Vice Treasurer	Keep O&M funds and spare parts. Keep accurate financial records. Report to the wpc and local community members on the financial position of the maintenance fund.
Water Point Committee Members (5 Members)	Participate in meetings and advise other members on important issues of community concern. Keep the environment of the water point clean. Contribute items to be included on the agenda of the next meetings based on facts gathered from other water point users. Assist in problem solving.

To have a properly functioning wpc many constraints have to be overcome. Some of the problems are explicated below:

Formation of a wpc

The wpc members have to be elected on a voluntary basis. Here the first problem arose because women did not readily volunteer for working on the wpc. for various reasons. First, a general lack of time was mentioned. There are other committees in the village (health, development etc.), in which they also had to be members. Second, especially the position of treasurer in the wpc was disliked by women because they felt to be not "strong enough" to collect the wpc fees from their neighbours. Also the position of the secretary was not much appreciated. The secretary had to keep the committee records but most of the rural women could neither read nor write. So in the end, some women had to be appointed by the village headman. Their willingness to collaborate in the wpc was, therefore, very low.

In some cases the traditional authorities determined the constitution of the wpc for the sake of their own interests:

> "Chiefs, elders and opinion leaders sometimes influence the selection behind the scene to protect their interests. I know that in some villages the selection and the appointment of wpc members are not free and fair" (Interview Hankin, Program director of the Kalembo Groundwater Programme in Mangochi District, 2005).

Training of wps members

Many of the interviewed wpc members had only an insufficient idea of what their role and functions were, and some had no idea at all. The reason is that external supply agencies prefer to invest in new water point constructions or in the extension of existing ones rather than in the training of the wpc members in operation and maintenance.

According to the recommendation of the Malawian Ministry of Water at the beginning of the implementation of water projects, awareness training should be carried out with all stakeholders (users, traditional authorities, teachers etc.) This is believed to be a prerequisite for the acceptance of the water point and the creation of a sense of ownership. Furthermore consultation and training of the wpc members about their roles and functions are necessary. This has to be carried out on a regular basis since some months may have passed, before any maintenance or repair may be necessary and the acquired knowledge may, by then, be forgotten. Some of the members may no longer be living in the village (due to marriage or death). So, with no regular training or no training at all, the function of the pump is most probably doomed to fail.

Siekmann found out that there had been a considerable deficit in training and consultation. The wpc members were, in general, most willing to participate in trainings but they did not receive it. On the other hand, however, they had never asked for it.

Financial aspects

A wpc has to access to a designated fund to carry out repairs on the pump and/or buy spare parts. Indicators for a well-functioning wpc in financial respects are therefore:

- Money is available when needed for repairs and spare parts
- Members and users are allowed to see the money at any given time (transparency)
- Money is kept in a safe place
- Villagers/users have trust in the person who keeps the money
- Person who keeps the money was chosen by the users
- Records are kept to trace back who has paid maintenance fees and how much he/she has paid.

The financial aspect was very crucial and involved many constraints. Besides the amount the point of time when the fees were to be collected, needed to be determined. Some users favoured the time when the pump has already broken down. They argued that before the incident the willingness to pay was low. Others were of the opinion that in this situation the tedious collection of fees was too late and the water point would be too long out of function. Also the modus of collection was disputed. Some users favoured monthly contribution but others voted for a collection once a year, preferably after harvest when cash was available.

The collection of funds was a tedious process and often objected by the argument: "I cannot pay because I am poor". This has to be considered carefully and one has to differentiate between the willingness and the ability to pay. In some cases an actual need (accident, illness, poor harvest etc.) may constrain the contributions but in most cases it is unwillingness. If money is collected beforehand a considerable amount has to be stored. As the distance to the next bank may be considerably great the treasurer was keeping the money at his or her house. Thus some users feared that it could be spent abusively by the treasurer. The willingness to pay was therefore dependant on the trust in the treasurer. He or she should write down who had paid and when, but only 2 of the 32 interviewed wpcs kept written records. Also cases of embezzlement (funds were spent by male treasurers on alcohol) were mentioned. So the willingness to pay was often marginal because of lack of confidence.

Initiative of the female wpc members

In many strategy papers the importance of women is accentuated but research in Karonga revealed that due to cultural traditions women most often show a lack of initiative. One wpc wanted to improve the infrastructure of its water point by erecting a fence to keep the cattle off the water point (Plate 40, the photo was taken in the centre of Malawi). The expenditure for these items do not fall under repair or maintenance and the members were not able to raise the extra money because the women "felt not strong enough" to collect the money from their neighbours. They relied completely on the support from government or external agencies and did not consider building for instance a community garden to raise the needed funds.

Even the collection of regular fees was problematic when the task had to be carried out by a female treasurer. If users were not paying their fees the women had to consider some sanctions to enforce the payment. For this they felt not strong enough, because according to traditional belief the performance of sanctions falls into the sphere of the traditional authorities.

Summers et al. have found that if sanctions are performed to punish unwanted behaviour they are applied in a subtle form and might be answered by counter measures:

> "They discouraged others from using their source through negative verbal commentary or the removal of the bucket and rope from a well. These social measures are more subtle than an outright ban, and appear to be in line with other elements of Chewa culture, where 'passive-aggressive' actions tend to be far more common than outright aggression. Many interviewees suggested that it would be seen as being selfish if they directly forbade other families from using their source. Some respondents also noted that if they banned others from using their source, they might experience vandalism or even poisoning the water source as response" (Summers et al. 2005, S. 6).

Plate 41 shows a standpipe of a gravity fed water scheme in Karonga where the tap was removed due to vandalism.

As the women feared to enforce sanctions in one village against some users who did not pay their fees, they wanted to attach a lock and chain to their pump to protect it against unauthorized usage (Plate 42, Photo taken in centre of Malawi). But even for the performance of this measure they "had no power". They rather confided in the authority of the village headman. To achieve the "empowerment of women", a term that is often cited in official declarations, there is still a long way to go in the rural areas of Karonga.

Lack of spare parts

Without a reliable supply and distribution of spare parts there can be no sustainability of the pump and hence the water point. For the wpc it is not only important to know which spare parts are needed and how they are built in. It is even more relevant to know where to get them from.

Concerning the spare parts one has to differentiate between items that are needed quite often (fast moving spare parts) and those that are needed for major repairs. The supply of spare parts for minor repairs had been organized in Malawi by the para-statal Chipiku stores found in nearly every smaller settlement that kept them in stock. The items were sold at wholesale prices and did therefore not render much profit. When the Chipiku stores were sold to a private owner the selling of spare parts was abandoned for lack of gain. So the villagers did not know where to get them from. After intensive investigation by the researcher the small centralizer made from plastic, which keeps the pump rod in the centre of the borehole, was found in the end on a hardware market (!).

The villagers knew that a centralizer was needed but they had no idea what its price was ("It is very much expensive"). So they did not even try to get one. In the end it was found out that the centralizer cost 80 Malawian Kwacha (US $0,40) on the market, less than a bottle of beer.

Obtaining the slow moving spare parts, which are more expensive, raises even more problems. To overcome them people steal for instance pump head, especially from pumps that are not situated in the vicinity of homesteads and sell them at much lower prices than in the shops. Njalam'mano (2007, p. 33) remarked that the occurrence of thefts often increases shortly before elections. He had found out:

"Some of the candidates ask boys a few days before addressing a rally in the area to go and steal spare parts. To show their (candidates) commitment that they will assist the constituents if voted into power they donate the spare parts which were stolen before from another water point."

Different approaches of external supply agencies

Concerning the usage of funds there was a great confusion in the area because the wpcs had got different information. According to the specification of the Government of Malawi the money had to be spent exclusively on spare parts. Also DANIDA or MASAF (Malawi Social Action Fund) had prescribed exactly for what the money was to be spent. On the other hand, CCAP (Christian Church of African Presbyterian) favoured the approach that the wpcs should decide autonomously and plan their expenditures themselves. Thus some contributions could be used to buy seeds for a community garden and some extra money could be earned by the sales.

The same confusion arose about the management of the water points. While some agencies put the responsibility for pump repairs exclusively on the wpc, which meant that a pump minder had to be employed (and paid), CCAP sent a field officer in case of need who carried out the repair free of charge.

Also the procedure of paying for the pump was different. While the Government of Malawi demanded

- a contribution of 5% of capital costs for the construction of a borehole, which amounts to 15.000 Malawian Kwacha (about US $107)
- a contributions in cash towards Operation and Maintenance
- the provision of materials for the construction of the borehole

other External Support Agencies (and Members of Parliament) built the water point free of charge. According (to the wrongly understood) Demand Responsive Approach the villagers voted in this case for the "more modern" but much more expensive Afridev pumps, where a cheaper shallow well would have been sufficient. Thus a lot of money was wasted.

Because of these different approaches the wpcs did not know to follow which line (Plate 43). Thus the performance of the management of the water points was poor.

Acceptance of technology

In the area of Karonga two types of water points had been installed: shallow wells with Mark V and Afridevs on boreholes. If the water table is not more than 15 m below the surface shallow wells are sufficient to guarantee a reliable water supply but nevertheless they were regarded by the villagers as inferior. The villagers preferred the Afridev pump: "It is like water in the cities, it is more modern". They argued:" Who has chosen this shallow well? Now we have got something we did not ask for. And now we should pay for it?" The shallow wells were seen as "second choice" and not accepted as a "real" water point. They were used reluctantly for the daily supply, but only until a more modern borehole was available.

The reason for this attitude was explicated by a village headman who told the interviewer that Members of Parliament sometimes promise the villagers on their rallies a "modern" Afridev pump if they will vote for him or her.

An Afridev pump cost about US $4.200, a shallow well with a hand pump US $650 and one with a windlass only US $400. If the hydro-geological conditions allow, CCAP favoured the shallow wells, because with the same amount of money more water points could be built. This is reasonable but the villagers had never been informed about these implications. If the users are not involved in the choice of the technology from the very beginning of the project the technology is not accepted. This had negative consequences on the management of the water point and made the collection of maintenance fees more difficult. Even small contributions were paid unwillingly as the shallow wells were regarded as provisional and temporarily. The activity of the wpc members was correspondingly low which is understandable when they did not get what they wanted (Plate 44).

Witchcraft

A reason for the poor functioning of a wpc which has been seldom mentioned in literature is the impact of witchcraft. "Witchcraft is the belief in a mystical power innate in certain individuals and exercised by them to harm others" (Wilson, 1951, p. 252). This belief, which is also found in big cities and even among academic people, is especially widespread in the rural areas and hampers the activities of the wpc members.

Certain "by-laws" like "no dish washing at the well, no children playing around the well, no watering of cattle at the well or no drawing of water without having paid the fees" are spread by verbal communication and known by all users. Field research, however, had shown that some of these rules were not exercised by the users, but the wpc members were reluctant to implement them. Only after intensive questioning it was found out that they feared to be bewitched if they put some sanctions on the violators. Macfarlane (1999, p. 248) described the consequences that they have to expect as: "Firstly, through the fear of being bewitched; secondly, through the fear of being thought to be a witch." Regarding this belief it is understandable that the wpc members will rather not exercise their roles and functions, but leave the (dangerous) tasks to the traditional authorities.

Effects caused by AIDS/HIV

The illness affects the management of water points on various levels. On the family level it firstly reduces the available money which has to be spent on medicine and extra nourishment of the ill person. Cash has to be saved and fees for school and for the wpc are reduced or not paid at all. Secondly it reduces the available time of the women which has to be spent on the care of the patient. Thus they cannot work for the wpc any longer.

On the wpc level it affects directly the cooperation if a member himself or herself falls ill or dies. Also the numerous funerals which last sometimes for one week and which have to be attended for cultural reasons reduce the available time of wpc members.

The same applies to the district level which is responsible for the major repairs of pumps. As especially young people in their productive age are affected by AIDS there is always a lack of technicians:

> "Absenteeism has become a problem, because of both AIDS related morbidity and funeral attendance. A funeral does last a week. People do not turn up for work. If there is a breakdown in a village, there is nothing we can do. People in the villages have to wait" (Interview Mr. Mwebe, Water Department, Karonga BOMA, 2004).

Thus also AIDS, which is seldom mentioned in the context of water point management, is a reason, why water points are only working with a fraction of their installed capacity.

The government of Malawi has recently launched awareness campaigns to fight AIDS (Plate 45).

4.2.2 Optimisation of water supply and sanitation services

The WHO has published in 2003 the following statements:

(http://www.who.int/docstore/water_sanitation_health/wss/sustoptim.html)

Significant efforts are being made to promote and to operationalise institutional and management approaches and techniques conducive to the sustainability and optimization of water supply and sanitation services. The sustainability aspects of water supply and sanitation systems have been badly neglected in developing countries over the past years. Normally, the operation and maintenance of water supply and sanitation facilities, which represent a major requirement for sustainable services, are regarded as low profile areas, with construction of new facilities being given the highest priority in the overall decision-making process. As a result, many water supply and sanitation facilities are collapsing and are only working with a fraction of their installed capacity.

Water supply and sanitation sustainability involves:

- ensuring the continuous availability of sufficient quantities of water of sufficient quality, within adequate institutional frameworks;
- applying sound management practices, appropriate technologies, and full-cost accounting, and effectively maintaining facilities and equipment.

In developing countries, however, management of water supply and sanitation systems is often poor, resulting in interruptions in the provision of services and sometimes in the complete collapse of systems. When the latter happens, users may be obligated to resort to traditional water sources which may be contaminated (Plate 37).

Contamination of distribution pipelines due to intermittent supply, low water pressure in the distribution network, inadequate wastewater collection systems and leaking pipes are also common problems in developing countries. If contaminated water penetrates distribution mains, water that has already been treated and disinfected may become re-contaminated.

Unaccounted-for water is another major water supply problem. In many large developing countries cities it has been reported as amounting to more than 50% of supplies. Most of this water is lost through leaking pipes or overflowing service reservoirs after abstraction, pumping or treatment, or during distribution. Those who suffer most from this inefficiency are populations living in impoverished, outlying urban areas. But if measures to ensure the sustainability and organization of facilities were implemented, extension of coverage to the fringe and poor areas of large cities would be possible. This would bring about considerable improvements in health. At the same time, the need to expand treatment and distribution facilities would be minimized, in effect releasing resources for other development activities.

One of the most crucial problems facing the sector is the lack of sustainability of sanitation services. Despite the huge efforts made over the past years, there is still a great need for considerable work on definition of principles, generate political will, formulate strategies and search for new technological, financial and institutional solutions.

In order to address the above issues, a working group on Operation and Maintenance (OMWG) was launched at a meeting attended by selected External Support Agencies at The Hague, in 1988. At its meeting in Oslo in 1991, the Water Supply and Sanitation Collaborative Council (WSSCC) confirmed the OMWG as one of its affiliated working groups. The Group became recently a network which has as principal functions to promote cooperation between external support agencies and developing countries and to promote sustainable water supply and sanitation services as a substantive and basic component of programs aimed at the social and economic development of Member States. The development, promotion and application of tools and methodologies for the formulation, implementation, monitoring and evaluation of programs to improve procedures aimed at the sustainability and optimization of services are also amongst the main concerns of this network.

Lack of sustainability and ineffective systems contribute considerably to aggravate the current status of the water supply and sanitation sector: over 1.000 million people do not have access to an adequate supply of safe water for household consumption and nearly 3.000 million lack a sanitary means of excreta disposal.

(http://www.who.int/docstore/water_sanitation_health/wss/sustoptim.html)

4.2.3 Constraints affecting the development of the water supply and sanitation sector

The adequate operation and the effective maintenance of water and sanitation systems continue to be a major priority within the sector. Due to the fact that operation and maintenance of water supplies and sanitation in developing countries is highly neglected, official data on the numbers of people served by these services often are overly optimistic because, in reality, many of these facilities are broken or operating at reduced capacity. In most cases management systems have failed to provide the necessary guidance and structure for effective operation and maintenance of water supply and sanitation facilities. The deterioration of these valuable physical assets is a major loss to national economies which can and should be avoided. Although most external support agencies do not fund programs aimed at improving the sustainability of services, rehabilitation projects have become an increasing part of many country support programs. Rehabilitation is a natural consequence of poor operation and maintenance which would not have been required, or would have been postponed if regular maintenance had taken place.

Many reasons have been identified as contributing to or causing the failure of water supply systems. These range from poor organizational structures in the responsible agency, lack of spare parts, inappropriate technology, lack of trained staff, tied aid, absence of career opportunities, insufficient funds, legal framework problems, lack of motivation by sector personnel, non-involvement of the users, the low profile of operation and maintenance in the sector in general, inadequate tariff and collection systems and negative political interference. These causes tend to be interrelated and intertwined.

The Operation and Maintenance Working Group of the Water Supply and Sanitation Collaborative Council (OMWG) identified the following main headings under which the main reasons for poor performance of water supply and sanitation services: (1) Sector Performance; (2) Institutional Performance; and (3) Technology Performance and Environmental Linkages.

The key issues contributing to poor performance of water supply facilities were identified as:

- Inadequate data on operation and maintenance
- Insufficient and inefficient use of funds
- Poor management of water supply facilities
- Inappropriate system design
- Low profile of operation and maintenance
- Inadequate policies, legal frameworks and overlapping responsibilities
- Political interference

Inadequate Data

There is an overall lack of data regarding operation and maintenance. Precise, accurate data on the number of systems which are not working are needed together with information on the main reasons why. Detailed figures are also necessary to determine how much it costs to undertake an adequate operation and maintenance program for different types of facilities.

Data are also required on the rates of breakdown of different systems such as pumping stations, distribution networks, treatment plants in urban systems, small gravity systems, and diesel motor pumping systems.

Until this information is forthcoming it will be impossible to accurately assess the performance of operation and maintenance and compute the financial losses due to poor operation and maintenance. These exact financial data are urgently needed to demonstrate to decision makers the advisability of implementing good operation and maintenance programs in order to reduce losses to national economies.

Insufficient and Inefficient Use of Funds

Insufficient funding has been identified as a major contributor to poor operation and maintenance performance. This lack of funds hampers the operating and maintaining of water supply facilities as money is not available to buy spare parts, train staff properly and provide competitive salaries to attract high calibre personnel. External support agencies have traditionally been reluctant to finance operation and maintenance activities while national governments have often given it a low priority. National governments are frequently stressed for cash, especially hard currency which is needed to pay for spare parts and the water supply agencies usually lose out to other, judged more important higher profile sectors.

The users are a potential source of finance for water supply systems. They are often unable or unwilling to pay. Usually it is that they are *unwilling* to pay rather than *unable* to. Evidence is mounting that even in the poorest and most underprivileged segments of the community people are willing to pay for a reliable, adequate supply of clean water but unwilling to be charged for an unreliable and unsatisfactory service. It is a vicious cycle. As the service level drops due to a lack of operation and maintenance the users withhold support and become less willing to pay which further constrains operation and maintenance activities.

Sometimes it is the inefficient use of funds rather than a lack of money which contributes to poor operation and maintenance. The poor management of facilities results in the squandering of resources which then reduces the viability of the water supply system. Those responsible for managing water supply facilities need to look carefully at their operations to ensure that they are operating efficiently. Common problems are too often many unskilled staff and poor logistical and organizational structures.

Losses of revenue from unaccounted for water are a problem for most systems. It is difficult to define what an acceptable level for unaccounted for water is. A figure of 25% may be appropriate as a first target for an agency working at unaccounted for water levels of 50%, but significantly lower levels can and should be achieved. What is an acceptable level of unaccounted for water has to be determined on the basis of local conditions, but true wastage should not be significantly above 10% once illegal connections, free supplies, and leakage are reduced to acceptable levels and adequate metering, billing and collections procedures are maintained. High rates of unaccounted for water, whether they are caused by illegal connections, leakage, free water supply, or the result of inadequate commercial operations, result in significant financial losses and consequent poor service performance of the agency.

Management of Water Supply Systems

The operation and maintenance of water supply facilities throughout the world is undertaken by a wide range of differently structured agencies. These range from community owned and operated water supply systems at one extreme to government owned and operated utility companies at the other. Some agencies are very small and may only be responsible for the supply to a small rural village using a low cost technology while other agencies may be controlling a utility employing thousands of staff and operating a high technology system.

However, no matter what the scale of the facility, the system will perform poorly if it is not managed efficiently and well. Typical management-problems include:

- inefficient organizational structures
- absence of career structures for staff
- low salaries
- poor relationships between the users and management.

The inefficient organization of many water supply agencies is a serious deficiency. If the organizational structure does not promote and allow efficient operation then the overall management will function poorly.

Personnel problems are another reason for poor management performance. Low salaries, absence of career structures, lack of trained personnel and the low profile of operation and maintenance as compared to new construction are all constraints. Some of these can be traced to a lack of sufficient funds in the agency but often they are the result of inadequate management.

The absence of transparent management and accountability to the users is another major issue. Often the users are not involved in the water supply agency and there is no feedback from the consumers to the management of the agency. This is particularly acute in government owned and operated agencies which tend to be bureaucratic. This non-involvement of the users in the management of the agency results in stress and in some cases the development of a confrontational relationship between the agency and the consumers. Studies of well-run water supply agencies have shown that good customer relations and a sense of management responsibility to the users are common denominations in these organizations, contributing to their overall success.

One of the lessons of the International Drinking Water Supply and Sanitation Decade has been the recognition that the user needs to play an important role in the development, implementation and operation of the facilities if the intended service is to be sustainable over the long term. This role varies according to local conditions. In rural and peri-urban projects, the user is likely to be intimately involved in the process and may assume planning, construction and, at a minimum, operating functions.

User participation must begin with the design stage, e.g. the intended user must determine what he is willing and able to pay for. Subsequently, management and operation of the agency must convince the user that he receives full value for the payment he makes. The means of doing so, other than providing good service, vary again with the local conditions and range from direct participation in the management by the user through boards or committees in rural and peri-urban organizations to public meetings, consultations and other participatory activities.

Inappropriate System Design

No matter how good the management of a water supply facility is, if it is not well designed technically, it will operate inefficiently. Many water supply facilities have been badly designed, poorly constructed and use technologies which are inappropriate. When a facility is improperly designed and constructed even with the best will in the world it cannot perform satisfactorily.

There are many reasons for poor systems design. In some instances consultants are chosen by external support agencies, that are not familiar with suitable technologies for use in the developing world and specify equipment and/or designs which are inappropriate. In other cases, there may be political interference to promote one particular technology or equipment supplier and they may not represent the optimum choice for that particular situation.

A lack of communication between the system designer and the operators of the system is a further drawback. This applies equally to a rural village receiving a hand pump well or to an urban centre with complex facilities. The operators of the system need to be familiar with, approve of and be comfortable with the technology. In addition there needs to be a continuous feedback of information from the operators to the designers to pinpoint problems with the design and suggest remedial measures.

Low Profile of Operation and Maintenance

Operation and maintenance in water supply agencies has a low, and usually an inferior profile as compared to new construction and system extension. Thus for career minded engineers the route to top management positions is recognized to be through new construction and not operation and maintenance.

The emphasis on and recognition given to new construction is partly due to its political visibility. The provision of a water supply to many developing world communities is a vote winning exercise while good operation and maintenance receives few political accolades.

Within the water sector there is an insufficient appreciation of the magnitude of operation and maintenance problems, importance and the skills required to properly operate and maintain the facilities. In part this is due to a lack of financial data. Accurate costs are not available which will demonstrate to decision makers the financial benefits of good operation and maintenance and conversely the losses to the national economy from poor operation and maintenance. An urgent priority in operation and maintenance is to collect precise figures which clearly show the financial benefits of operation and maintenance to decision makers in External Support Agencies and national governments.

This low priority assigned to operation and maintenance by decision makers is a severe constraint. In order to improve operation and maintenance performance it must be accorded a high priority and importance by national governments in their programs.

Inadequate Policies, Legal Frameworks and Overlapping Responsibilities

There is a need for clear sector policies, compatible legal frameworks and a clear division of responsibilities and mandates within the water and sanitation subsector. Due in part to the low priority assigned to operation and maintenance, no clearly defined policies have been enunciated which adequately address this issue. Commonly the lines of responsibility between the various organizations involved are often blurred. This is particularly true of the relations between water supply and sanitation where the maintenance agencies usually have no or limited contact.

The policies of ESA's with reference to operation and maintenance are frequently different and may be at variance with the approaches of national governments. National governments and ESA's should collaborate and coordinate their approaches in order to achieve higher levels of performance for O&M.

Political Interference

Political interference has been identified as a serious contributing reason for poor performance of water supply and sanitation agencies. This is most noticeable in countries where the government is directly involved in owning, operating and maintaining the water supply facilities. Political interference manifests itself in several ways. In some cases for political reasons water is free or is not charged according to the costs of operation and maintenance and to cover capital costs. This decision not to charge properly for water makes it difficult to run a self financing viable system, even if government provides funding. When governments are short of cash, often it is the water supply facilities which are soft targets and experience the greatest budget cuts.

Political interference is often evident in the choice of technologies. Government officials may for one reason or another support the purchase of a particular technology or system which may not be the best or most appropriate selection. Equipment suppliers and ESA's frequently hinder the wise choice of a technology by lobbying politicians or through restrictive policies of tied aid.

The contracts awarded for building even small rural water supply facilities are significant and there is considerable competition between contractors to be selected. In some cases the job may be awarded for political reasons rather than on the basis of performance with the result that the completed facilities may be shoddily constructed.

A possible alternative for the better management of water supply facilities is to devolve the responsibility of managing systems from government to autonomous agencies which will manage the facilities under technical, financial and administrative guidelines from the government. This would greatly limit the extent of political interference by governments and allow the facilities to be managed more efficiently.

(http://www.who.int/docstore/water_sanitation_health/wss/sustoptim.html)

4.3 Gender, water and sanitation

The following text is based on http://www.unwater.org/downloads/unwpolbrief230606.pdf. The figures given below sometimes differ from other figures in this paper due to different literature sources.

In most societies, women have primary responsibility for management of household water supply, sanitation and health. Water is necessary not only for drinking, but also for food production and preparation, care of domestic animals, personal hygiene, care of the sick, cleaning, washing and waste disposal. Because of their dependence on water resources, women have accumulated considerable knowledge about water resources, including location, quality and storage methods. However, efforts geared towards improving the management of the world's finite water resources and extending access to safe drinking water and adequate sanitation often overlook the central role of women in water management.

Current status and trends

The importance of involving both women and men in the management of water and sanitation has been recognized at the global level, starting from the 1977 United Nations Water Conference at Mar Del Plata, the International Drinking Water and Sanitation Decade (1981–90) and the International Conference on Water and the Environment in Dublin (January 1992), which explicitly recognizes the central role of women in the provision, management and safeguarding of water. Reference is also made to the involvement of women in water management in Agenda 21 (paragraph 18.70f), and the Johannesburg Plan of Implementation (paragraph 25). Moreover, the resolution establishing the International Decade for Action, 'Water for Life' (2005–2015), calls for women's participation and involvement in water-related development efforts. The Water for Life Decade coincides with the timeframe for meeting the Millennium Development Goals (MDGs).

In many cases, showing that water projects work better when women are involved has a greater impact on mobilizing finance for gender-biased projects than showing that access to water has an impact on gender equality. A study by the International Water and Sanitation Centre (IRC) of community water and sanitation projects in 88 communities in 15 countries found that projects designed and run with the full participation of women are more sustainable and effective than those that do not. This supports an earlier World Bank study that found that women's participation was strongly associated with water and sanitation project effectiveness.

The recent increase in the number of women appointed as water and environment ministers is an exciting trend which may provide an impetus to gender and water programmes. In late-2005, there were 40 women ministers of water or environment, representing every region and level of development in the world. H.E. Maria Mutagamba, Minister of State for Water of Uganda, is currently the chair of the African Ministerial Council on Water (AMCOW) and of the African Ministers Initiative on WASH (Water, Sanitation and Hygiene), supported by the Water Supply and Sanitation Collaborative Council (WSSCC). The Women Leaders for WASH are championing the role of women in decision-making, capacity building, educating children on sanitation and hygiene, and mobilizing political will around other priorities such as the linkages between water, sanitation, hygiene and HIV/AIDS.

These leaders constitute the critical mass needed to get gender integrated into water and sanitation policies and programmes. Working closely with these dynamic women leaders is important for advancing a gender perspective at global and national levels during the 'Water for Life' Decade, and developing a network on gender and water.

Sustainable management of water resources and sanitation provides great benefits to a society and the economy as a whole. Thus, it is crucial, first, to involve both women and men in water resource management and sanitation policies and to ensure that the specific needs and concerns of women and men from all social groups are taken into account. Second, it is vitally important to determine what people (consumers of water and sanitation) want, what they can and will contribute and how they will participate in making decisions on the types and levels of service, location of facilities and operation and maintenance. For reaching this second goal, it is indispensable to analyse a given target group from a gender perspective. Only then can efforts be truly effective and sustainable.

Issues of Particular Concern

The following are some of the major factors that need to be addressed to implement a gender approach to water resources and sanitation management. A focus on both women and men is crucial to the approach.

Equitable access to water supply

Access to safe drinking water is a basic human right and essential for achieving gender equality, sustainable development and poverty alleviation. Yet, at the end of 2004 still some 1.1 billion people, or 18% of the world's population, lacked access to safe drinking water, while 2.6 billion or 40% of the world's population lacked access to improved sanitation services. Providing physically accessible clean water is essential for enabling women and girls to devote more time to the pursuit of education, income generation and even the construction and management of water and sanitation facilities.

Equitable access to land rights and water for productive use

Equitable access to water for productive use can empower women and address the root causes of poverty and gender inequality. However, lack of access (ownership) to land may be the underlying cause of women's limited access to water and a key reason for the greater poverty of female-headed households, as has been shown in World Bank research studies. In many countries (e.g., most of Latin America), land ownership is a precondition for access to water. Shockingly, women hold title to less than 2% of the world's private land. Moreover, even where women do have a legal right to land, customs often prevent them from taking *de facto* control of land and natural resources, such as in Burkina Faso, Cameroon and Zimbabwe.

In poor regions, food security is often dependent on women's subsistence production to feed the population. Evidence shows that women are responsible for half of the world's food production (as opposed to cash crops) and in most developing countries, rural women produce between 60–80% of the food. Women also have an important role in establishing sustainable use of resources in small-scale fishing communities, and their knowledge is valuable for managing and protecting watersheds and wetlands.

The real problem faced by many female farmers, however, is that they have very little or no access to irrigation water for agricultural purposes and are entirely dependent on rainfall. Therefore, it is crucial to accord to women recognition as land holders and contributors to the development process. Responding to the needs of poor farmers requires a detailed understanding of men's and women's local knowledge systems, resource utilization and income generating opportunities.

Access to sanitation

Lack of sanitation facilities and poor hygiene cause water-borne diseases such as diarrhoea, cholera, typhoid and several parasitic infections. Moreover, the incidence of these diseases and others linked to poor sanitation – e.g., round worm, whip worm, guinea worm, and *Schistosomiasis* – is highest among the poor, especially school-aged children. Each year, more than 2.2 million people in developing countries die from preventable diseases associated with lack of access to safe drinking water, inadequate sanitation and poor hygiene. The social and environmental health costs of ignoring the need to address sanitation (including hygiene and wastewater collection and treatment) are far too great. Plate 46 shows that the need is highest in Sub-Saharan Africa and Southern Asia.

A focus on gender differences is of particular importance with regard to sanitation initiatives, and gender-balanced approaches should be encouraged in plans and structures for implementation. Simple measures, such as providing schools with water and latrines, and promoting hygiene education in the classroom, can enable girls to get an education, especially after they reach puberty, and reduce health-related risks for all. Moreover, the design and the location of latrines close to home may reduce violence against women, which may occur when women have to relieve themselves in the open after nightfall.

Capacity development

Building capacity means bringing together more resources, more people (both women and men) and more skills. Yet, when looking closely at capacity building in water supply and sanitation in developing countries, it becomes clear that most of the training is aimed at water resources and water supply specialists. Very few programs and projects are aimed at expertise in social development, sanitation, or hygiene education that emphasizes a gradual scaling down to those responsible for operation and maintenance of water supply and sanitation, who are primarily women. Targeting women for training and capacity building is critical to the sustainability of water and sanitation initiatives, particularly in technical and managerial roles to ensure their presence in the decision-making process.

A successful example of a demand-responsive approach is reported from Ghana: In the Ejura-Sekyedumasi District of Ghana, the Ghana Rural Water Project (GRWP) was initiated by World Vision Ghana (WVG) to address a serious infestation of guinea worm and poor access to potable drinking water. The project has shifted from a strictly technology-driven approach to a community-based, people-oriented, demand-driven focus, including gender mainstreaming, poverty alleviation and the well-being of children. Through the GRWP initiative, WVG supplied the village with two boreholes fitted with hand pumps, two public Ventilated Improved Pit (VIP) latrines and a urinal. The community has since identified this water and sanitation project as having had a high level of community participation and gender integration. It has improved the education of girls, who accounted for 53% cent of primary school students in 2005, compared to 43% in 1995.

Participation and equity in decision-making

Women are under-represented in the 'water world', with careers and training in water management dominated by men. If water management is to be democratic and transparent – and represent the needs of the people – both men and women must have an equal say. A start has been made through the increase in the number of women serving as ministers of water and environment, but the empowerment of women as water managers must also be felt at the grassroots level.

In South Africa, Lesotho and Uganda, the women ministers for water are implementing affirmative action programmes in the water sector to train women for water and sanitation related careers, including science and engineering. At the local level, women have found their voices and have now been trained to locate water sources in the village, to decide on the location of facilities and to repair pumps. Since these changes were made, the incidence of pump breakdown has decreased considerably. While it may be hard to imagine a change in orientation of water policy in many countries in the near future, affirmative action policies such as 'women in water' awards and a bursary for young women to take up careers in the water sector in South Africa have proved to be a successful means of empowering women.

Protection of the resource base: indigenous perspective

Indigenous peoples possess traditional knowledge and skills concerning the sensing/locating of water and protection of the source. Water sources on indigenous lands are often considered a sacred element, and indigenous women may be the holders of 'water knowledge'. Their traditional land management skills often provide the most effective method of water resource management in their settlement areas. However, indigenous peoples are seriously affected by their uncompensated and unsustainable loss of water to farming and other industries introduced from outside their communities. In the worst cases, governments have closed water sources in an effort to forcibly relocate indigenous peoples from their traditional territories. In other instances, indigenous peoples are not provided with clean safe drinking water to the same level as other nationals in a given country. Measures must be taken so the indigenous people can develop their capacities to achieve sustainable and equitable self-development.

Resource mobilization

The volume of external financial assistance is not likely to grow fast enough to meet water and sanitation needs around the world. Governments will have to continue to be primarily responsible for raising and using public funds (from general revenue, cross subsidization, user fees, and borrowing) for water resources and sanitation infrastructure needs. Formal and informal women's organisations and networks can play important and stimulating roles in mobilizing resources for sustainable and equitable water and land management projects. For example, The Swayam Shikshan Prayog in India has facilitated the formation of over 1.000 women's savings and credit groups that have mobilized their own savings to provide loans for one another. Women started organizing to address development issues such as water supply in their communities.

While their potential contributions are considerable, women in developing countries often lack access to tools such as computers and Internet to disseminate their ideas and apply for funds. Instructing women in project management and fund raising may empower them to launch new projects and to contribute to poverty alleviation independently.

Private sector participation, pricing and the right to water

An issue that has created controversy on many levels is the involvement of the private sector in the provision of water services. Those who are opposed to privatising water services argue that water is a fundamental human right and not a commodity that can be bought and sold for profit. This is in line with the November 2002 ruling (General Comment No. 15) of the United Nations Committee on Economic, Social and Cultural Rights that states that access to adequate amounts of clean water for personal and domestic use is a fundamental human right. Opponents further point to recent empirical evidence which shows that privatisation in developing countries can have negative consequences in terms of water distribution for the poor, who are unable to pay for adequate supplies (Plate 47).

Simultaneously, those in favour of private sector involvement point out that water tariffs are required to improve water allocation and efficiency and encourage the resource's conservation. When water is priced, people have a strong incentive to use it more efficiently. Nonetheless, whether or not water has a price is not directly related to private sector involvement in water services. Partnerships involving both public and private providers can be very effective in expanding services to a wider network of customers. As long as government retains oversight over water quality and ownership of the resource, private sector involvement can provide positive benefits.

Water conflicts, hazards and emergencies

Conflicts and emergencies that exacerbate water scarcity can lead to a double hardship for women. When water is scarce, women and girls may have to travel longer distances to obtain water, and conditions are more dangerous.

Women are also disproportionately affected by natural disasters, such as floods and earthquakes, as a result of gender inequalities regarding political and economic status, human rights, education and health. Women have high death rates in disasters, as they often do not receive warnings or other information about hazards and risks. Their mobility in disasters may be restricted or affected due to cultural and social constraints. Gender inequality can complicate and extend the time for women's recovery, for example, if women do not receive timely care for trauma experienced in disasters.

During floods in Mozambique in 2000, when clean water was in short supply, many women were forced to resort to using floodwater for cooking, thereby increasing the risk of disease outbreak.

Recommended areas for action

To ensure that the gender perspective is successfully incorporated into the global water and sanitation agenda, it is essential to advocate for the direct involvement of both women and men at all levels: national governments; regional/local governments; communities and civil society organizations; donors; and international organizations. Some actions for each are suggested below:

A. National Governments

Governments need to have a clear commitment to both incorporate water and sanitation programmes explicitly into their national development strategies, and to ensure that a gender perspective is mainstreamed into this agenda. Some suggested actions are outlined below:

Mobilize resources to improve access to safe water and sanitation

- Facilitate access to grants or credit on concessionary terms for women's groups for installation and maintenance of adequate drinking water supply and sanitation facilities;
- Allocate resources to civil society organizations and small-scale providers of water and sanitation services, particularly those that include women as full partners;
- Provide micro-credit and creative alternative financing mechanisms to gender-sensitive organizations for improving or building community-based water and sanitation services.

Strengthen legislation and facilitate access to land and water for productive uses

- Recognize women's important role in agriculture, livestock and fisheries, assist them in gaining access to water for productive uses and accord women equal rights to land tenure;
- Support and promote equitable land and tenure arrangements that enable female producers to become decision-makers and owners;
- Improve women's productivity in using water for agriculture and small business through training, market linkages and access to information.

Promote access to sanitation

- Ensure that the overall national sanitation framework is gender-sensitive;
- Earmark funds for hygiene education in school curricula and separate sanitation facilities for boys and girls;
- Commission research to identify, through gender analysis, where social and economic groups are chronically excluded from access to sanitation.

Develop capacity and encourage participation

- Introduce affirmative action programmes for training women in technical and managerial careers in the water and sanitation sector;
- Ensure that a minimum percentage of women participate in decision making from the ministerial down to village levels;
- Provide assistance to facilitate research into gender considerations in water resource management;
- Allocate funds to the capacity development of women and girls;
- Encourage both women and men to participate in businesses involved in water resource management and sanitation schemes.

B. Regional/Local Governments

- Encourage gender mainstreaming in local government and community levels;
- Promote hygiene education messages through women's groups, schools and health clinics;
- Design and implement capacity building to consider the needs of women and men in the design of water, sanitation and hygiene education programmes;
- Remove internal gender biases and discrimination in public sector organizations;
- Encourage gender sensitive budgets so that local governments can assess the economic value of policy commitments on gender equality.

C. Communities and Civil Society

- Lobby for better services targeted towards women and children;
- Assist in collecting information on men and women's roles, access, needs, priorities and perspective on water and sanitation related issues;
- Support equality for women in the decision-making process at a local level;
- Enable women and girls to acquire access to information, training and resources related to water and sanitation initiatives.

D. Donors and International Organizations

- Engage women leaders, especially environment and water scientists and ministers, to serve as role models in the effort to mainstream gender into water management at all levels;
- Promote gender mainstreaming in water and sanitation through linking with MDG 3: 'Promote gender and empower women'.
- Compile and disseminate examples of good practices and develop norms and guidelines for gender mainstreaming;
- Invest in the capacity building of the water sector, with emphasis on empowering disadvantaged women and men;
- Encourage the media, in both developed and developing countries, to provide more coverage on gender and water issues;
- Promote equal opportunities for men and women within the donor sector;
- Provide capacity building support of gender focal staff;
- Cooperate with partner organizations to develop a framework of conventional wisdom between water and gender employees from each organization;
- Support the development and implementation of a gender sensitive water policy framework both on national and international level during the decade 2005–2015.

4.4 Inadvertent impacts on hydrological processes

"Freshwater ecosystem alterations have been carried out through much of modern history, with the intensity of modifications increasing in the early to mid-1900s. Common waterway modifications, such as the construction of dams and irrigation channels, inter-basin connections and water transfers, can impact on the hydrology of freshwater systems, disconnect rivers from floodplains and wetlands, and decrease water velocity in riverine systems. This, in turn, can affect the seasonal flow and sediment transport of rivers downstream, impacting on fish migrations and changing the composition of riparian ecosystems. Exotic species often thrive at the expense of indigenous ones, leading to an unquantifiable loss in freshwater biodiversity and inland fishery resources". (http://maps.grida.no/go/graphic/tigris-and-euphrates-rivers-fragmentation).

One example of the inadvertent impacts on hydrological processes is the irrigation of farmland leading to salinisation of soil and drainage return waters. There has been no more tragic case than the salinisation of the irrigated land of the Aral Sea basin, combined with the drying up of the Sea and the rivers that used to feed them.

For a better understanding of the problem some information on irrigation and salinisation is given, before dealing with the case studies in particular.

4.4.1 The problem with irrigation

Currently an estimated 15% of the world's cultivated lands had been irrigated for food crops, accounting for almost half the value of global crop production. The world's irrigation areas are expected to reach 290 million hectares by 2010, and by 2025 about 330 million hectares.

67% of the global water demand is consumed by agriculture to feed the growing population, but more than 50% of this amount is wasted by inappropriate irrigation systems. Plate 48 gives some figures from California of the efficiency of the various types of irrigation techniques that differ in how the water obtained from the source is distributed within the field. The figures are nearly in accordance with those from Namibia:

Efficiency of irrigation systems in Namibia

Surface system (flood)	55%
Conventional sprinkler	75%
Centre pivot	80%
Micro jet	85%
Drip irrigation	90%

(Ministry of Agriculture, Water and Rural Development, 2000, p. 16)

In general, the goal is to supply the entire field uniformly with water, so that each plant has the amount of water it needs, neither too much nor too little.

In surface irrigation systems water moves over and across the land by simple gravity flow in order to wet it and to infiltrate into the soil. Surface irrigation can be subdivided into furrow, border strip or basin irrigation. It is often called flood irrigation when the irrigation results in flooding or near flooding of the cultivated land. Historically, this has been the most common method of irrigating agricultural land.

In these systems the levels are controlled by dikes, usually plugged by soil. This is often seen in terraced rice fields (rice paddies), where the method is used to flood or control the level of water in each distinct field. It can be applied when the ground is level or only slightly tilted. The system is globally widespread, but in sandy soils little effective because of large losses through seepage. The danger of salinisation is low because of the constant downward water movement, but the system needs large amounts of water because of constant high evaporation. In this context the board in Plate 49 is especially piquant.

With border strip irrigation the water moves slowly between small ridges over the slightly tilted surface, but in contrast to flooding the lower end is not dammed, so that the surplus water can run off. At the more labour intensive furrow irrigation the plants grow on small ridges, whereas the water flows downwards through the furrows.

At the sprinkler irrigation the water is sprayed over the crops either by sprinkler bars moving slowly on steel wheels over the field (Plate 50, older system) or by more modern sprinklers moving on rubber tires (Plate 51). In this system the water is taken from a concrete feeder canal (Plate 52). Also carousels or pivot systems with a fixed feeder point in the centre of the field are in use. The circular fields can be seen even when flying over them in very great altitudes. All sprinkler systems can be applied on sandy soils and on more tilted surfaces, and the water can be dosed according to demand, but the losses through evaporation can be high.

The most efficient method is the drip or micro irrigation. It is also known as trickle irrigation and functions as its name suggests. Water is delivered by tubes lying on the surface or buried under ground at or near the root zone of plants, drop by drop. In Plate 53 the sub-surface polyethylene hoses cannot actually be seen, but one feeder point (No. 31) in the foreground is visible, were some surplus water is leaking. This method can be the most water-efficient method of irrigation, if managed properly, since evaporation and runoff are minimized and fertilizers can be added to the irrigation water. How efficient the method is shows an example from Israel. Here farmers changed to drip irrigation and could double their yields using the same amount of water than before.

4.4.2 The problem of soil salinity

In arid and semi-arid regions irrigated lands are prone to salinisation. Salty (saline) soils are soils that have a high salt content. The predominant salt is normally sodium chloride (NaCl, "table salt"). The problems are often associated with high water tables, caused by a lack of natural subsurface drainage to the underground. Poor subsurface drainage may be caused by insufficient transport capacity of the aquifer or because water cannot exit the aquifer for instance, if it is situated in a topographical depression.

The primary cause of man-made salinisation is the salt brought in with irrigation water. All irrigation water derived from rivers or groundwater, however 'sweet', contains salts that remain behind in the soil after the water has evaporated (Plate 54).

For example, assuming irrigation water with a low salt concentration of 0.3 g/l (equal to 0.3 kg/m³ and a modest annual supply of irrigation water of 10.000 m³/ha (almost 3 mm/day) brings 3.000 kg salt/ha each year. In the absence of sufficient natural drainage (as in waterlogged soils) and without a proper leaching and drainage program to remove salts, this would lead to a high soil salinity and reduced crop yields in the long run.

Much of the water used in irrigation has a higher salt content than in this example, which is compounded by the fact that many irrigation projects use a far greater annual supply of water. Sugar cane, for example, needs about 20.000 m³/ha of water per year. As a result, irrigated areas often receive more than 3.000 kg/ha of salt per year and some receive as much as 10.000 kg/ha/year.

The second cause of salinisation is water logging in irrigated land. Irrigation causes changes to the natural water balance of irrigated lands. Large quantities of water in irrigation projects are not consumed by plants. In irrigation projects it is impossible to achieve 100% irrigation efficiency where all the irrigation water is consumed by the plants. The maximum attainable irrigation efficiency is about 70 to 85% but usually it is less than 60%. This means that a minimum of 30%, but usually more than 40% of the irrigation water is not evaporated and it must go somewhere.

Most of the water lost this way is stored underground which can change the original hydrology of local aquifers considerably. Many aquifers cannot absorb and transport these quantities of water and the water table rises leading to water logging. This causes three problems:

- the shallow water table and lack of oxygenation of the root zone reduces the yield of most crops
- it leads to an accumulation of salts brought in with the irrigation water as their removal through the aquifer is blocked
- with the upward seepage of groundwater more salts are brought into the soil and the salinisation is aggravated

Globally, the salinisation of agricultural land affects a considerable area of irrigation projects, in the order of 30%. When the agriculture in such a fraction of the land is abandoned, a new salt and water balance is attained, a new equilibrium is reached, and the situation becomes stable.

To control soil salinity drainage is the primary method. The system should permit a small fraction of the irrigation water (about 10 to 20%, the drainage or leaching fraction) to be drained and discharged out of the irrigation project.

In irrigated areas where salinity is stable, the salt concentration of the drainage water is normally 5 to 10 times higher than that of the irrigation water. Salt export matches salt import and salt will not accumulate.

When reclaiming already salty soils, the salt concentration of the drainage water will initially be much higher than that of the irrigation water (for example 50 times higher). Salt export will greatly exceed salt import, so that with the same drainage fraction a rapid desalinization occurs. After one or two years, the soil salinity is decreased so much, that the salinity of the drainage water has come down to a normal value and a new, favourable, equilibrium is reached.

In regions with pronounced dry and wet seasons, the drainage system may be operated in the wet season only, and closed during the dry season. This practice of checked or controlled drainage saves irrigation water.

The discharge of salty drainage water problem may pose environmental problems to downstream areas. The environmental hazards must be considered very carefully and, if necessary mitigating measures must be taken. If possible, the drainage must be limited to wet seasons only, when the salty effluent does inflict the least harm.

The drainage system designed to evacuate salty water also lowers the water table. To reduce the cost of the system, the lowering must be reduced to a minimum. The highest permissible level of the water table (or the shallowest permissible depth) depends on the irrigation and agricultural practices and the kind of crops.

In many cases a seasonal average water table depth of 0.6 to 0.8 m is deep enough. This means that the water table may occasionally be less than 0.6 m (say 0.2 m just after irrigation or a rain storm). This automatically implies that, in other occasions, the water table will be deeper than 0.8 m (say 1.2 m). The fluctuation of the water table helps in the breathing function of the soil while the expulsion of carbon dioxide (CO_2) produced by the plant roots and the inhalation of fresh oxygen (O_2) is promoted.

The establishing of a not too deep water table offers the additional advantage that excessive field irrigation is discouraged, as the crop yield would be negatively affected by the resulting elevated water table, and irrigation water may be saved.

The statements made above on the optimum depth of the water table are very general, because in some instances the required water table may be still shallower than indicated (for example in rice paddies), while in other instances it must be considerably deeper (for example in some orchards). The establishment of the optimum depth of the water table is in the realm of agricultural drainage criteria (http://en.wikipedia.org/wiki/Soil_salinisation#Drainage_systems)

If water is scarce the relation between the required amount of water and the yield in a specific area should be carefully considered. This can be demonstrated by experiences from India: Sugar cane needs a lot of water. If for instance potatoes were grown instead of sugar cane, with the same amount of water an area could be irrigated that is five to ten times bigger, because potatoes need considerably less water. So the monetary return on the same plot was four times greater. If pigeon peas or finger millet were grown a thirty time's bigger area could be irrigated with the same amount of water and the profit rose rise by the factor 8 (Clarke, 1994, p. 180).

4.4.3 Case study: The Aral Sea crisis

In the sixties of the last century the Soviet government had the plan to increase the irrigated area in the region to 10 million ha by 1990. Most of this would be used to develop cotton production as a strategic resource and rice production for the local population. The cotton uses 10.000 to 15.000 m^3 per hectare, but the rice consumes 25.000 to 55.000 m^3. Over 10.00 m^3 of water is needed to produce 1 to of rice. The irrigation water was to be taken from the two rivers Amu Dar'ya and Syr Dar'ya.

These diversions dramatically reduced the river inflows, causing the Aral Sea to shrink by more than 50%, to lose two-thirds of its volume (Plate 55), and to greatly increase its salinity. At the current rate of decline, the Aral Sea has the potential to disappear completely by 2020.

In 1963, the surface of the Aral Sea measured 66.00 km^2, with an average depth of 16 m and a maximum depth of 68 m. During the 1960s, upstream irrigation schemes for growing rice and cotton consumed 90% of the natural flow of water from the Tian Shan Mountains. By 1987, 27.000 km^2 of former sea bottom of the Aral Sea had become dry land; about 60% volume had been lost, its depth had declined by 14 m, and its salt concentration has risen from 10 g/l to 50 g/l by 2003 (Oceans 35 g/l).

Today, about 200.000 t of salt and sand are carried by the wind from the Aral Sea region every day, and dumped within a 300 km radius. The salt pollution is decreasing the available agriculture area, destroying pastures, and creating a shortage of forage for domestic animals. The number of domestic animals in the region has become so low that the government has issued a decree to reduce the slaughter of animals for food.

Fishing in the Aral Sea has ceased completely, while shipping and other water-related activities have declined; the associated economic changes have taken a heavy toll on agricultural production. Rising unemployment has led to a major exodus from the region. In Aralsk Rayon, for example, the population has dropped from 82.900 to 72.500 people in the past 10 years.

The quality of drinking water has continued to decline due to increasing salinity, bacteriological contamination, and the presence of pesticides and heavy metals. Diseases like anaemia, cancer and tuberculosis, and the presence of allergies, are on the rise. The incidence of typhoid fever, viral hepatitis, tuberculosis and throat cancer is three times the national average in some areas.

The problems now facing the Aral Sea basin demonstrate the need for an integrated plan to cover the whole environment. A variety of proposals have been made:

- Withdrawal of land from irrigation (15% of this land is in an extremely unsatisfactory state. Ceasing irrigation would save 15–20 km^3 a year)
- Reducing the rice production by 1 Mio. ha (saving 3 km^3 of water per year)
- Improve the irrigation system (The mainly primitive systems are only 55–67% effective, whereas modern automatic sprinkler technology could make them at least 88% effective and save 40–70 km^3 per year)
- Improve management of drainage water (46 km^3 of return water currently drains into rivers, lakes and groundwater, adding to salinisation. This could be diverted directly to the Aral Sea or barren closed depressions, or else desalinated and reused. A scheme was begun in 1989 involving a 1500-km-long right bank collector canal to drain return waters from the mid-Amu irrigated region to the Sea, but is was poorly designed and most of the water is lost through evaporation or infiltration into the desert sand)

- Re-establishing soil fertility naturally (This may be achieved by crop rotation and replacing high water demand crops by vegetables and grapes)
- River regulation (It might allow up to 30 km^3 to be retained and releases in drier years. It would help irrigated agriculture, but not have much effect on the Aral Sea itself, since only the temporal distribution rather than the total discharge is effected)
- Exploiting groundwater (Groundwater resources are several times greater than surface water. Up to 10 km^3 of extra groundwater could be used without causing a reduction in river flow, and even brackish water might be used. Ultimately, however, the danger of adding to salinisation is ever-present and this is likely to be a short-term and ecologically unsound solution)
- If all measures were adhered to, a substantial recovery might be achieved within 20 years, although it is doubtful that the Aral Sea will ever be restored to the conditions that existed before the large-scale diversion of its inflowing rivers (Jones, 1997, p. 218).

4.4.4 Case study: Lake Chad almost gone

A similar example for the shrinkage of a lake caused by over-utilization for irrigation water is Lake Chad which is almost gone. It has been a source of freshwater for irrigation projects in the states of Chad, Niger and Cameroon in West Africa. Maps drawn from a series of satellite images show a dramatic decrease in the size of the lake over the past 30 years. Since 1963, the lake has shrunk to nearly a twentieth of its original size, due both to climatic changes and to high demands for agricultural water (Plate 56).

Since 1963, the surface area of Lake Chad has decreased from approximately 25.000 km^2 to 1.350 km^2. The changes in the lake have contributed to local lack of water, crop failures, livestock deaths, collapsed fisheries, soil salinity, and increasing poverty throughout the region.

Between June 1966 and January 1973, the surface area of Lake Chad shrunk from 22.772 km^2 to 15.400 km^2. In 1982, the lake's surface area was estimated to be about 2.276 km^2. In February 1994, Meteosat images measured it at just 1.756 km^2. Between 1953 and 1979, irrigation had only a modest impact on the Lake Chad ecosystem. But between 1983 and 1994 irrigation had increased four-fold. About 50% of the decrease in the lake's size since the 1960s is attributed to human water use, with the remainder attributed to shifting climate patterns. Invasive plant species currently cover about 50% of the remaining surface of Lake Chad. Research carried out over the past 40 years indicates that the main factors in the shrinking of the lake have been

- the major overgrazing in the region, resulting in a loss of vegetation and serious deforestation, contributing to a drier climate
- Large and unsustainable irrigation projects built by Niger, Nigeria, Cameroon and Chad, which have diverted water from both the lake and the Chari and Logone rivers.

4.5 Large dams and impounding reservoirs

The efficient development of large dams and reservoirs requires a delicate balance between physical hydrology, human demands, economic and technical feasibility and environmental impact. Although computer techniques of synthesis, simulation and decision making have made an important contribution to both design and management, the major problems can still be caused by lack of hydrological information, poor environmental assessment or an uncertain socio-economic context.

The construction of large dams – defined as those with walls at least 15 meters high – has increased significantly over the past 50 years (Plate 57). The average height of new dams, estimated at 30–34 m from 1940–1990, increased to about 45 m in the 1990s, due largely to construction trends in Asia. The average area and volume of freshwater reservoirs have also steadily increased, rising to about 50 km^2 between 1945 and 1970, declining through the 1980s to 17 km^2, and increasing again in the 1990s to about 23 km^2. By 1997 there were more than 45.000 large dams worldwide, 22.100 of them alone in China.

Other nations with many large dams include the United States (with 6.390 large dams), India (with more than 4.000), and Spain and Japan (with 1.000–1.200 each). The countries with the greatest number of large dams under construction, in order of significance, are: Turkey, China, Japan, Iraq, Iran, Greece, Romania and Spain, and countries in the Parana basin in South America. The river basins with the largest dams under construction are: the Yangtze with 38, the Tigris and Euphrates, with 19 each, and the Danube, with 11.

Damming and flood control can have negative impacts, such as declining fish catches, loss of freshwater biodiversity, increases in the frequency and severity of floods, loss of soil nutrients on floodplains, and increases in diseases such as schistosomiasis and malaria. On the Mississippi River, for example, the rising frequency and severity of flooding – attributed to local flood control structures – have reduced the river's ability to support native flora and fauna, while a dramatic increase in floods on the River Rhine has been attributed to increased urbanization, engineering, and the walling off of the river from its floodplain.

(http://maps.grida.no/go/graphic/damming-the-world)

"The concept of building a dam and diverting the water for direct use has been the mainstay of water resources engineering throughout history. Until the mid-twentieth century schemes were relatively unsophisticated and were commonly operated as single-source, single-use system. Even where topographic or engineering restrictions required a series of linked reservoirs rather than one single dam, they were essentially operated like one large source.

Over 60% of reservoir capacity is now in the Developing World, where the greatest expansion has occurred since 1960. These developments have often been problematic and controversial. Criticism has tended to concentrate initially on the flooding of land and displacement of people. In India, the Narmada River project is being funded by the World Bank, despite protests from many of the one million people due to be displaced and claims of an environmental disaster. Thirty large dams and thousands of supplementary dams are to be built in the basin, flooding 4.000 km^2.

After construction, criticisms are commonly levelled at schemes which have not produced the predicted returns. To this is now being added concern for public health implications in hot countries. Diseases like schistosomiasis and malaria have spread and intensified, as reservoirs have caused population migrations and as water surfaces have increased the populations of vectors carrying the diseases, like fluke worms and *Anopheles* mosquitoes.

China has for long followed the traditional path of building small dams for local use. Between 1950 and 1980, China built 90.000 such dams. But it too is opting for grandiose schemes. The Three Gorges project on the Yangtze River began in 1992 and is planned to take 18 years to complete and cost US $30 billion. It will involve displacing 1.3 million people and flooding 41.000 ha of farmland, but the 185 m dam could provide hydropower equal to 12% of national power requirements, plus water supply and flood control. Half a million people have died in Yangtze floods this century. The greatest fears are that it will silt up rapidly, disrupt navigation and the erosional and ecological balance of the river environment and cause more flooding upstream. Critics argue that the aims could be better achieved by building numerous smaller dams, although 10 smaller schemes are already underway upstream to generate 12.000 MW" (Jones, 1997, p. 281).

4.5.1 Environmental effects of large dams and reservoirs

"All large-scale manipulations of water resources are bound to have environmental effects. It is now somewhat belatedly, that a major task of planning and management must be to predict the disadvantageous effects and minimize them (demand of areas leading often to the displacement of large populations; frequently significant ecological losses; indirect impacts caused by activities facilitated by the reservoir such as irrigation and salinisation; increase in water-borne and other related diseases in tropical regions; economic burden of loans to finance construction; dam failure; social and political conflicts caused by economic stress and disagreement on use or apportionment of water.

Problems are by no means confined to the Developing World. Although physical failure of large dams is unlikely in the USA, the Federal Emergency Management Agency estimates that up to 1.300 smaller dams are unsafe and threaten populated areas. In 1986 Congress voted US $15 million per year for improving dam safety.

Reisner (1993) presents a compelling if polemic account of the dual hegemony of irrigation and dams in American water resources policy. The USA has some 250.000 dams, of which 50.000 are "major". Building dams for irrigation in the drylands west of the l00th meridian began in earnest in the 1880s after droughts had caused a number of agricultural catastrophes. Major John Wesley Powell's Irrigation Survey established both the need and the potential. The Desert Lands Act required proof of irrigation before a farmer could own the land. Irrigation was enshrined in 1902 Reclamation Act, which set up a Reclamation Fund to finance projects. Thereafter, Reisner (1993) claims, the irrigation program 'became a monster'.

It led directly to the Bureau of Reclamation's policy of river basin planning and accounting. Ostensibly, this was a laudable policy. It fitted in well with New Deal' social policy adopted by President Roosevelt to create economic regeneration after the Great Depression, which led to the Tennessee Valley Authority (TVA) program in 1933. Under the TVA the river basin was viewed and planned as a whole, both land and water, for the first time. The TVA became world-famous as an example of environmental integration. Indeed, much was achieved, particularly in the realms of land reclamation, soil conservation and farm management, which was aimed specially at reducing siltation in the reservoirs. The US Soil Conservation Service grew out of the TVA experiment. This provided a vital service, since considerable damage had already resulted from irrigation projects supported by the Reclamation Fund but based on little understanding of soils and drainage processes.

Nevertheless, "new dams were the cutting edge of the TVA'" and this strongly influenced national policy. The TVA dams were built primarily for hydropower, although they also improved navigation facilities and provided flood protection. There were two important consequences: (1) the success of the TVA fortified the engineering view that nature can be completely controlled, that it can be groomed and tidied by engineering structures; and (2) it strengthened the bureau's view that integrated basin projects were a means of deriving revenues from more economically viable aspects to fund other parts of the program. The former view has been heavily questioned since the 1993 Mississippi floods. The bureau's concept of accounting led to a widespread policy of building hydropower dams to fund uneconomic irrigation schemes. Reisner (1993) described the result as a "perversion of a sensible idea" and the "death sentence for free flowing rivers".

The bureau produced similar basin-wide plans. In the 1950s, the Colorado River Storage Project produces ten dams that between them store 60 billion m^3, 5 to 8 times the annuals flow of the river, with evaporation losses greater than the storage capacity of most existing US reservoirs. It includes the Hoover Dam and Lake Mead, the largest in the world, from which water is diverted to feed irrigation in the Imperial and Coachella valleys around the Salton Sea in California (environmentally the most damaging aspect) and the discharge is used to generate electricity for Los Angeles (environmentally the best aspect)". (Jones, 1997, pp. 282–284).

4.5.2 Case study: The impact of the Aswan High dam on the River Nile

"The Aswan High Dam was completed in 1964 at a cost of US $1 billion and the resettlement of 120.000 people to provide irrigation, hydropower and fish production in Lake Nasser, at a time when scant regard was paid to long-term environmental consequences. lt was intended to underpin an agricultural and industrial revolution in the country and President Nasser made it a nationalistic symbol for an Egypt recently "freed" from post-colonial monarchy. In this, it was only partially successful. The agricultural objectives were largely fulfilled during the first 10 years of operation. Year-round irrigation did permit three harvests a year on the floodplain, where from time immemorial the annual Nile flood had supported only one. An additional 405.000 ha of land was reclaimed from the desert, and irrigation saved the rice and cotton crops during the 1972 and 1973 droughts.

But from 1974, Egypt's historical position as a net exporter of food began to falter. This was partly due to high population growth at 2.5% per year, but it was also due to the severe lack of consideration for environmental effects, many of which rebounded on food production. The dam traps 60 million m^3 of sediment a year and blocks the passage of the vital nutrient-laden silt that for millennia passed down the Nile to fertilize the floodplain. These croplands needed artificial fertilizer to compensate, and much of the newly created hydropower has been absorbed in producing fertilizer costing US $100 million p.a. The more continuous, low-velocity irrigation without adequate drainage has caused mineral salts, which used to be flushed out by the flood, to accumulate in the floodplain soils. And salinisation has begun in the new croplands. Because of salinisation, two-thirds of the land reclaimed over the last 30–40 years is now out of production or marginal. Three-quarters of the gain in food production from the new, but less productive, irrigated land has been offset by salinisation.

Fisheries have also suffered in the lower Nile and offshore of the Nile Delta. With the loss of the nutrient-laden silt the lobster, shrimp, sardine and mackerel fisheries have almost disappeared, and have yet to be balanced by catfish, carp and has from Lake Nasser. More hydropower may be absorbed in producing chemical substitutes to help the fisheries.

Lower sediment loads in the river water are also creating erosional problems. Bridges and dams are being undermined. The increased transparency of the river water aids eutrophication. Agricultural land is being lost through bank erosion, as the river flow is more competent, and through shore retreat, saltwater intrusion and subsidence in the delta due to lower rates of replenishment combined with a rise in sea level (Plate 7). The delta shoreline has been retreating at up to 40 m per year. A proposed US $250 million program of ten check dams aims to limit bank and bed erosion by reducing the channel gradient.

Water quality and public health are also threatened by reduced river flows. Shallow or stagnant water encourages malaria and schistosomiasis. Urban wastewater entering the river is less diluted and urban colonization of formerly flooded islands near Cairo has increased the risks.

Water levels could be further affected if an Egyptian Ministry of Irrigation plan to divert water to Sinai were ever implemented. Hydrologists developed a multi-objective programming model to study this proposal, looking at the trade-offs between economic and political objectives and the interactions with water quantity and quality, navigation, crop rotation and irrigation techniques. They concluded that the costs would be high und economic sacrifices would have to be made if the political aims of colonization were to be achieved. They also showed how all decisions are sensitive to the cost of water elsewhere in Egypt.

The final result is that a quarter-century after Lake Nasser was due to be full it is still barely two-third full and there is no immediate prospect of a significant rise. With Sudan und Ethiopia now developing their own sections of the Nile, it may never fill" (Jones, 1997, p. 284).

Further readings

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For indicators for the water sector: examples from Malawi see:

http://www.wateraid.org/documents/plugin_documents/indicatorswatermalawia.pdf

For community mapping as a tool for community organising see:

http://www.iapad.org/publications/ppgis/community_mapping_manual_oct_2005.pdf

4.6 Tasks:

- Write an assignment of about 1.200 words in which you compare the statements of the WHO (2003) with the findings of Siekmann (2009), and find out how much progress has been made in the meantime.
- Prepare for a presentation in class: The environmental impacts of the Aswan Dam.
- Discuss in class the general advantages and disadvantages of large dams and reservoirs.
- Present to the class the Narmada River project in India with special focus on the problem of resettlement of people.

5 Methods and Techniques for Water Management

5.1 Integrated Water Resource Management (IWRM)

In many countries a large number of water supply and sanitation projects and water polices were developed in isolation from each other. These sectoral approaches carried out by different agencies led to overlapping activities and fragmented institutional responsibilities with sometimes detrimental effects. To overcome these problems the appropriate tool of Integrated Water Resource Management (IWRM) has been developed.

"IWRM promotes participatory approaches, demand and catchment area management, partnership, subsidiarity and decentralization, the need to strike a gender balance, the environmental, economic and social value of water and basin or catchment management. It replaces the traditional, fragmented sectoral approaches to water management that has led to poor services and unsustainable resource use. It is based on the understanding that water resources are an integral component of the ecosystem, a natural resource and a social and economic good" (WWAP, 2003, p. 376).

According to Jones (1997, p. 345) IWRM has three guiding principles: *multiple purpose, multiple objectives and multiple means*. Integrated plans need to balance a wide range of water uses and management purposes. They need to include objectives that balance economic productivity with environmental quality, health and social considerations. And they should achieve these ends by combining physical structures with regulations and economic incentives. This may involve sacrificing some economic advantage to preserve resources for the next generation or to maintain and enhance the value of water to society.

IWRM is commonly seen as relating to the river basin unit, but this is increasingly inadequate. The "hydrological unit" could be an aquifer or an artificial unit created by inter basin transfer. Challenging as this is on a national scale, it can be forbidding when the units are international. The 1993 UNESCO report suggested that "detailed integrated planning for such large river basins is probably administratively infeasible", and noted that even the Lower Mekong Commission had to date only concerned itself with framework planning and data collection. Smaller basin units in the Philippines or Caribbean offered greater chance of success for IWRM.

Integrated water resource management is being actively promoted by the UN as a means of linking the development and protection of both natural and human resources within a basin under one overarching management structure. Problems caused by piecemeal developments and fragmented institutional responsibilities have been all too common, especially in Developing Countries.

The tool of IWRM can be applied to any water related problem. Jones (1997, p. 343) has applied it for example on the management of watershed management. Plate 58 presents a systems view of the framework for IWRM. It combines a scientific focus on the surface and subsurface water resources, and their links with the soil and biota, with careful consideration of their value to society and its economic and social objectives (Plate 59).

The basic aim is to avoid developments in one field, like urban expansion or forest clearance that might have important detrimental impacts upon another. Human occupancy of floodplains is one such case that has increased hazards for inhabitants downstream as well as the risk of local flood damage (Plate 60).

Most cities in the humid tropics currently suffer from severe lack of integrated planning, combined with grossly inadequate databases, and lack of scientific analysis of urban hydrology or concern for wastewater control. But this is not solely a problem for Developing Countries. The northern Italian floods of January 1994 were widely blamed on a combination of lack of planning control for building development on the floodplains and continuing environmental degradation and deforestation in the Alpine headwaters. Plate 60 illustrates the ways in which IWRM may help.

Some general conclusion

"lt is rarely possible to undertake developments without any deterioration of environment or resource, but it should be possible to minimize these side-effects and it must be possible to avoid irreversible damage. Integrated and environmentally aware development combined with demand management and waste reduction offer the safest way forward.

Importing strategic resources from other areas need not be antipathetic to these aims, but it needs to be carefully considered in terms of its likely environmental impact, the durability of the solution and a range of alternatives, including socio-economic adjustments.

Sustainability is the keyword for future development. Stable sustainability will probably only be achieved by controlling demand, by recycling, by reducing pollution and by cutting overall water use. However, it may be difficult to achieve true stability within natural, technical and economic environments that are constantly changing. Technological developments, cheaper methods or changing economic priorities may enable new approaches, such as desalination or importing icebergs, which could expand local resources in some areas. History suggests, however, that engineering new resources only 'buys time' until demand catches up, and there are still many legitimate environmental and technological reservations over widespread use of these technologies.

We should also be careful to avoid the narrow anthropocentric view of sustainability, as the sustainable management of resources for humanity. The scale of human interference with the hydrological cycle now demands a more altruistic view of the impacts upon the rest of the living world. In the eloquent words of US Vice-President Al Gore (1992): "The rains bring us trees and flowers; the droughts bring gaping cracks in the world. The lakes and rivers sustain us; they flow through the veins of the earth and into our own. But we must take care to let them flow back out as pure as they came, not poison and waste them without thought for the future."

Gore (1992) identified five strategic threats to the global water system: the redistribution of freshwater; rising sea levels; changes in land use, especially deforestation; worldwide contamination of water resources; and rapid population growth. Water is at last on the international political agenda and thankfully on a higher plane than 'water wars'.

Environmental protection is still, nevertheless, too often regarded as the preserve of Developed Nations. And even in these countries many aspects of understanding and enforcement need further development. Transferring concepts of environmental protection to different environments and to nations that understandably regard them as a secondary consideration to economic development can be problematic. But it will be necessary.

Increased international cooperation in science and technology will hopefully play an important role in achieving sustainability. Natural systems need to be thoroughly understood before they can be safely managed. Too often in the recent past, technological solutions devised in one environment have been transported to less well understood environments where they have proved inappropriate or even damaging. In this, the work of the International Association of Hydrological Sciences (IAHS), the World Meteorological Organization (WMO) and United Nations Educational, Scientific and Cultural Organization (UNESCO) is of paramount importance, particularly as vehicles for communicating methods of 'best practice' and for identifying regional scientific and data needs" (bases on Jones, 1997, pp. 342–346).

To support management decision on a global level the Global International Water Assessment's (GIWA) assessment tools for monitoring the world's water resources have been developed. They are incorporating five major environmental concerns and applications of the Driving Forces-Pressure-State-Impact-Response framework (DPSIR). Plate 61 shows the GIWA Assessment Tools and GIWA's five main environmental concerns, which are: freshwater shortages; pollution; the unsustainable exploitation of fisheries and other living resources; habitat and community modification and global change.

(http://maps.grida.no/go/graphic/global_international_waters_assessment_tools)

5.2 Methods of testing the water quality

To evaluate the quality of water in rivers or lakes is the assessment of how much dissolved oxygen is present in the water. It is possible to measure the ultimate oxygen demand by determining the difference between the amount of oxygen dissolved in a sample of water and the amount of oxygen left after the organic matter has used up as much as it can. For this method two tests have been devised.

5.2.1 BOD (Biological Oxygen Demand)

The first test is the BOD (biological or biochemical oxygen demand), which is the most important indicator of organic pollution. A sample is kept in the dark for five days in a sealed bottle at a temperature of 20 ^{0}C and the initial and the final oxygen content are determined. The test relies on the biological action and is a simulation of actual processes which occur in polluted watercourses. The more oxygen has been used up the more polluted is the water by organic matter.

Most pristine rivers will have a BOD below 1 mg/l, and moderately polluted rivers may have BOD values in the range of 2 to 8 mg/l, whereas untreated sewage may have values around 600 mg/l.

The test is not a good indicator of industrial pollutants, since such wastes are toxic and often inhibit the activity of microorganism on which the BOD test relies.

5.2.2 PV-Test

The second test is PV-test (permanganate value), which uses a known concentration of acidified potassium manganate (permanganate) to oxidize both organic and inorganic materials. Here, the concentration of the manganate solution is measured at the start of the test and then again after three minutes and four hours at 27 ^{0}C. The difference reflects the uptake of oxygen and is expressed in g m^{-3}. It has been found that the ration of the concentration of oxygen uptake after four hours to that used in three minutes gives an indication of the origin of polluting materials. It is an approximate measure of the ration of organic to inorganic oxidisable materials.

5.2.3 COD (Chemical oxygen demand test)

In the chemical oxygen demand test (COD) the water sample is boiled for two hours in a mixture of potassium dichromate and concentrated sulphuric acid in the presence of silver nitrate as a catalyst. This ensures the complete oxidation of most of the organic and inorganic materials present. It usually gives a higher value for the oxygen uptake than either the PV or BOD test (based on Wright, 2003, p. 287).

5.2.4 The biotic index

A further measure of pollution in a particulate site of a river is the biotic index. One way of determining the water quality is the Biological Monitoring Working Panel (BMWP), a method which is common in the UK and Europe. Aquatic invertebrates have different pollution tolerances and an arbitrary score is allocated to each species according to their resistance to pollution.

Aquatic macro-invertebrates are abundant and found in water bodies throughout the world, they are not extremely mobile (as compared to other aquatic organisms such as fish) and they carry out part or all of their life cycle within the stream or river. So it is possible to sample a stream for chemical testing when the pollution is temporarily not present or when the pollution source has passed by. However, care must be taken when interpreting a biotic index because pollution may not be the only effect acting on the organisms. Plate 62 shows how biotic indices can be used to calculate an overall score (based on Wright, 2003, pp. 311–312).

Further readings

Lenton, R. & Muller, M. (Ed.) (2009). *Integrated Water Resource Management in Practice: Better Water Management for Development.* London: Earthscan.

5.3 Tasks:

- Present to the class: The biotic index to determine the pollution of river waters (Plate 62) is used mainly in the UK and in Europe. Find out from the internet if there is a similar biotic index used in your country. If there is, present a list of used organism types to the class. If there is no index find out and present how pollution is measured in your country.
- Present to the class the Global International Water Assessment Tools, preferably on an African example. Use v. a.: http://www.unep.org/dewa/giwa/giwa_doc/documents_article.asp

6 Water and economics

(This chapter is mainly based on World Water Assessment Programme, 2003, p. 326–342).

Growth in population, increasing costs of water service delivery, changing consumption preferences, deterioration of water quality, dwindling supply and the increasing realization of the opportunity costs of water have lead to the insight expressed in principle 4 of the Dublin Statement (Chapter 3.1.13): 'Water has an economic value in all its competing uses and should be recognized as an economic good', but it is followed by the important qualifier: "It is vital to recognize the basic right of all human beings to have access to clean water and sanitation at an affordable cost". This principle is not directly quoted in Agenda 21 (UN 1992), but it is however detailed in Chapter 18 on Freshwater Resources. Both tried to revise the conventional wisdom on the right of usage through "prior appropriation" in order to take into account the social, economic and environmental values of water. The term "economic value of water" was commonly referred to as the value imputed to its use in the productive process to emphasize that water should have a price.

6.1 'Value' of water

Valuing water has been a very controversial issue. Different users perceive the value of water differently. The same quality and quantity provides different values to consumers in different parts of the world. The value to people for domestic purposes is linked to their ability to pay, the use of water (drinking, bathing, laundry toilet flushing, garden watering), the ability of alternative sources of inferior quality (river water may be a freely available source for bathing and laundry), and social factors. It is thus important to distinguish between the value of water, which is measured in terms of its benefit to the beneficiaries, the price of water (the charges to consumers) and the cost of supplying the water (the capital and operation costs of the works needed to abstract, treat and transfer the water to the point at which it is used). When aiming to meet the needs of the poor at affordable prices and to recover the costs of water supplies through tariffs, it is important to consider that water should not be sold at a price above the value placed on it by potential consumers.

It is widely recognized that water has traditionally been regarded as a free resource with zero cost at supply point and at best, water users have been charged only a proportion of the costs of extraction, transfer, treatment and disposal. All associated external costs have been ignored and users have been offered very little incentive to use water efficiently and not waste it. Major arguments for assigning price for the use of water have mostly originated from these concerns. Because costs of water supply delivery have escalated, it has become clear that economic measures such as pricing in general and demand management instruments have to play a distinct role in ensuring the more efficient use of water.

One of the five key recommendations of the freshwater conference in Harare (1998) for an integrated approach to freshwater resource management was:

- **Covering costs:** All costs must be covered if the provision of water is to be viable. Subsidies for specific groups, usually the poorest, may be judged desirable within some countries. Whenever possible, the level of such subsidies and who benefits from them should be transparent. Information on performance indicators, procurement procedures, pricing, cost estimates, revenues and subsidies needs to be provided in order to ensure transparency and accountability, maintain confidence and improve investment and management capacities in the water sector.

As one specific target it was identified that mechanisms should be established by 2015 to facilitate full cost pricing for water services while ensuring that the needs of the poor are guaranteed.

To determine the value of water is very difficult because it depends to a large extend on where it is available. Its value is site-specific and, because of this, it is also time-bound: water captured by a dam or in a lake can be used as and when required, while water in a river is only available when there is a flow. Not surprisingly, the perceived value of water for domestic purposes is usually much higher than its value for irrigation. Poor people in developing countries value a reliable source much more than the intermittent, unpredictable supply commonly experienced.

The economics of water resources rarely influence water policy, even in water-short regions. As a result, the principal asset of the water resource base remains highly undervalued and readily used without much concern for its value to others. An example: In terms of opportunity cost, the short-term water value in hydropower in industrialized countries is typically quite low, often not higher than the value in irrigated agriculture. It is generally stated that hydropower is a non-consumptive use and therefore does not impose costs on others. By modifying flow regimes and the time of water to downstream users, however, hydropower installations can impose major costs on other users. The key issue is not consumptive or non-consumptive use, but the costs imposed on others by a particular use of the resource.

Surface water bodies and aquifers are generally hydraulically linked to aquatic ecosystems and they provide, usually on a seasonal basis, base flows that permit the good functioning of the ecosystems. In return, water resource systems benefit from aquatic ecosystems that can play a role as a buffer or filter (for instance the Sudd marshes on the upper Nile – Plate 36). Exchanges between water resource systems and aquatic ecosystems are usually intrinsically complex in terms of valuing water and insufficiently understood due to lack of monitoring. The multiple roles of the aquatic ecosystems confer a value to water and to humanity that may exceed the one derived from most other sources such as irrigation or hydropower.

The value of water has thus economic, social, cultural and environmental dimensions, which are often interdependent. For example, the social value of water for health has economic returns because a population in good health is more productive. Similarly, the environmental value of water has obvious economic and social implications. Such interactions can be characterized within three main clusters:

- Water is a vital common resource as it covers basic human needs and is required to sustain most life support systems
- Water, in its productive capacity, helps to maintain economic activities and has a fundamental role in managing other resources
- Water provides both use and none-use benefits: it can generate taxes, derive products for consumption and help create employment of various kinds.

6.2 Global financing of water supply

Financing the Millennium Development Goals (to halve, by the year 2015, the proportion of people who are unable to reach or to afford safe drinking water, as outlined in the Millennium Declaration, Johannesburg 2002) is probably one of the most important challenges that the international community will have to face in the next years. Different organisations have estimated that meeting the MDGs on drinking water supply coverage would require between US $10 and US $30 billion a year on top of the amount already being spent. The African Ministerial Conference on Water (2002 in Abuja) announced that Africa required US $10 billion for the development of water infrastructure in order to meet the MDGs by 2015.

It is quite clear that there is a massive investment gap and that the sources of financing are inadequate. The commitment by developed countries to provide 0.7% of Gross National Product for official development assistance to developing countries is far from being met and this has caused a significant investment gap in development financing, including the water sector.

6.3 The role of water in public-private-partnership (PPP)

One of the options for financing urban water supplies is seen in PPP, but the concept is controversial because it is argued that it can distort the notion of 'value' by replacing it with one of 'price' and, in doing so, it can sideline all social objectives related to water. Some consequences of privatisation can be seen in Plate 47.

By bringing water to people water resellers extend the coverage of piped water and provide a service with important benefits for households – but at a price. That price rises with distance from the utility, as defined by the number of intermediaries between the network and the end consumer. Having a regular supply of clean water piped into the household is the optimal type of provision for human development. Experience suggests that households with water delivered through one tap on a plot (or within 100 meters) typically use about 50 litres of water a day, rising to 100 litres or more for households with multiple taps. Household connections to a utility offer financial benefits. In unit price terms, utility water is by far the lowest cost option. Because of economies of scale once the network is in place, the marginal cost of delivering each additional unit of water falls sharply. Subsidies are another important price-reducing mechanism: Utilities are usually the gatekeeper for a wide range of direct and indirect subsidies that keep the price of water well below cost. Every step removed from the household tap adds to the price. Water vendors often act as a link between unconnected households and the utility. In some cases water is purchased from the utility and sold on to households, as in the case of private standpipe operators. In other cases water is purchased from the utility and sold to intermediaries, who in turn sell to households. As water passes through the marketing chain, prices increase. Water delivered through vendors and carters is often 10–20 times more costly than water provided through a utility. In Barranquilla, Colombia, the average price of water is US \$0.55 per m^3 from the utility and US \$5.50 per m^3 from truckers. Similarly, in the slums of Accra and Nairobi people buying water from vendors typically spend eight times as much per litre as households with piped water supplied by public utilities. Thus public services provide the cheapest water (Plate 47).

6.4 The role of water in cost recovery

Economic valuation of water should be seen within the context of its social and economic implications, reflecting the importance of meeting basic needs. Consideration should be given to the gradual implementation of pricing policies that are geared towards cost recovery.

Many governments have taken action to put the Integrated Water Resource Management principles into action. Water pricing has increasingly become an integral part of water sector management, but value of water is still insufficiently applied in the context of IWRM. Agriculture is with around 70% the largest water consumer worldwide. It has been recognized that water pricing creates conditions for a more prudent use of the resource. Moreover, cost recovery has made water services providers more responsive to the demands of their users, resulting in improved management of irrigation systems. As in the drinking water supply subsector, many cases of cost recovery do not take into account investments in infrastructure nor replacement costs. Many governments continue to invest in irrigation capital works, and the payment received from water service is generally limited to the recovery of the costs for operation and maintenance. For many irrigation water users, the amount paid does not even correspond to the costs of O&M.

6.5 Water pricing

Full cost recovery is liked to water pricing and tariffs. The introduction of water tariffs infers that water has a recognized value. Growing unavailability of and increased competition for water resources require water demand to be well managed, so that water is efficiently used. Some forms of demand management must ultimately be applied and the use of pricing is an instrument which can be effective and defended by rational and objective arguments. It is an efficient tool, yet is has to be used with caution if water management is to promote the human right to water.

6.6 Governance of water

Available options for better valuation of water and infrastructure development depend much on appropriate governance and institutional arrangements, whether it is a decision to get into arrangements with water operators or to set a tariff policy or to ensure better water allocation.

In the developing countries, an approach that is increasingly being practiced is to decentralize water management responsibilities to the lowest possible levels of the administration. It should be stressed however that unless adequate capacities exist at decentralized levels, such measures are not likely to be successful, in particular for protecting the interests of the poor. For example, price regulation by municipalities or local authority may result in information asymmetry in developing countries. It has been seen that lower level authorities may not have the desired leverage to exercise control on service providers. A national report indicated that in many developing countries decentralisation is regarded as a vehicle to achieve cost recovery and improved governance. For example, in Ghana, the promulgation of a National Community water and sanitation Program in 1994 first ensured community ownership and management with strong national and regional implementation. Since 2000, efforts have been made to further decentralise the development of water projects through district assemblies. Similarly, Malawi's national Water Development Policy commits to decentralization and to bring on board communities, water boards, local authorities, the private sector, non-governmental organizations and government line agencies.

6.7 Targeting water valuation

Although there is a clear need for proper valuation of water, it should be apparent that when the supply systems are deficient, the poor are the first so suffer. As the conditions of water stress develop, water becomes more expensive for those who are less privileged. A disturbing fact is that poor people with the most limited access to water supply have to pay significantly more for water. The end result of theses inequalities is that wealthier and more powerful persons can benefit from new opportunities at the expense of the poorer and less powerful. Therefore, if the attempt is serious about reducing inequality, it is a prerequisite that water valuation becomes more effectively 'targeted'.

Although subsidies may undermine the economic approach and may obliterate the potential of eliminating wasteful practices and encouraging increased efficiency and conservation, there is a growing consensus that if the subsidized water can generate positive social effects such as maintaining the rural landscape and traditions, supporting local economies or contributing to food security levels, subsidized water charges may be justified.

6.8 Conclusion

Allocation mechanisms should balance competing demands, both within and between different water-using sectors as well as between countries and should incorporate the social, economic and environmental values of water. There is no magic formula because of the wide variability of country-specific conditions. Currently, water remains highly undervalued. The problem of cross-subsidization across sectors and different user groups makes it even more important to allocate water optimally, based on its value for different uses.

Further readings

Young, Robert A. (2005). *Determining the economic value of water. Concepts and Methods.* RFF Press. Washington.

6.9 Tasks:

- Write an assignment of about 1.200 words on the social, environmental, economic and cultural values of water and how they are interdependent. For cultural values you should present examples from different continents.
- Define the terms: withdrawal, consumption, consumptive and non-consumptive use and their impacts on water resources.

7 Management for sustainability

The water and sanitation crisis claims more lives through disease than any war claims through guns. The situation is critical in many developing countries but it is especially precarious in the rural areas of Africa (Plate 63).

7.1 Rural water supply and sanitation in sub-Saharan Africa

7.1.1 Rural drinking water supply

Whereas the urban population is supplied by purified drinking water (chapter 2.5) the rural population can only cover their demand by surface water, groundwater or by rain water harvesting.

Surface water

If water is taken from rivers, dams or pools that might be contaminated it has to be purified. If it contains a lot of suspended solids these first have to be removed by sedimentation. If no other means are available it should be boiled for several minutes to kill the bacteria, but in most African regions this is out of question because of lack of firewood.

Another means of sterilization is to expose a clear glass or plastic capped bottle filled with relatively clear water to solar radiation. After 4 hours most all bacteria will be killed. Also a low strength chlorine solution manufactured for bleaching can be used to purify water. A teaspoon in a 10 l bucket disinfects the water within 60 minutes (2 teaspoons in 30 minutes). Both methods, however, produce only a small amount of clean water.

A more yielding method of achieving clean water is the use of a sand filter. A 200 litre drum filled with sand should provide at least 50 l of water per day, enough for a small family of four or five persons. The technique is shown in Plate 64.

If more persons have to be supplied a community sand filter of about 24 m^3 is needed, which may serve up to 300 persons, assuming a consumption rate of no more than 20 l per day per person. The water deviated from a down running stream is first grossly cleaned in a gravel filter, which has to be backwashed from time to time to remove the silt, and then the water is led to the actual sand filter (Plate 65).

Groundwater

Groundwater can be found in confined and unconfined aquifers and extracted from three types of wells: artesian; flowing artesian and a water table well in an unconfined aquifer (Plate 66).

In rural areas the most primitive source of water is an open water hole dug into the groundwater table (Plate 37) or an unprotected well (Plate 67). Both types are almost ever strongly contaminated by the feet of the users or by the rope or by surface water running into the well during the rainy season.

A better water quality is achieved by hand dug wells, hand drilled tube wells or deep boreholes (Plate 68). An upgraded well (Plate 69) is covered with a lid and equipped with a wind lass (Plate 70) or a pump. To avoid the danger of collapsing upgraded wells are lined with bricks or cement rings (Plate 71). Because these wells with a diameter of 1.5 to 2 m are dug by hand their depth does normally not exceed 15 m.

Shallow wells are more and more replaced by narrow diameter wells called tube wells. Most boreholes drilled with mechanized rigs can be described as tube wells, and these often penetrate into very deep aquifers where water is found in weathered rocks or fractured rocks layer. The boreholes can be drilled by Vander Rigs by the local community, but most boreholes are drilled by rigs mounted on trucks. As these heavy vehicles are difficult to manoeuvre in rough terrain a striking concentration of bore holes can sometimes be found. So in the region of Karonga (Northern Malawi) on both sides close to the tarred trunk road M 1 many boreholes could be found. Their density decreases rapidly with the distances from the road, leading to an extremely uneven distribution of bore holes in the area.

Types of pumps

Shallow wells and bore holes in the rural areas are nowadays always equipped with hand pumps of various types, which lift the water on upstroke or down stroke: Afridev pumps (Plate 72 and 73) and Mark V pumps (Plate 74 and 75) supply smaller communities, whereas the Bush pumps (Plate 76) with a block of teakwood, "which made it one of the most successful hand pumps used in the Developing World" (Morgan 1990, p. 65) is used when the number of people to be supplied exceeds 60 persons. As this type can lift water from considerable depth (water column is long and therefore heavy), it has an extra long lever, but this causes problems for small children who cannot reach the end of the long lever. The Bucket pump (Plate 77) is often not considered a real pump, because a bucket and a rope or chain is applied.

The occurrence of different types of pumps in the same area often causes problems of repair when the compatible spare parts are not readily available.

The water quality is dependant on the length of the passage of the surface water through the ground. So the far down-reaching boreholes deliver the best water (Plate 78).

Rain water harvesting

The collection and storage of rain from run-off areas such as roofs, rocks and other surfaces has been practiced since ancient times and is particularly suitable for areas where pumped water is not available (Plate 79). "By careful design it is possible for a family to live for a year in areas with as little rainfall as 100 mm per year" (Morgan, 1990, p. 225). The technique is very cheap but as all harvester surfaces are exposed throughout the year they are subject to contamination by dust, insects and birds and those at the ground level are also liable to be contaminated by animals and humans. So the latter should be properly fenced. In all cases the first flush of new rains should be run to waste.

Water point design

To achieve a maximum of water quality a water point should have the following conditions:

- It should be located in an elevated position so that in the rainy season the rainwater is not collecting here.
- It should have an apron with a diameter of 3 m surrounded by a ridge to collect the spilled water. This should be drained away by a 6 to 10 m long channel at the end of which it is seeping into the ground or is used for watering a small garden. Plate 80 shows a very unpleasant example of not having built a proper drainage.
- It should be protected by a fence against grazing animals (Plate 40) and
- It should have a distance of minimal 40 m to any source of pollution (Plate 81).

7.1.2 Rural sanitation

Lack of sanitation is the world's biggest cause of infection. The situation of rural sanitation is especially precarious in Africa. Plate 82 shows that most sub-Saharan countries remain far behind proper sanitation. Here in many rural areas simple holes with one or two planks across and surrounded by a grass shield for privacy are used as pit latrines. They smell very badly and act as breeding places for flies. As many as 150.000 flies a year can breed and emerge from a single pit latrine. They can carry diseases and are a great nuisance to the homestead.

To improve these unhygienic conditions several constructions of improved pit latrines have been developed. One is the Blair latrine which was developed by the Blair Institute in Harare (Plate 83). Its superstructure does not have a door but a spiral shape which ensures that the interior is semi-dark. Flies will be attracted from the pit to the greatest light source, which normally is the vent pipe when the superstructure is semi-dark within. When seen from the depth of the pit, a fly is normally attracted to light coming from the inside of the roof. The ventilation pipe is therefore covered with a screen to prevent the flies from flying out. A good vent pipe, a clean interior and the semi-dark conditions are in combination an essential requisite for fly control.

7.2 Operation and maintenance: making water supply and sanitation a sustainable reality

Lack of sustainability and ineffective systems contribute considerably to aggravate the current poor status of the water supply and sanitation sector. This is most often due to the fact that Operation and Maintenance (O&M) of water supplies and sanitation in developing countries is highly neglected. How can O&M lead to sustainability? Too often it is thought to mean only repairing leaks, replacing pipes, and corrective maintenance. While these are all vital functions of O&M, they address only the effects of problems, not the underlying causes.

The working group of the Water Supply and Sanitation Collaborative Council (WSSC) has therefore published some tools which can be used at the country level to improve O&M performance (see http://www.who.int/docstore/water_sanitation_health/wss/o_m.html)

Operation and Maintenance has greater potential

O&M principles can be applied at the organisational and managerial levels of water supply and sanitation services to deal effectively with the underlying causes of problems. This avoids the costly and devastating effects of unaddressed problems on system efficiency and performance. Pre-empting problems also make for major cost savings. These funds can then be used to expand the capacity of existing systems or to build new ones.

Operation and Maintenance pre-empts problems

To realize these benefits, O&M needs to be integrated into all decisions concerning water supply and sanitation, both for new projects and for existing facilities (Plate 84). In this way the implications for O&M will be taken into account at all stages of project development and during the functioning of the system. Making O&M a priority will thus lead to sustainability, greater efficiency and the opportunity to increase income to expand services.

Integrated Operation and Maintenance maximises investment

The best way to explain this integrated O&M approach is with an example. An integrated approach to the development of a new system or replacement of part of an existing system would be achieved in the following way.

First, before planning even starts, an assessment would be made of the local capacity for funding, manufacture, construction, supply of materials and spare parts, technical input, and availability of trained people. This information is then used to develop a plan which is appropriate to the local situation. The role and responsibility of the community in financing and managing O&M would also be worked out. The level of community involvement in rural situations will be vastly different from that in urban areas. Community managed systems depend for their success on an environment which enables the community to be effectively involved. Enabling factors include: joint planning, training, developing accountability mechanisms, and using participatory methods to ensure the full involvement of both men and women in the process. Systems which are too expensive to be locally maintained should be disregarded from the start. Instead, systems which can be operated independently of external funding based on local ability to provide funds for repair and expansion should be selected. This leads to self-sufficiency and to systems that can eventually finance their own expansion.

Technical specifications take into account the local capacity to supply equipment for construction and to provide spare parts in the future. If capacity is lacking in these areas, there is time to build it up before it is needed.

The same applies for human resources. Plans can be made well in advance to train local people and/or recruit appropriate technical experts so that the skill and knowledge base to maintain the system at its full potential exists from the very beginning.

O&M personnel should be involved in planning, design, and construction; so that they are able to understand fully the system they are going to have responsibility for operating and maintaining. This can also avoid inappropriate designs and bad technology choices.

The next stage is operation. Unfortunately, this is frequently when O&M is first considered. However, at this stage it is usually too late to address issues such as inappropriate plan design, bad technology choice, lack of spare parts, and inexperienced or untrained staff. Once the facility is operating, these problems will become obvious through breakdowns, lost capacity and inability to meet the needs of users.

O&M principles can be used to organize and manage services so they operate more effectively and fulfil their intended purpose. This important function of O&M is often overlooked. O&M has the potential to make the difference between systems that are successful, independent and self-sustaining, and those that fail. But, to do so, it must be a priority.

Operation and Maintenance overcomes common problems

Many of the common problems like massive unaccounted water losses, frequent and long breaks in supply, high failure rates and the need for premature rehabilitation of systems and people suffering unnecessarily can be overcome by O&M:

Massive unaccounted water losses

In some cases, up to 50% of water capacity does not reach the end user. This represents not only a loss of scarce resources but also the loss of an income opportunity. This income, if collected, could be used to pay for running costs and to build new facilities to meet the needs of more people. If O&M is integrated into all water supply and sanitation decisions, O&M can overcome the causes of these massive water losses, instead of being limited to treating the effects.

Frequent and long breaks in supply

Users are unwilling to pay for poor service. This in turn causes further deterioration in services because finance is not available for repairs and maintenance. But the cycle can be broken because users are prepared to pay for a reliable service. *Proper consideration of how O&M is to be financed and managed will avoid this cycle of poor service, dissatisfaction, poor payment and deterioration.*

High failure rates and the need for premature rehabilitation of systems

Systems stop operating. These failures are most often caused by inappropriate technology choice. Constraints in the local environment, which have been overlooked in the planning phase, make it difficult for routine maintenance to be carried out. These problems, if left unattended, quickly lead to system failure and expensive rehabilitation, well before it should have been needed. *These massive costs can be avoided if O&M concerns influence all phases of the project cycle.*

People suffering unnecessarily

In the end, consumers suffer the most. They go without water and sanitation services; they are forced to accept poor quality and make do with less than they need. In doing so, they are unnecessarily exposed to major health risks, including diarrhoea, intestinal worms, schistosomiasis, cholera, typhoid, and guinea-worm. *These risks can be prevented through adequate water supply and sanitation.*

In 1991, the O&M Working Group was created to raise the profile of O&M and to highlight the importance of an integrated approach to Operation and Maintenance for achieving sustainability and effectiveness in the water supply and sanitation sector. An important aspect of this is developing resource materials to help in the implementation of more effective O&M strategies.

The O&M Working Group

The O&M Working Group, which is coordinated by the World Health Organization, is one of the working groups set up by the Water Supply and Sanitation Collaborative Council to advance the development of the sector.

Members of the O&M Working Group are experts, professionals and consultants from national governments, multilateral and bilateral agencies, and nongovernmental organizations in both developed and developing countries, representing different interest groups in the sector.

The O&M Working Group provides a forum for the exchange of views, information and expertise. Through this cooperative effort, the Working Group has gained a greater understanding of the issues impacting on O&M. This has enabled group members to identify the key factors inhibiting effective O&M and develop strategies to overcome these.

Targeting the obstacles to effective Operation & Maintenance

The strategy of the Working Group is to help O&M reach its full potential by improving:

- policy formulation;
- sector collaboration and coordination;
- the profile of O&M at both the national and global level;
- services management;
- availability of O&M data.

Practical tools to achieve effective Operation & Maintenance

The Working Group has developed a series of tools which can be used at the country level to improve O&M performance. The tools have been developed in response to the demand for practical solutions to the sector's problems. They include guidelines, manuals, training packages, and case studies.

Individual tools have been designed to meet the specific needs of sector participants, from the information needs of policy makers in both private and public operations to the more practical needs of engineers and technicians. Collectively, the tools help all those involved in water supply and sanitation.

Those currently available are:

- *Tools for Assessing the Operation and Maintenance Status of Water Supply and Sanitation in Developing Countries*. These comprehensive guidelines show how to assess O&M performance in both rural and urban areas.
- *Operation and Maintenance of Urban Water Supply and Sanitation Systems: A Guide for Managers*. This publication examines the factors which may prevent existing urban water supply systems working efficiently, and provides guidelines and solutions for optimization.
- *Leakage Control: Source Material for a Training Package*. This material, which trainers can adapt for use in local training courses, covers all aspects of leakage control and is divided into individual modules for ease of use.
- *Upgrading Water Treatment Plants*. This document summarizes many different field experiences in improving the quality of water and upgrading the capacity of water treatment plants. It provides a practical approach to improving the performance of water treatment plants.

- *Operation and Maintenance of Rural Water Supply and Sanitation Systems.* This package contains resource material for training courses aimed at improving the management of O&M in rural areas.
- Models of Management Systems for the Operation and Maintenance of Rural Water Supply and Sanitation Systems. This document evaluates the factors which influence the development of O&M management systems for rural facilities. It describes models in eight representative countries and offers guidance to planners and designers in selecting the most appropriate one.
- *Linking Technology Choice with Operation and Maintenance*. This document helps users to make more appropriate technology choices by providing information on the O&M implications – particularly the costs – of selecting a specific technology.

For further information on the tools see:

http://www.who.int/docstore/water_sanitation_health/wss/o_m.html

Further readings

Newson, M.D. (2009). *Land, water and development: Sustainable and adaptive management of rivers*. 3rd Edition. London: Routledge.

For *Lessons from a low-cost ecological approach to sanitation in Malawi* see http://www.susana.org/en/resources/library/details/605

7.3 Tasks:

- All mentioned hand pumps are equipped with a pump rod and a foot valve. The water is lifted or pressed upwards. Why are suction pumps not being used that work on atmospheric pressure?
- Describe the processes by which the rural population can purify their drinking water.
- Describe in detail by which processes surface water is purified when it is trickling down through the soil to the groundwater table.
- Describe confined groundwater and its advantages for water supply.
- Describe the process of saltwater intrusion at coastal regions.
- Describe the reasons why operation and maintenance (O&M) is in many cases not working properly and what steps have to be taken to make O&M successful and sustainable.

8 Other case Studies from within SADC

Evolution in development policies around the world points to the need for broader, more integrated platforms. “The new integrated water resource management policy of Zambia is intent on integrating water management throughout all sectors. As a result of this integration of water and national development planning many donors have incorporated water-related investments in their assistance packages to Zambia” (WWAP, 2009a, p. 287).

8.1 Case study: Water policy in Zambia

Zambia (Plate 85) is facing difficult challenges such as persistent poverty and increasing climatic variability. Although it has sufficient land and water resources, its success in addressing its problems depends largely on how it implements its plans and strategies for water resources.

Setting the scene

Zambia is a landlocked country in southern Africa surrounded by Angola, Botswana, the Democratic Republic of the Congo, Malawi, Mozambique, Namibia, the United Republic of Tanzania and Zimbabwe. The country lies mainly in the Zambezi River basin, and partially in the Congo River basin in the north. Zambia has a population of 11.7 million (2006) and a surface area of 752.614 km^2. It sits on the high plateau of Central Africa at an average altitude of 1.200 metres, and enjoys a mild, subtropical climate. Annual average rainfall ranges from 600 mm in the south to 1.500 mm in the north.

Climate change and variability: increasing frequency of extreme events

A 2007 survey concluded that in the previous nine years, local communities had been exposed to extreme climatic variation that included droughts, floods, increased rain intensity, extreme heat waves and a shorter rainy season. In fact, between 2000 and 2007 Zambia experienced unusually unstable weather, with a sequence of two flood years, two drought years and two years with normal rainfall.

State of the resource: future competition among sectors

Zambia’s surface water potential totals some 100 billion m^3, with the Zambezi River contributing over 60% of the runoff. Consequently, as a major stakeholder in the Zambezi River Authority, along with Zimbabwe, Zambia is helping establish the Zambezi Watercourses Commission. Groundwater is also a major resource, especially during the dry season. Although no accurate assessment is available, the average renewable groundwater potential is estimated to be 49.6 billion m^3.

By far the largest user of water is hydropower generation. Of about 38.5 billion m^3 of overall water withdrawal, 36.3 billion m^3 is used to generate electricity for internal use and export to neighbouring countries. Some 70% of the country's hydropower potential awaits development. There is as yet no real competition for water among the various sectors.

Water use by sector, 2008

Sectoral use	Water consumption (billion m^3)	Share in overall water consumption
Agricultural	1.8	4,67%
Industrial and municipal	0.4	1.03%
Hydroelectric	36.3	94.30%
Total	38.5	100%

(WWAP, 2009b, p. 16)

However, with irrigation expanding and awareness on environmental issues growing, water released from hydropower stations will need to be regulated so that the needs of agriculture and the environment are both served. The government recognizes the role of integrated water resources management (IWRM) in meeting the needs of all users, but successful application of the IWRM approach will require prioritizing investment and strengthening the capacity to manage national and trans-boundary water resources.

Around 40% of Zambia's population lives in urban settings. The capital, Lusaka, and the Copperbelt region in the north-west are the most densely populated areas. In 2005, 86% of people living in towns had access to safe water, compared with only 37% in rural areas. For the same year, just 13% of the rural population had access to improved sanitation, whereas there was 41% coverage in urban areas.

Zambia has good agricultural potential, with 56% of its surface arable. Only 14% of the arable land is farmed, and most cultivation is rain fed. Irrigated crops cover only about 1.000 km^2. The government established an Irrigation Development Fund in 2007 and is encouraging farming operations by making loans available at concessionary rates. However, agricultural development is hampered by insufficient financing, a lack of accurate data and capacity information on water resources, and inadequate market services and infrastructure.

Policy framework and decision-making: towards integrated and participative approaches

The Water Act of 1948, the foundation of Zambia's water legislation, deals with ownership, allocation and regulation of the nation's surface water resources without covering groundwater or the trans-boundary aspects of rivers such as the Zambezi which constitute international boundaries.

To address these shortcomings, reforms have been undertaken since the early 1990s, including the adoption of the National Water Policy in 1994. It recognized water as an economic good, highlighted the important role of the water sector in overall socio-economic development, promoted water resources development through an integrated management approach and defined institutional responsibilities of stakeholders in the sector so as to achieve effective management and coordination. The policy also provided for adequate, safe and cost effective water supply and sanitation services while assuring environmental protection.

In carrying out its reforms in the water sector, the Government of Zambia started with the water supply and sanitation subsector, enacting the Water Supply and Sanitation Act in 1997. This institutional arrangement for urban water supply and sanitation obliges local authorities to provide water and sanitation services using various arrangements, such as partnerships with private firms for build-operate-transfer models as well as for concessions and management contracts. They may also create organizations known as Commercially Viable Water Supply and Sanitation Utilities, or CUs. All these institutional arrangements must undergo viability testing in order to be licensed by the regulator, the National Water Supply and Sanitation Council (NWASCO).

CUs operate as commercial businesses within a framework regulated by NWASCO. They are expected to deliver efficiencies meeting private sector standards and to be self-financing, though the government may help modestly with initial working capital and infrastructure investment. CU managers are recruited under competitive private sector conditions.

The CUs have made significant progress even though government investment in water and sanitation infrastructure has been limited. Though many struggled to meet the wage bill when first established in 2000, some CUs averaged 102% recovery of operation and maintenance costs in 2007/2008. It is hoped that by 2010 more than half the CUs will reach a similar level of effectiveness. Although performance and quality of service had been on a downwards trend, today an upwards trend is evident in a number of service indicators.

The government later turned to the water resources management subsector with the Water Resources Action Programme in 2001. The programme developed a Water Resources Management Bill, a new Water Resources Institutional Framework, an improved Water Resources Management Information System and a draft action plan on addressing challenges related to water resources. Moreover, the Fifth National Development Plan (FNDP, 2006–2010) is specifically geared towards applying IWRM nationwide. To assist in carrying out the water-related programmes in the FNDP, in 2008 the government adopted an IWRM and water efficiency implementation plan, with crucial stakeholder participation (which also took place when the FNDP was being drawn up). These processes are intended to help Zambia plan and manage its water resources to further socio-economic development.

Stakeholder participation was also secured through the formation of the Water Sector Advisory Group, which consists of four subsector advisory groups: (a) water supply and sanitation, (b) water resources management, (c) water resources infrastructure development, and (d) monitoring, evaluation and capacity building.

The subsector groups provide for inclusion of stakeholders from outside the water sector, such as the Ministry of Finance and National Planning, which chairs the subgroup on monitoring, evaluation and capacity building. Inclusion of outside stakeholders in planning and decision-making is important for achieving an integrated approach to water management and for long term sustainability of decisions.

The main challenges

Combating poverty: Zambia is among the world's least developed countries, ranked by the United Nations Development Programme as 163rd out of 179 countries on the Human Development Index. Since 2005, under the Heavily Indebted Poor Country Initiative, Zambia has received debt relief equivalent to some US $6 billion. This has had a positive impact on the national budget and hence on poverty. Nevertheless, 63.8% of the population still lives on less than US $1 a day, and 46% of Zambians are undernourished. Conflicts in neighbouring countries have caused movement of refugees into Zambia, further aggravating the situation. Extreme poverty is especially significant in rural areas, where the majority of households depend on subsistence farming.

Meeting public health needs: Water-related diseases such as malaria and diarrhoea are major health problems in Zambia. The toll of malaria alone is nearly 4 million clinical cases and 50.000 deaths per year: it accounts for as much as 20% of maternal mortality and 23% of all deaths. Diarrhoea accounts for 6.9% of all illness reported (2003). Zambia has also been affected by HIV and AIDS, with about 9% of the population being HIV positive (2000). The 2008 Health Survey indicated that HIV and AIDS affected 14% of people aged 15 to 49 – the country's prime workforce. Another issue is that increasing environmental degradation, affecting forests, wildlife and fish populations, especially hurts the livelihoods of the poor, who depend the most on these resources. Wealthier communities are less affected.

Addressing environmental concerns: Copper mining is an important source of income in Zambia, but it involves pumping water out of mines and into natural waterways, which degrades the environment and water quality. For example, Konkola Copper Mine discharges some 300.000 m^3 of water per day into the Kafue River, which supports most of the country's economic activities and over 40% of the population. The Copperbelt Environment Project has aimed at addressing environmental consequences of mining. Stronger regulation is needed for mines and other industries whose effluents affect the environment. Although there are some positive effects from mine discharges, such as making more water available in the Kafue River for downstream users, particularly in drought years, these have not received much attention. Furthermore, the effects of mine pumping on groundwater have not been studied in detail yet.

Deforestation in Zambia is advancing at a rate of 3.000 km^2 per year. It has resulted in localized flooding, increased erosion, reduction in surface and groundwater availability and loss of aquatic life. Accurate estimates are hampered by the lack of an updated forest resources inventory.

Decreasing surface and groundwater quality, due to an increasing nutrient load, industrial and agricultural pollutants and a falling groundwater table, is a growing problem in highly populated urban areas. Sanitation and solid waste management are also major concerns. Waste collection and management are inadequate, posing a serious threat to groundwater quality, particularly in peri urban areas and informal settlements, where between 40% and 80% of the urban population resides.

Conclusions

Zambia is a country with enough water and land resources to facilitate development. However, inadequate data and capacity, in every dimension, seriously impair the government's ability to address many challenges, most notably poverty and hunger. Increasing the share of the population with access to safe water and improved sanitation, especially for people living in peri-urban and rural settings, would help curb the spread of preventable diseases that claim too many lives and reduce productivity. Application of IWRM, which is awaiting the necessary legal and institutional structure, will help combat poverty and malnutrition while assuring sustainable socio-economic development and preserving a healthy ecosystem (based on WWAP, 2009b, pp. 15–18).

8.2 Case study: Cuvelai Basin in Namibia

About 600 years ago people settled in the Cuvelai area (Plate 86) because of the ephemeral oshanas (shallow water courses). Taking advantage of the abundant woody vegetation, with water infrastructure introduced by the missionaries and colonists, the population soared. The oshanas that were once one of the main reasons for people to settle in the area are increasingly becoming a challenge. Due to the rapid population increase and associated demands for more land, more and more people build their houses in the oshanas during the dry period when there is no water in these shallow water bodies. However, when the rainfall season comes and the oshanas fill with water, these houses are flooded and it even happens that people drown.

This illustrates that the use of oshanas as a source of water is less important in these highly populated areas, as people have become more dependant on purified water delivered at water taps. This is of course an improvement of peoples' livelihoods, but it has also resulted in people not knowing how to deal with oshanas as permanent natural features. Instead of sustaining the life of the people, the oshanas are now threatening the health of the people living close to them as they are breeding grounds for, *inter alia*, mosquitoes, accelerating the spread of malaria in these areas. On the other hand, the ponds are still a useful water resource as they continue to provide fish, water and grazing for livestock and natural foods such as water lilies.

Key issues to be discussed below are:

- Payment for water and technological development: a discussion of the present intentions of Rural Water Supply to hand over the basic maintenance of water points to the communities using the infrastructure, and the cost recovery approach requiring users to pay for the water delivery service provided.
- The history and present status of IWRM in the Cuvelai basin: presentation of the background to water supply in the basin, the process of establishing a basin management committee in the Iishana sub basin and the present status of this initiative.
- Previous initiatives that provided technology to the rural areas in central northern Namibia: improved access to water, an example from the construction of water pipelines in the Ombuga saline grassland, Oshana region.

When applicable, the process towards implementing IWRM in Cuvelai basin will be discussed in the light of the four Dublin principles (chapter 3.1.13), which form the core of IWRM:

1. Fresh water is a finite resource, sustaining life and should be managed using a holistic approach
2. Water development and management should be based on a participatory approach, involving users, planners and policy makers at all levels
3. Women play a central part in the provision, management and safeguarding of water and should be empowered to participate at all levels in water resource programs
4. Water has an economic value in all its competing uses and all human beings have a right to access clean water and sanitation at an affordable price.

8.2.1 Water and land use in the Cuvelai basin

Natural and artificial water sources in the Cuvelai basin

In the past most people and livestock in central northern Namibia relied on surface water accumulated from rainfall, collected in earth dams and in shallow hand dug wells as their main water source. Today, hand dug wells mainly occur in the western, southern and eastern parts of the area (Plate 87), where the salinity of the ground water is sufficiently low for cattle to drink. Water from these hand dug wells is collected by use of ropes and buckets, or by climbing down to the water table on steps dug into the side walls of the well. Other water sources are excavated dams and natural pans.

The use of excavated dams was only introduced with colonisation. These water supply systems are still in use in rural areas of central northern Namibia. However, in response to increasing population and generally very saline ground water, a bulk water supply system was developed in 1960s and 70s.

The construction of the first canal from east to west between Ombalantu and Oshakati began in 1959. The purpose of the canal was to capture water flowing southward into the oshanas and channel it to the population centres that were developing around Oshakati at that time. In 1970 the canal was extended westward to transport water pumped from the Kunene river into the canal system. In 1975 this development was followed by the construction of a pipeline transporting purified water from Ogongo to Oshakati. Importantly, taps and livestock water points were established along the pipeline. From this first pipeline an extensive pipeline system has then been developed, providing purified water to settlements and water points for cattle to areas where previously, the lack of fresh water prevented extensive grazing. The water in the pipeline system comes from the Kunene river, via the Calueque dam in Angola, just north of the border, and an open canal, to Olushandja balancing dam on the Namibian side of the border, transferred in a canal to treatment works at Olushandja, Outapi, Ogongo and Oshakati where the surface water is purified, before it is pumped through the pipeline system to the consumers.

The complex network of dams, canals, pipelines and purification plants serving thousands of water points throughout the most densely populated areas is about 2.600 km long. In 1991, 60% of the water supply was dependent on dug wells, 10% on drilled wells, and 30% on a pipeline system. A number of drilling programmes, especially for emergency drought relief, were conducted during the 1990s. Another 2.000 km of pipeline is planned in the Oshivelo-Omuthiya, Engela-Endola, Ondobe-Eenhana-Okankolo-Oshigambo and Outapi areas and also back into Angola. Current pumping rates from the Kunene vary between 47 and 63 million m^3/a, which is much less than the rate of 180 million m^3/a agreed to between Namibia and Angola. However, it is known that the Kunene flood plain is an ideal place for irrigation, and if Angola decides to use more of her water for irrigation, then less would be available to be distributed to Namibia. The present agreement between Angola and Namibia dates back to 1964 and Angola is now asking to renegotiate the terms of this agreement, an indication that the amount of water distributed to Namibia might change in a near future.

Water quality

Traditional water sources differ from artificial water supply in both availability and quality. Water from local sources is seldom perennial and water quality generally declines with time. Artificial water supply, on the other hand, is purified and is in most cases available all year around. Even though the quality of water from traditional sources often is poor, it is common that during the rainy season humans also use water from oshanas or dams or other sources of surface water. The main reasons are that the quality of the water is best at that time of the year and the source may be nearer than a particular water point.

Another important factor to consider is that many farmers prefer to use water from oshanas to avoid paying for water. In some areas it is even common to close water taps when it has rained and "free drinkable water" is accessible. The water quality in excavated dams depends to a large extent on the depth to the saline water table. Normally excavated dams are open on the side so that local water from the oshana can fill them. In some areas the water table is as shallow as 2 m, but in some favourable places the water table is as deep as 5 m. Dams supplying water for human consumption are normally fenced off while dams for livestock are unfenced and have less steep slopes. However, the fences surrounding the dams are often broken or taken down to allow cattle to drink the water.

The sharing of open water sources between livestock and humans poses a health risk. Dams for livestock were designed to provide a supply of water for two years, which includes evaporation losses. However, the high evaporation losses make these dams uneconomical. Therefore the concept of pumped storage dams was introduced. Before Independence, 1990, there were at least 17 pump storage dams constructed in the Cuvelai basin to supply water to hospitals, schools and community centres. Water was sand filtered but because of problems with fine sand, simple purification system works were introduced to treat water for human consumption. However, these dams are also a health risk to the population as the water can easily be contaminated.

Access to water in central northern Namibia

According to the Directorate of Rural Water Supply (2004), the Namibian government has committed itself to provide safe water to all citizens within a maximum distance of 2.5 km walking distance from their homestead (In Malawi the maximum distance is 500 m). In 2001 in the region Oshana 93%, in Oshikoto 88%, in Omusati 83% and in Ohangwena 78% of all households had access to safe water within the 2.5 km distance.

Investigations in the area have shown that there are no severe water conflicts. The only problem identified was the fact that not everyone is paying for water. For instance people using water from pipelines that have not been upgraded since independence are still enjoying free water, while people using water provided from the modern pipeline system are supposed to pay for their water. This has caused confusion and irritation among the water users.

In addition, not everyone pays the same price for the water, something that will be further discussed below. Another area of conflict related to water supply is the effect of introducing the water pipeline to former grazing reserves in central Cuvelai. However, this conflict is not so much about water use but about the loss of productivity of the rangeland, caused by the increased numbers of livestock grazing in the area, as a consequence of freely accessible water.

Even though there are no serious water use conflicts in the Cuvelai basin at this point of time, this does not mean that there is no potential for such conflicts to occur in the future, because the fresh water distributed in the extensive pipeline system, supporting large parts of Cuvelai basin originates in Angola. Should Angola decide to use her water herself, (which is a likely scenario, given the high potential for irrigation on the Kunene floodplain), then that might lead to a serious conflict, both between water users in the Cuvelai basin and between Namibia and Angola on a government-to-government level.

To fulfil its goals to provide safe water to everyone in central northern Namibia, the Community Based Management project of the Directorate of Rural Water Supply in the Ministry of Agriculture, Water and Forestry is extending the pipeline system and drilling new boreholes. The main target area for expansion of the water supply system is the Oshivelo Artesian Aquifer that is presently tapped by production wells supplying some 2.5 million m^3/a of fresh groundwater via a pipeline to the Oshivelo-Omutsegwonime-Okankolo area. In 1999 the Oshivelo scheme supplied 0.3 million m^3/a to the local population while the total abstraction amounted to 0.75 million m^3/a.

There is a risk of saltwater intrusion into the fresh-water horizons, especially from the west and from underlying strata. Therefore, the aquifer must be investigated in detail, before its full potential can be used. So far there has been no detailed assessment of the water quality of these aquifers, however, there is a new EU funded project, the Cuvelai ACP, which most likely will have the resources to carry out this assessment.

Improved access to water: a blessing in disguise?

In the Ombuga grasslands in northern Namibia land for cultivation and grazing is becoming scarce. Ground water is saline which in the past limited permanent settlement in the area. The first permanent settlements were established in 1968. Population numbers remained low until the beginning of the 1990s, when a rapid increase led to the present population density. The population increase coincides with an effort to improve the access to water by the construction of water pipelines into the grasslands in 1992. In response the number of livestock increased dramatically. There are no reliable livestock figures for the area, but according to the national population census that was conducted in 2001 the annual population increase between 1991 and 2001 was over 5%. It is reasonable to assume that livestock numbers increased in a similar rate during that period.

A study carried out in the Ombuga area in 2004 and 2005 showed:

- The most common reason to come to the Ombuga grasslands was to find grazing for the livestock and land to cultivate
- When the respondents first arrived there was much grass, tall trees and shrubs and plenty of wildlife in the area
- The most significant difference today is lower quality and a reduced availability of grazing
- Some farmers claim that they have noticed a shift in grass species composition, i.e. palatable perennial grasses have decreased or completely disappeared from the area.

The villagers' explanation for the observed changes is that when availability of water no longer limited access, large numbers of livestock were brought into the area from other parts of northern Namibia, resulting in an unsustainably high grazing pressure on the land. This migration of farmers from the 'outside' resulting in decreased access to grazing has led some of the inhabitants to move their cattle southwards, towards the northern boundary of the Etosha National Park.

The findings of the study emphasize the contradiction in development efforts. Farmers/cattle owners admit that the intention with the pipelines, i.e. to improve access to water for the inhabitants of the area, was desired and met. However, the overall situation for many households has not improved. In response to the deteriorating grazing resources along the pipelines, they are now forced to move their cattle to areas served only by traditional, less reliable water sources.

The study does not only illustrate the issues related to access to water but also the problems associated with introducing new technologies without involving all stakeholders from the start. The various difficulties related to providing new technology as part of development and improved conditions for the receivers of this technology is a well known issue. Already in the 70s, the negative effects of large scale development projects, initiated in collaboration between governments in developed and developing countries, and implemented by donor agencies were apparent. The lack of involvement of the recipients of these initiatives often led to catastrophic results, manifested by infrastructural decay and collapse after the project funding came to an end.

CuveWaters is a modern project, also aimed at providing modern technical solutions to rural and urban communities in parts of the Cuvelai basin. These interventions are intended to be undertaken in the light of IWRM, and should therefore be firmly in line with the four Dublin principles. Holistic management, participation, gender equality and cost recovery with affordable pricing must be central in the planning and implementation of the technical solutions provided by the German project team.

The study shows that the Dublin principles were not taken into consideration. The development initiative, which came about shortly after Namibia's independence, at a time when the area was experiencing drought conditions and a rapid increase of both human and livestock numbers, did not involve local water users in the planning or future maintenance of the provided infrastructure. The example clearly illustrates the risks associated with introducing new technology and infrastructure into an area. In the case of the pipeline system in the Ombuga grassland, the main cause of the negative outcome of the initiative is most likely the failure to involve the local community in the project from the beginning. This was exacerbated by the lack of a management plan developed by the local users, together with the service providers involved in construction and maintenance, controlling the use and access of the water points along the pipelines. The lack of management procedures of these open access water points has led to overuse of the resources, causing degradation of the rangeland. This is now forcing farmers to move away from the pipeline and revert to using traditional water sources.

Role of livestock in the livelihoods of people in the Cuvelai basin

Livestock plays a central role in the livelihoods of both the rural and urban populations of the Cuvelai basin. It is therefore essential that the members of the project team have a good understanding of the rationale behind keeping livestock, how livestock and rangelands are managed, and what financial benefits farmers receive from their animals.

In central northern Namibia, livestock is generally seen as a cultural asset and a sign of wealth. Many people are of the opinion that livestock is an essential part of subsistence farming and that livestock provides security during droughts when crops fail or other extreme circumstances cause hardship to the people. Many use livestock to generate cash for school or clinic fees, for weddings and funerals and for ploughing their fields.

One major factor limiting the sale of livestock is that livestock north of the veterinary cordon fence (VCF) cannot be marketed to the south due to Foot and Mouth Disease (FMD) and Contagious Bovine Pleuro-pneumonia (CBBP) restrictions. This does however not mean that farmers north of the VCF have no opportunity to market their livestock. By placing their animals in quarantine, meat from animals from the north can be sold to South Africa. However, formal marketing of livestock in the northern communal areas nevertheless remains very low. Even though many initiatives to inform local farmers about the benefits of using the formal markets, the local informal market seems to be the preferred way of selling livestock in central northern Namibia.

A recent project, the Oshikoto Livestock Development project (OLDeP), contributed significantly to informing farmers about the benefits of marketing their livestock (DRFN, 2004). The project even facilitated an auction, where farmers from north of the VCF could sell their animals. The results from the auction show that there is a willingness to sell livestock if the opportunity is given, and of course, if the price is right.

On the other hand it is important to note that not everyone owns livestock. The majority of farmers in the Cuvelai basin have too few cattle to be able to market them regularly. To be able to sell animals a herd size of at least 30 animals is generally required and only few families own such numbers of animals.

Introduction of new technology comes at a price. One possibility to increase people's ability to pay for these innovations might be to encourage farmers to market more livestock more regularly. However, if that is done only the members of the community with sufficiently large herds would benefit from such initiatives, as they are the ones that can afford to sell their animals.

Regardless of where the farmers market their livestock, the selling of livestock takes place on a needs-basis. Interviews with farmers in central northern Namibia show that decisions about when to sell or buy livestock are made by the head of the household, who also decides how such money, will be used. Most of the sales and purchases are cash transactions and do not involve formal banks, loan schemes or savings clubs. Very few if any of the sales or purchases are undertaken in the context of an overall management plan. People with employment elsewhere commonly invest their earnings in livestock, which are kept in the Cuvelai and are looked after by family members or employed herders.

In central northern Namibia accurate livestock numbers are difficult to obtain. Farmers are normally reluctant to provide figures when asked. According to data provided by the Directorate of Veterinary Services, the total number of cattle in central northern Namibia was 685.285 in 2004, approximately 25% of all cattle found in Namibia.

Given the importance of livestock to the livelihoods of the people living in the Cuvelai basin, the condition of livestock is a factor that has to be taken into account when implementing IWRM.

Water consumption of livestock in the Cuvelai basin

One aspect of livestock in the Cuvelai basin that is directly related to IWRM is the amount of water consumed by livestock. Given that a large stock unit (LSU = a head of cattle) requires approximately 45 litres of water per day, and there are about 685 000 heads of cattle in the area, some 30 million litres are consumed every day. Further, if one adds the water consumed by small stock units (1 LSU = 6 SSU), the daily consumption of water from domestic stock is over 35 million litres per day, excluding horses and donkeys. This figure is interesting as much of the water provided to livestock is purified and distributed by pipeline. The large volume of water consumed by livestock per day suggests that total numbers and distribution of livestock in the Cuvelai basin is central when managing water demands there.

8.2.2 Integrated Water Resources Management in Namibia

Integrated Water Resources Management (IWRM) refers to "meaningful participation of all stakeholders in the development, planning and management of water resources, institutions and mechanisms put in place and legislation enacted within the context of local, regional, national and international policies".

The need for forming institutions to manage the water and other resources within a basin has been identified in the Water Resources Management Act (Republic of Namibia, 2004). In Namibia, the concept of managing water resources at basin level was introduced to and accepted by stakeholders during the water sector review process in the late 1990's. Regional consultations with various stakeholders indicated that they are interested in being involved in the management of their natural resources. Functional responsibilities for integrated management are given to Basin Management Committees (BMC), which are intended to be established in major basins in the country. It is assumed that Basin Management Committees provide an opportunity for government and communities to work together to assure that integrated water basin management is achieved.

The concept of basin management has been implemented in Namibia since the 1990s. Today, two groundwater basin management committees have been established by water users themselves in order to manage their scarce resources. These are located in the Tsumeb area, focused on what is known as the Karst Aquifer, and in southern Namibia focusing on the Stampriet Artesian Aquifer. These committees are supported by the Geohydrology Division of the Department of Water Affairs (DWA). A third basin management committee was established in the Kuiseb River basin supported by donor funding (EU). This development was supported by the Hydrology Division of the DWA. Recently, attention has been turned to the Cuvelai basin in central northern Namibia. All these initiatives were undertaken before the Water Resources Management Act was in place and they used the Theme Papers developed during the water sector review, the National Water Policy White Paper and the evolving draft Bill for guidance.

Community Based Management and payment for water

NamWater, the national bulk water supplier, supplies water directly to the Directorate of Rural Water Supply (DRWS) for further distribution to rural communities. DWRS was established in 1993 in response to the Water Supply and Sanitation Policy (WASSP) (Republic of Namibia, 1993), and is responsible for rural water supply infrastructure and planning. The main goal is to support Community Based Management (CBM) of water supply while directly ensuring that the resource itself is used in a sustainable manner.

Since 1993, the Government's policy is to involve communities in the supply of their water services, with the main objective to recover cost and encourage stakeholder participation. Community Based Management is administered by water point associations that include all users of water points, managed by elected water point committees being in charge of their water points. A Water Point Association (WPA) comprised all users of a specific water point. Of these, eight representatives are elected to form a Water Point Committee (WPC.)

All households using water points along the same branch from NamWater's main pipeline form a Local Water Association (LWA). Representatives from the LWA are elected to serve on the Local Water Committee (LWC). Extension officers from Rural Water Supply interact with both Water Point Committees and Local Water Committees, and report to the respective Regional Offices of Rural Water Supply, who represent both the water users (WPA/WPC and LWA/LWC) and the service providers in the Basin Management Committee. Investigations on the functioning of water point committees in the Cuvelai basin have shown that in a typical case eight members of the committee were originally trained. However, as people often move around looking for jobs elsewhere, there is often just a Caretaker (usually male), a treasurer and a secretary (usually both females) actively working for the committee. In future the water point associations will be fully liable for the operation and maintenance and payments of all the cost related to water use, except major repairs.

According to the Summer Desertification Programme (SDP) 13 (2004) there are different forms of payment in place. Some water point committees have water users pay a flat rate, e.g. N$10/month, while others ask for payment according to the volume of water actually consumed. In many cases, all users of a specific water point pay the same amount, irrespective of whether they have many livestock or not.

SDP 13 (2004) also showed that some Water Associations, at least in the Olukonda area close to Ondangwa, are supplied from old pipelines that have not been rehabilitated. The water supplied by such pipelines is free of charge. Some Associations get water directly from the main pipes and pay NamWater directly. Other Associations get water from branch lines and pay to the Directorate of Rural Water Supply (DRWS). This often results in confusion among the water users, especially when these different schemes are located close to one another.

In Namibia, water users don't pay for water per se but they pay for the supply services. This practice means that anyone, anywhere can take a bucket and fill it with water for free; but if they want clean water delivered to their village or into their house they must pay for the supply service. However, investigations in central northern Namibia regarding people's perceptions about payment for water services have shown that many people in the rural parts of the Cuvelai basin have difficulties understanding the concept of cost recovery, and why and for what they are supposed to pay. For instance, many people think that water should be free as it is provided by God. A common argument is: 'the government supplied free water before independence, why must people pay for water in a free Namibia?'

Much of the confusion seems to stem from the fact that many people don't understand what it takes to supply water; and therefore an effort must be made to explain the difference between purified, piped water and water that is freely available in the oshanas. One step towards improving this understanding among the water users has been to arrange tours of influential people to the NamWater facility in Oshakati, which have clearly improved understanding among water users. An important lesson to learn for the CuveWaters project team is that if payment is expected for new infrastructure and/or new technology, training of recipients of these innovations is essential in order to ensure that they understand why they have to pay for such technologies and services. Another issue that has emerged from the discussions with water users is that in general, people think 'appropriate technology' is inferior technology. This commonly results in low acceptance rates of initiatives that are different from what people are used to or what they see other people having.

Several gender issues associated to the implementation of water point committees were revealed. These issues are of particular importance as they relate to the third Dublin principle, i.e. 'Women play a central part in the provision, management and safeguarding of water and should be empowered to participate at all levels in water resources programmes'. The results show that the treasurer of a water point committee is often a female, who has to collect and record the money, and often has to travel for 50+ km to pay the money to Rural Water Supply or NamWater. During interviews women frequently commented on their discomfort of carrying this money as people know they are the treasurer of the WPC, which makes them an easy target to be robbed. Furthermore, in central northern Namibia women tend to stay at their homestead taking care of home and children, while the men leave the area in search of work elsewhere. The fact that women are the ones being around makes them the natural water point committee members. On the other hand, men often considered women to be too 'weak' to be caretakers.

Gender imbalance was revealed in relation to the ownership of water resources. Men are often said to be the 'owners' of the water when they are responsible for the infrastructure while women are responsible to 'provide' water to the family whenever it is needed, e.g. for cooking, washing and cleaning. Furthermore, men sometimes claim to be the 'owners' of the water because it is their income that pays for the monthly water bill.

The above issues are of critical importance and have to be taken into consideration when implementing a project aimed at contributing to the water provision to rural central northern Namibia. Results presented here indicate that women have to be firmly involved in these initiatives as they are the ones managing the water resources in the area, however, often not receiving an acknowledgment for it. In line with the Dublin principles, focused efforts should be made within the CuveWaters project to strengthen women in their various positions related to water point committees and water point associations.

Status of IWRM development in the Cuvelai basin

Bi-lateral issues

To oversee the implementation of IWRM in the entire Cuvelai basin a bi-national Cuvelai River Commission (CuveCom) between Angola and Namibia was intended to be formed. However, CuveCom was never initiated, so currently there is no trans-boundary committee for the Cuvelai basin. Instead it has been decided that the Cuvelai is part of the Kunene Basin.

There is an international commission for the Kunene, the Permanent Joint Technical Committee (PJTC), under which Cuvelai issues are handled. Currently there is a Kunene basin IWRM plan being developed for PJTC, in which the Cuvelai basin should be included. However, Angola has not agreed to this, saying that Cuvelai is a separate basin and needs its own IWRM plan. The unwillingness of Angola to include Cuvelai in the plan means there is no joint management of the Cuvelai basin between Namibia and Angola, resulting in the two countries carrying out their own management decisions without consulting each other.

National issues

The process of establishing the Cuvelai Basin Management Committee started with stakeholders meetings in 2003. The objective of these meetings was to understand those issues of concern from the people living in the basin, and to get ideas of who should be included in the BMC membership. Most of the stakeholders were introduced to the concept of water management at basin level during the consultation that took place during the formulation of the water resources management bill.

During the consultations, issues relevant for the establishment of basin wide management, identified by local stakeholders, were recorded. Most of the issues raised were inter-regional issues, i.e. cross-cutting the regions. Water shortage in the Cuvelai basin is of greatest concern to local stakeholders. The main issues identified were:

- *Keeping water in the basin* by harvesting it before it disappears into the Etosha Pan, and prioritise the use for human consumption and agricultural development. Referring to some stakeholders, sufficient water comes into the basin but this is not properly utilised or harvested. It was said that most floodwaters disappear a few days after a flood, leaving the area dry again. According to local stakeholders, the water is lost due to evaporation and surface flow into Etosha. However, it should be emphasised that surface flow into Etosha pan is a rare phenomenon, occurring only in about 8 years out of 20. Stakeholders suggested the construction of dams to capture water before it leaves the area. Related issues, for instance, what would happen if water was prevented from flowing freely into the wetlands towards Etosha and into the pan itself, and how that would influence protected areas, e.g. Ramsar sites and tourism in the area, were raised.
- *Ensuring that Angola opens up the dams so that water can flow towards Namibia*. According to some stakeholders water does not flow as freely from Angola as it used to. Some people claim that the rivers have been blocked upstream on the Angolan side. As this is an international basin, research and investigations were requested to substantiate the matter, e.g. by use of satellite imagery or aerial photography of the Angolan part of the basin.

- *The high salinity of groundwater in the central parts of the basin, which prevents infrastructural development*. It was suggested to establish a desalination plant to improve the water quality, or at least make it drinkable for livestock, in areas where groundwater is brackish. If this is pursued, the experiences in desalinisation of Rössing Foundation at Okashana, shortly after independence ought to be taken into account.
- *Deepening the Etaka canal*. Many stakeholders believe that the Etaka canal can be deepened so that water from Olushandja dam can be diverted into the channel to flow to the downstream users, or another artificial channel.
- Water pollution and water sharing were stated to be a problem especially in the southern part of the basin. It is not clear what water sharing the stakeholders referred to, but it is likely that it has to do with the increased number of people moving towards the southern parts of the Cuvelai basin in search for grazing, which has led to more people and livestock making use of the water provided by pipelines there.

At the onset of the process of establishing the Cuvelai Basin Management Committee, the high numbers of people living in the basin were concerns believed to complicate the process. In order to simplify the pilot phase of the establishment of the committee, it was suggested that a smaller sub-area should be selected to test the process. A meeting with stakeholders was held to start the process of dividing the Cuvelai basin into sub-basins and to decide which of the sub-basins will be piloted in the future.

Stakeholders agreed to divide the Cuvelai basin into four sub-basins, namely: Olushandja, Iishana, Niipele and Tsumeb sub-basins. Iishana sub-basin was selected to be the first pilot basin in Cuvelai where basin management would be tested. Between June 2004 and October 2005, the Iishana Basin Management Forum prepared itself to form a committee. Once the demarcation of the sub-basin was agreed upon, the list of potential stakeholders was revised and the organisations within the Iishana sub-basin were identified and invited to attend forum meetings.

The establishment of the BMC used the following steps:

- Start-up phase: basin identification and preliminary demarcation, stakeholder identification, information dissemination, meetings,
- Stakeholders forum development, build up information base amongst stakeholders, build capacity,
- Basin Management Committee phase development, i.e. establish and implement the BMC.

Throughout the process information sharing, presentations and fieldtrips were included to enhance the capacity of stakeholders and increase the knowledge of their basin. Minutes of meeting were also recorded. The Committee also developed an operational plan and a constitution. By the end of October 2005, the Minister of Agriculture, Water and Forestry officially launched the Iishana Basin Management Committee.

8.2.3 Conclusions

Biophysical issues

One of the key constraining biophysical issues in the model region is the *salinity of the groundwater*. There are three different aquifers in the area, with varying salinity. This is a problem as the area cannot sustain its water needs, but depends on water provided from Angola, which is purified in Namibia, and then distributed to the rural areas via an extensive pipeline system. The example clearly illustrates the *risks associated with introducing new technology and infrastructure into an area* that previously only was used when surface water was available, during and shortly after the rainfall season. The main cause of the negative outcome of the initiative is most likely the failure to involve the local community in the project from the beginning. This was exacerbated by the lack of a management plan developed by the local users, together with the service providers involved in construction and maintenance, controlling the use and access of the water points along the pipelines. *Plans to ensure participation of all major stakeholders, and sustainable management plans should be in place before technological solutions are provided to the inhabitants of the model region*.

Socio-cultural issues

It has been shown that *livestock has a central role in the livelihoods of both the rural and urban population of the model region*. However, it was also shown that not everyone owns cattle, and that many households have too few animals to be able to sell regularly. Introduction of new technology comes at a price. *Before to start introducing new technology a clear plan towards how local users of the technology will pay for the services rendered has to be in place*. As was shown here, selling livestock might not always be the solution to increase people's ability to pay, as only the members of the community with sufficiently large herds would benefit from such initiatives, as they are the ones that can afford to sell their animals.

Institutional issues

It was shown that *there are presently no serious water use conflicts in the Cuvelai basin*. However, the fresh water distributed in the extensive pipeline system, supporting large parts of Cuvelai basin originates in Angola. The present agreement between Angola and Namibia dates back to 1964 (Water Use Agreement, 1964), an agreement that Angola now is asking to renegotiate. *Should Angola decide to use her water herself*, (which is a likely scenario, given the high potential for irrigation on the Kunene floodplain), *then that might lead to a serious conflict*, both between water users *in the Cuvelai basin and between Namibia and Angola on a government-to-government level*.

The CuveWaters project will be carried out in the Iishana sub-basin. The Iishana Basin Management Committee (IBMC) is central to the management structure and will therefore most likely be one of the key stakeholders in this project. It is therefore important to know on what level the IBMC presently operates. The detailed account given of activities undertaken by the IBMC shows that most of the efforts have so far been aimed at building capacity of the Basin Management Committee. Most likely this is a good start. However, it also shows that very little has been done by the IBMC towards actual management of the sub-basin. This implies that the project team might have to contribute to the capacity building of the IBMC before the committee can become a strong counterpart in the implementation of the project. Given that the IBMC is still in its initial stage of development, it is advisable to *involve the existing Water Point Committees and Local Water Committees on an early stage in the project planning and implementation* to ensure local participation in the project (based mainly on Klintenberg, 2007 and Amakali, 2003).

8.3 Tasks:

- For the urban water supply and sanitation the Zambian government suggests build-operate-transfer models, concessions and Commercially Viable Water Supply and Sanitation Utilities. Explain how these public-private partnership models work.
- Explain the main water related impacts on the Zambian environment.
- Explain with the help of internet the advantages and disadvantages of oshanas in the Cuvelai basin with regard to water supply, wildlife, agriculture and livestock.
- The people in the Cuvelai basin have problems with salty groundwater. Why do they not use sand filters (as shown in plate 64 or 65) to purify the water?
- Explain what actual and potential conflicts exist with Angola about water usage.
- Explain why the improved water supply in the Cuvelai basin can be called "a blessing in disguise"?
- Explain which *special* factor has to be taken into account when implementing IWRM in the Cuvelai basin.
- Compare the case study of the Cuvelai Basin with the case study of Karonga (4.2.1) with regard to the introduction and acceptance of new water supply technologies and the users' attitude towards payment for water.

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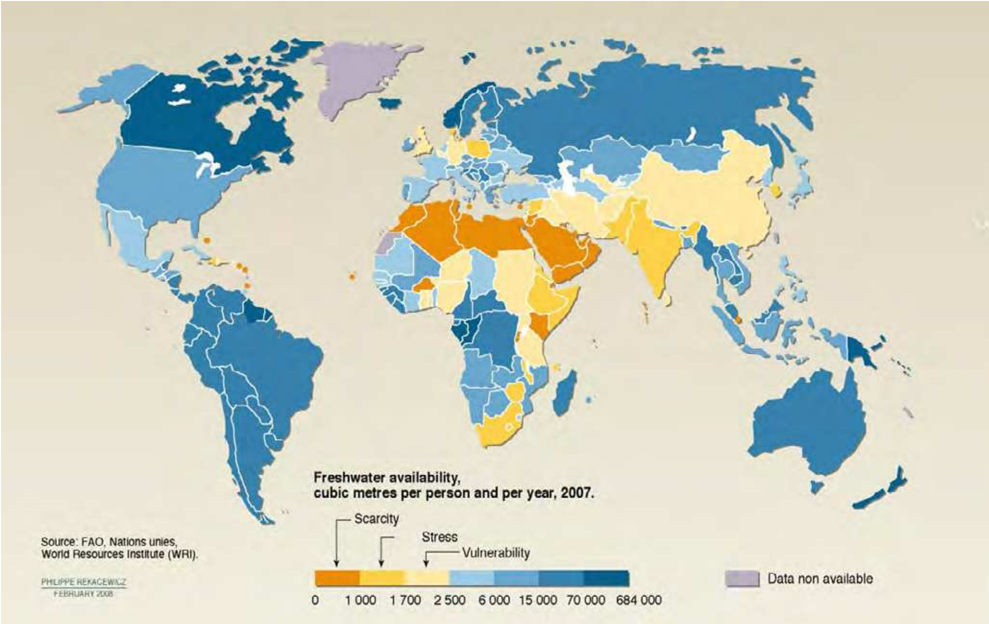
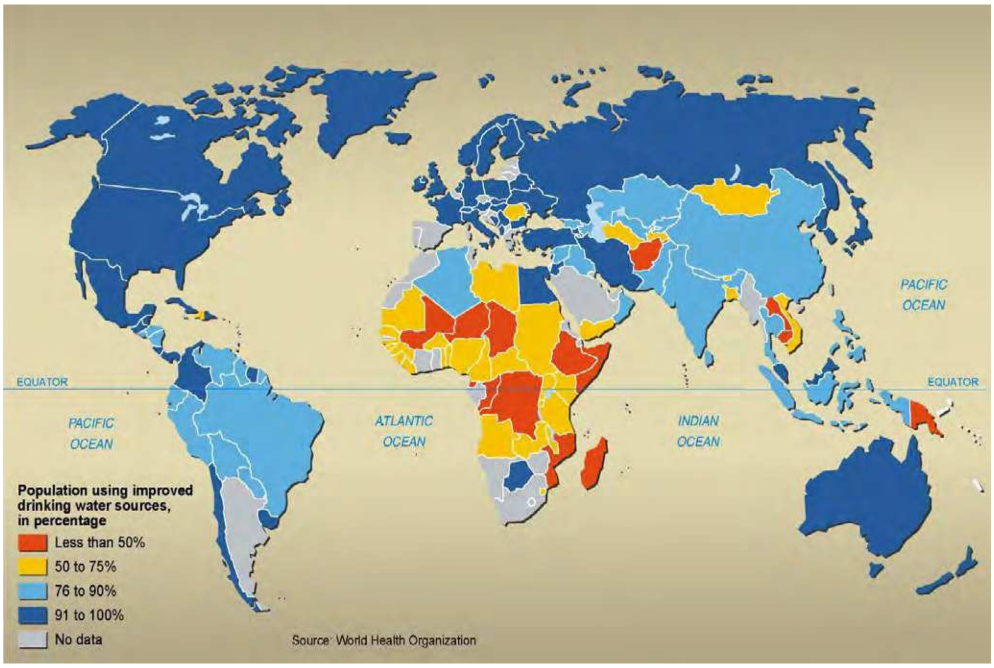
10 Plates

Plate 1 Global water stress and scarcity



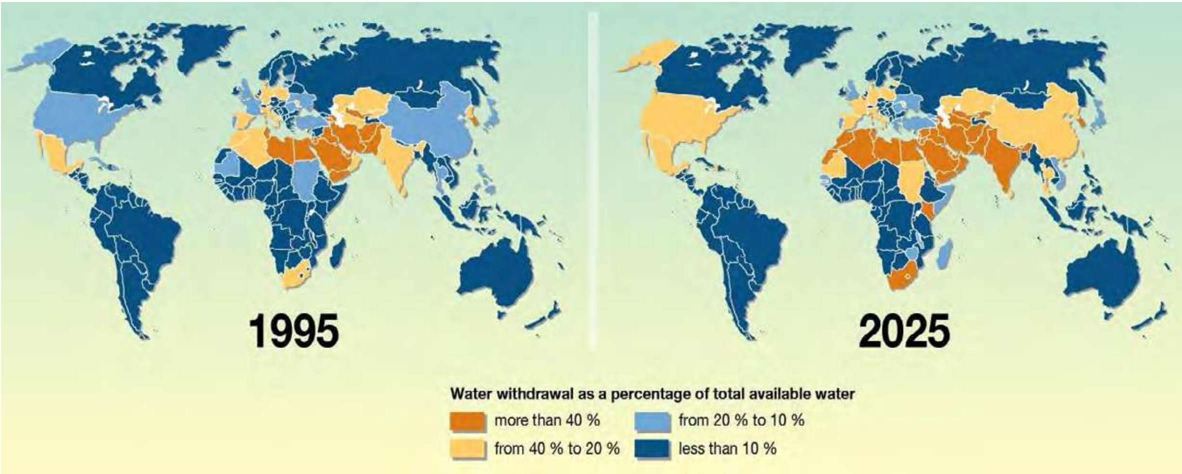
http://maps.grida.no/go/graphic/global-waterstress-and-scarcity

Plate 2 Proportion of population with improved drinking water supply



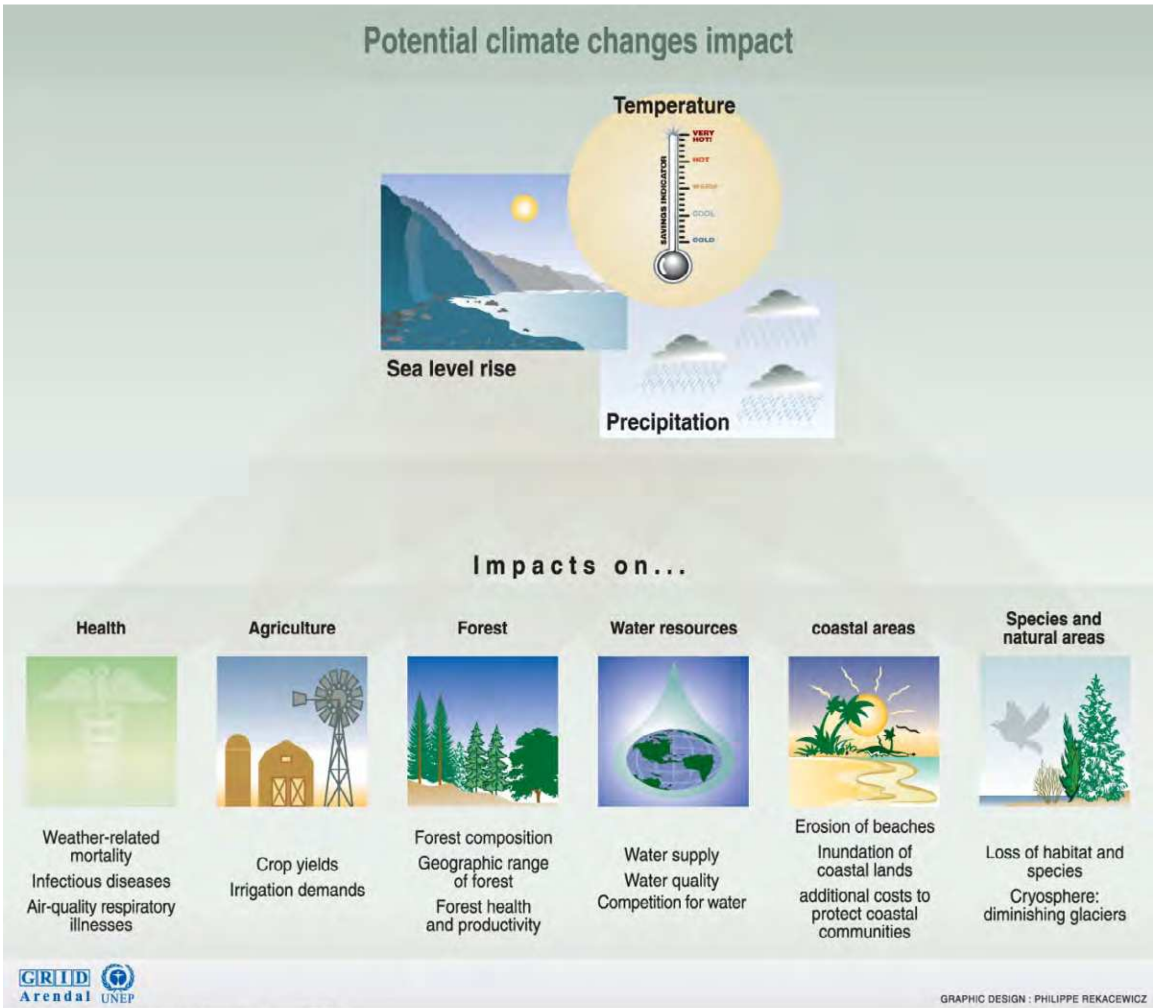
http://maps.grida.no/go/graphic/proportion-of-population-with-improved-drinking-water-supply-in-2002

Plate 3 Increased global water stress



http://maps.grida.no/go/graphic/increased-global-water-stress

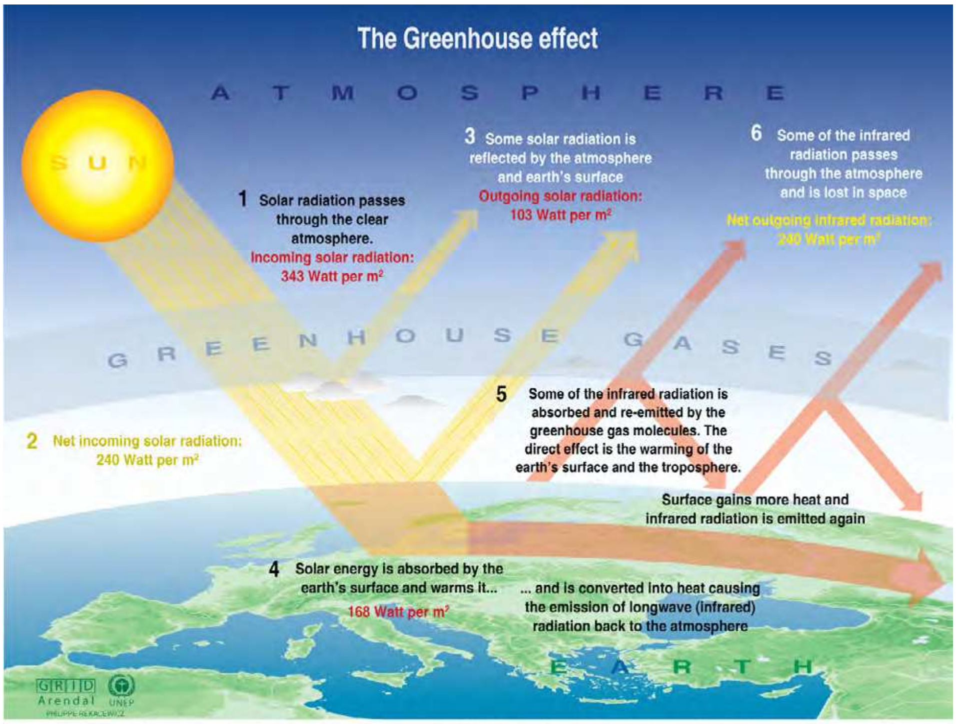
Plate 4 Potential climate change impacts



Source: United States environmental protection agency (EPA).

http://maps.grida.no/go/graphic/potential-climate-change-impacts

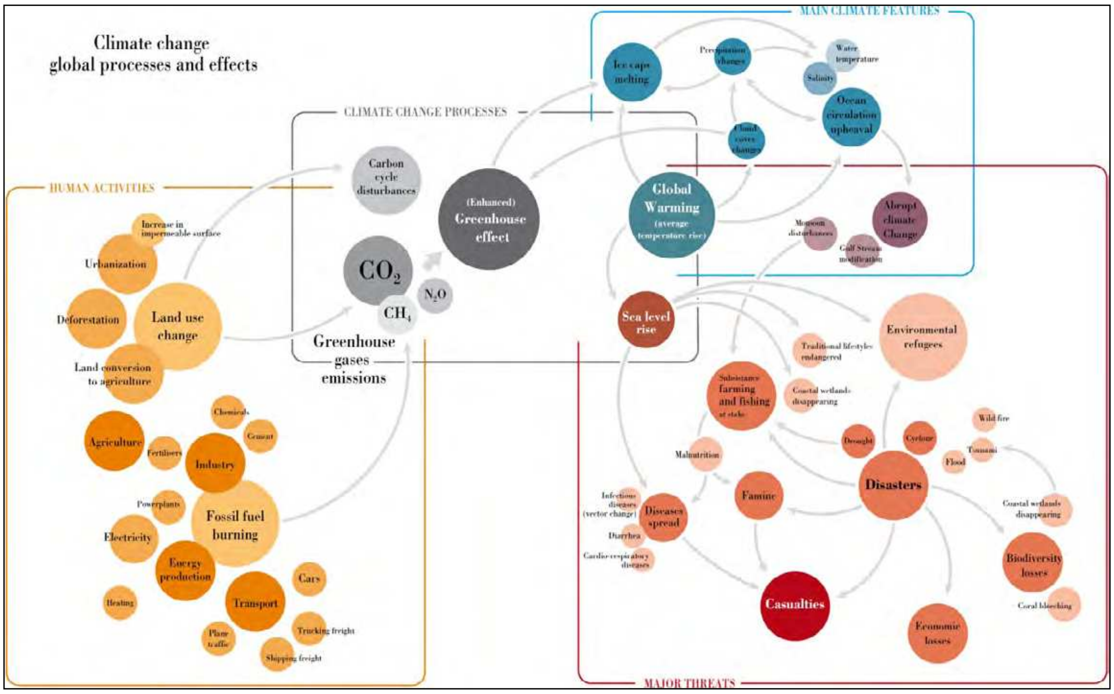
Plate 5 The greenhouse effect



Sources: Okanagan university college in Canada, Department of geography, University of Oxford, school of geography; United States Environmental Protection Agency (EPA), Washington; Climate change 1995, The science of climate change, contribution of working group 1 to the second assessment report of the intergovernmental panel on climate change, UNEP and WMO, Cambridge university press, 1996.

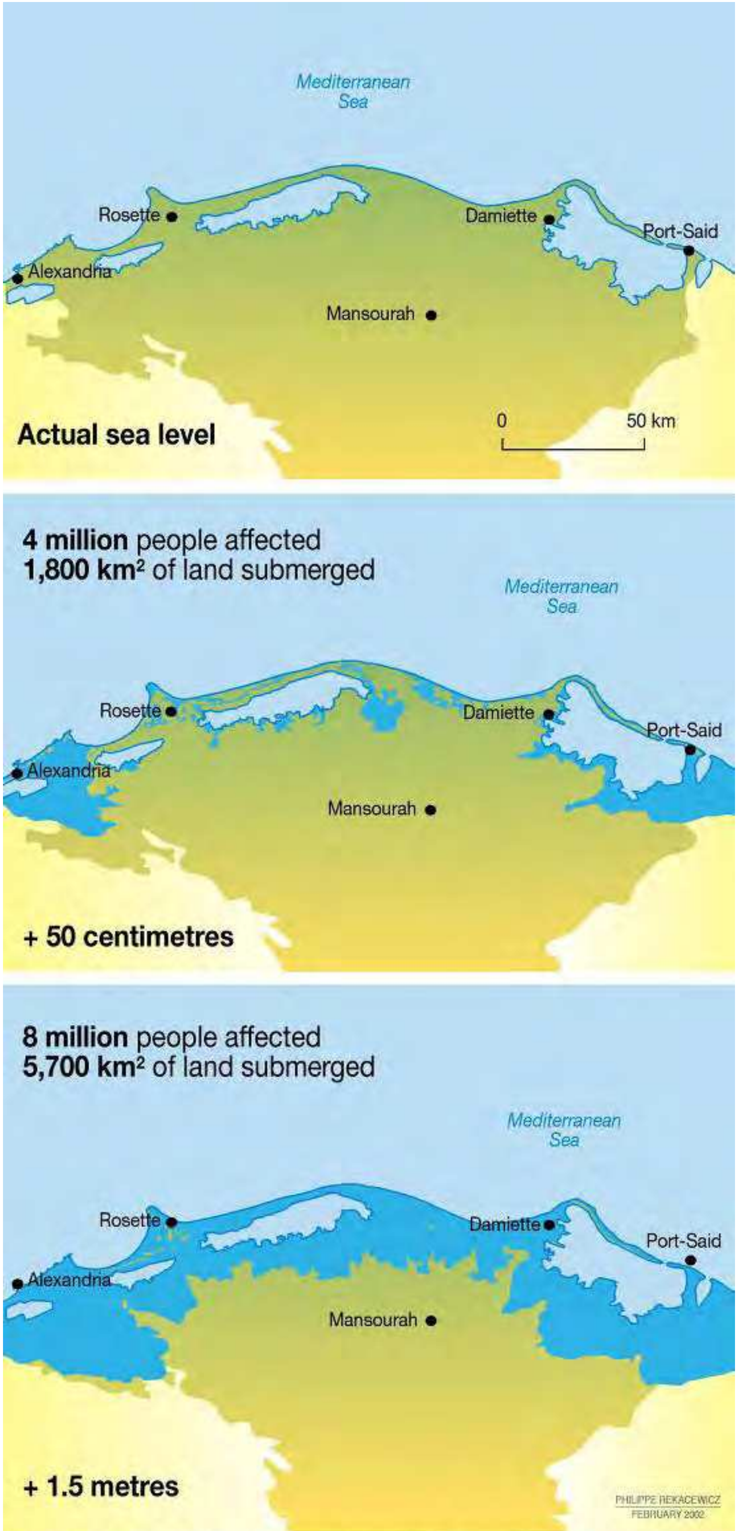
http://maps.grida.no/go/graphic/greenhouse-effect

Plate 6 Climate change – global processes and effects



http://maps.grida.no/go/graphic/climate-change-global-processes-and-effects1

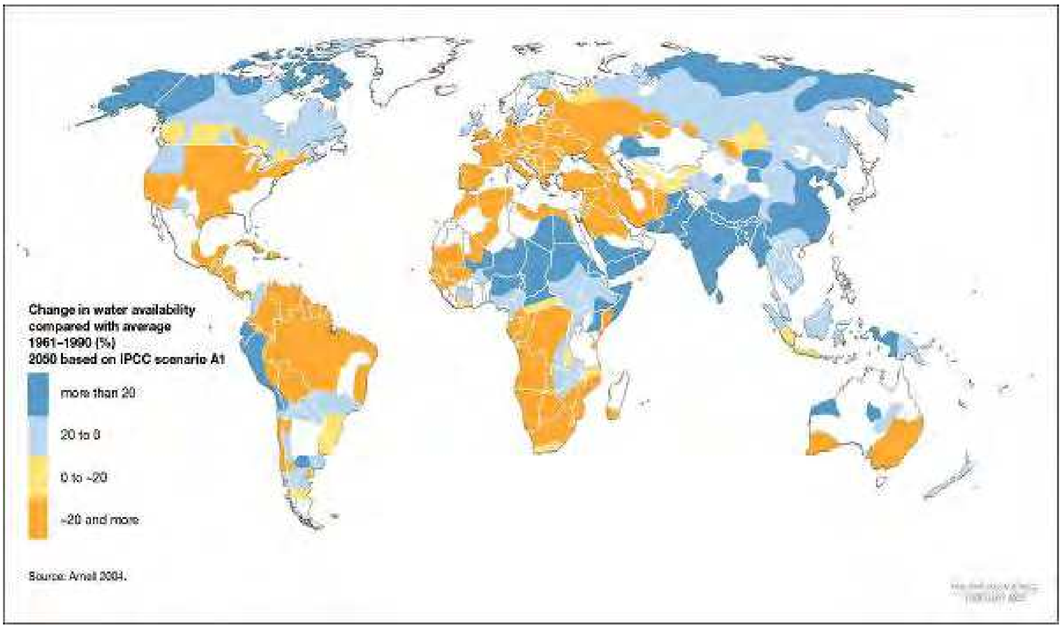
Plate 7 Impact of sea level rise on the Nile Delta



Sources: The Sea elevation model has been calculated by Otto Simonett (UNEP/GRID, Arendal and Nairobi) at the beginning of the 1990s.
See also http://blog.mondediplo.net/2008-01-22-Le-delta-du-Nil-menace-par-les-eaux

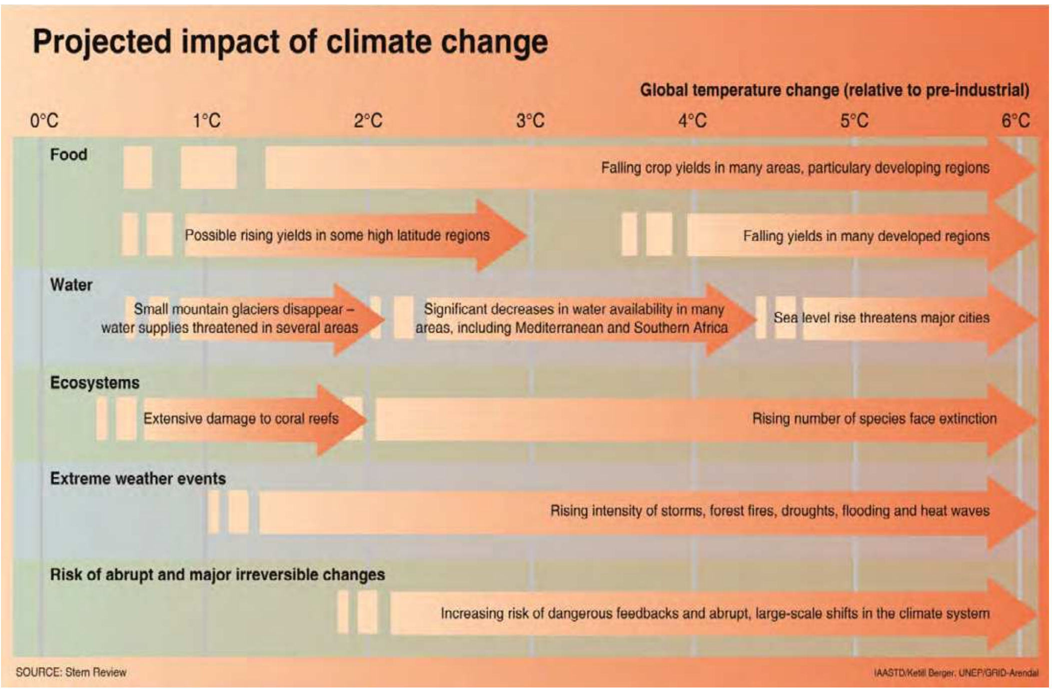
http://www.grida.no/publications/vg/water2/page/3292.aspx

Plate 8 The contribution of climate change to declining water availability



http://www.grida.no/publications/vg/water2/page/3294.aspx

Plate 9 Projected impact of climate change



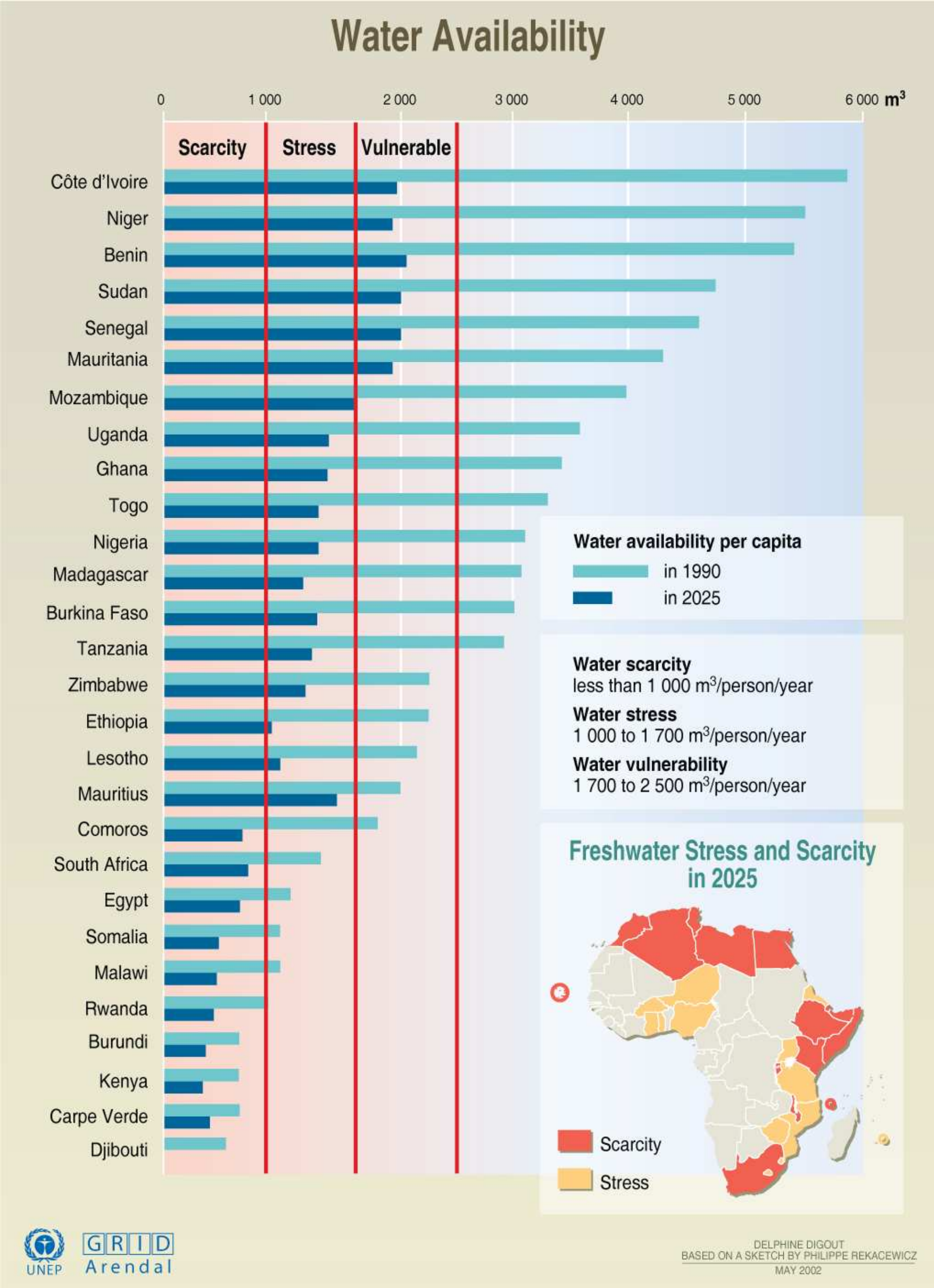
http://maps.grida.no/go/graphic/projected-impact-of-climate-change

Plate 10 Climate Change Vulnerability in Africa

Sources: Anna Ballance, 2002.

http://maps.grida.no/go/graphic/climate-change-vulnerability-in-africa

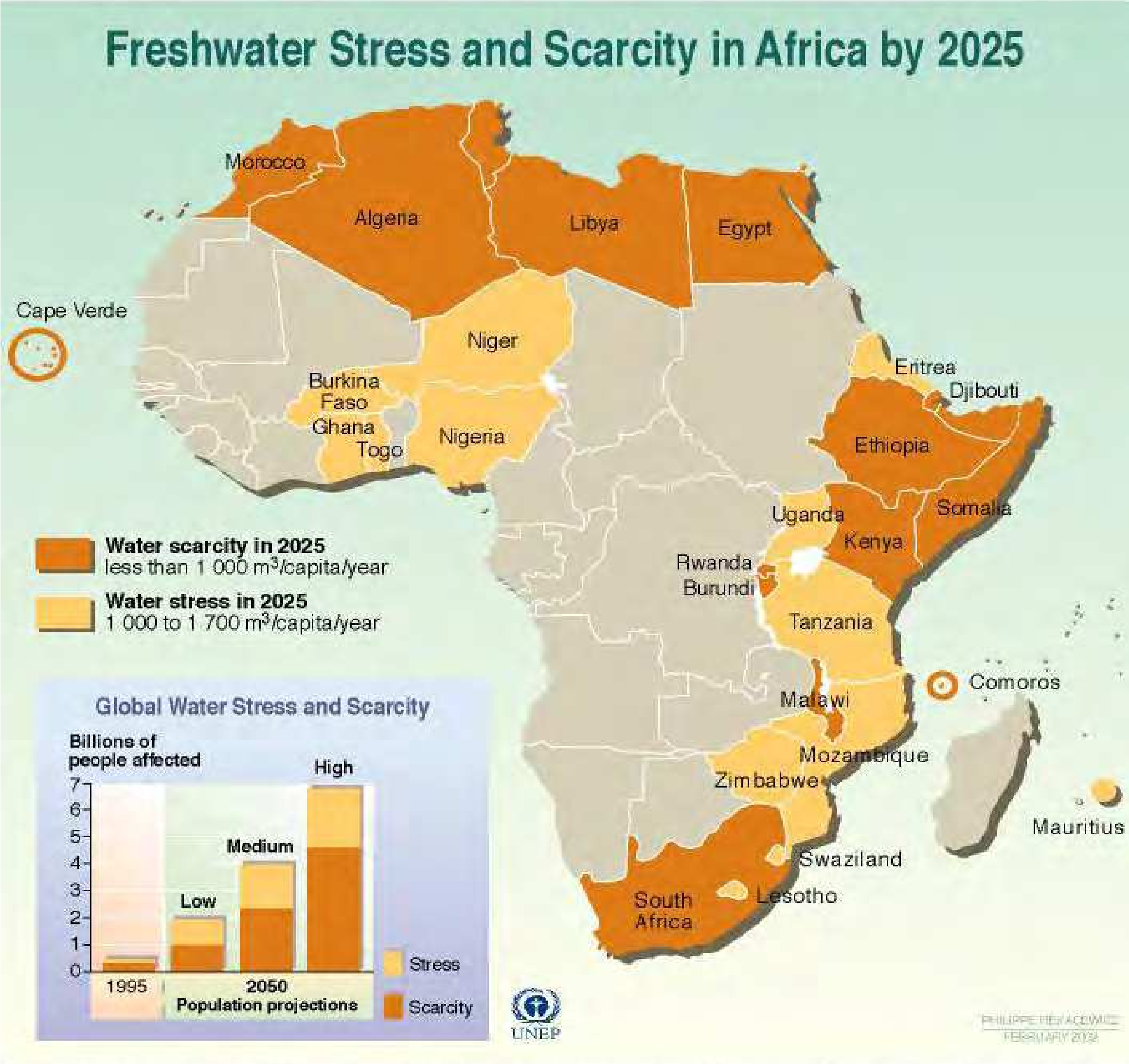
Plate 11 Water Availability in Africa



Source: United Nations Economic Commission for Africa (UNECA), Addis Abeba ; Global Environment Outlook 2000 (GEO), UNEP, Earthscan, London, 1999.

http://maps.grida.no/go/graphic/water_availability_in_africa

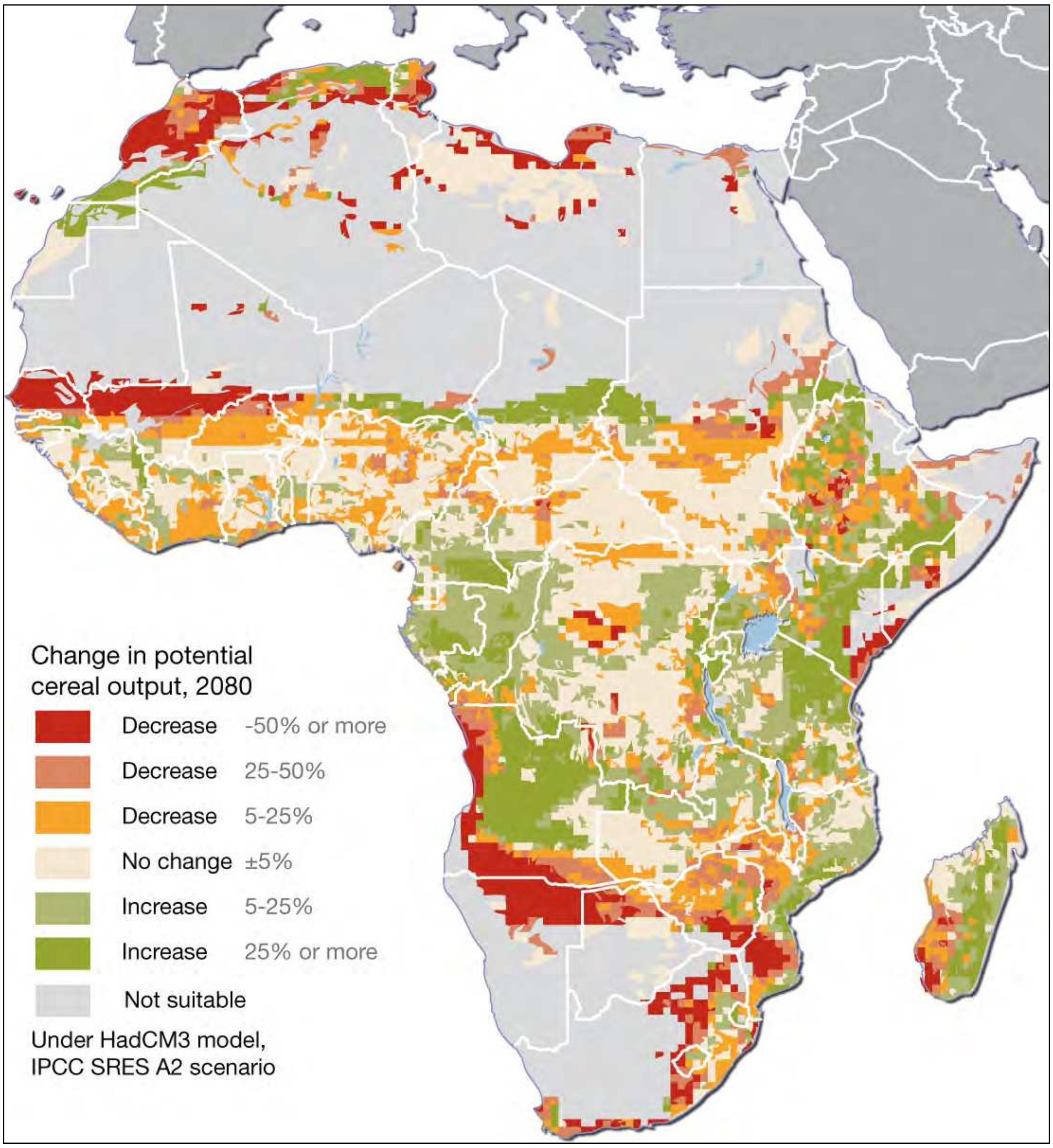
Plate 12 Freshwater Stress and Scarcity in Africa by 2025



Source: United Nations Economic Commission for Africa (UNECA), Addis Ababa; Global Environment Outlook 2000 (GEO), UNEP, Earthscan, London, 1999; Population Action International.

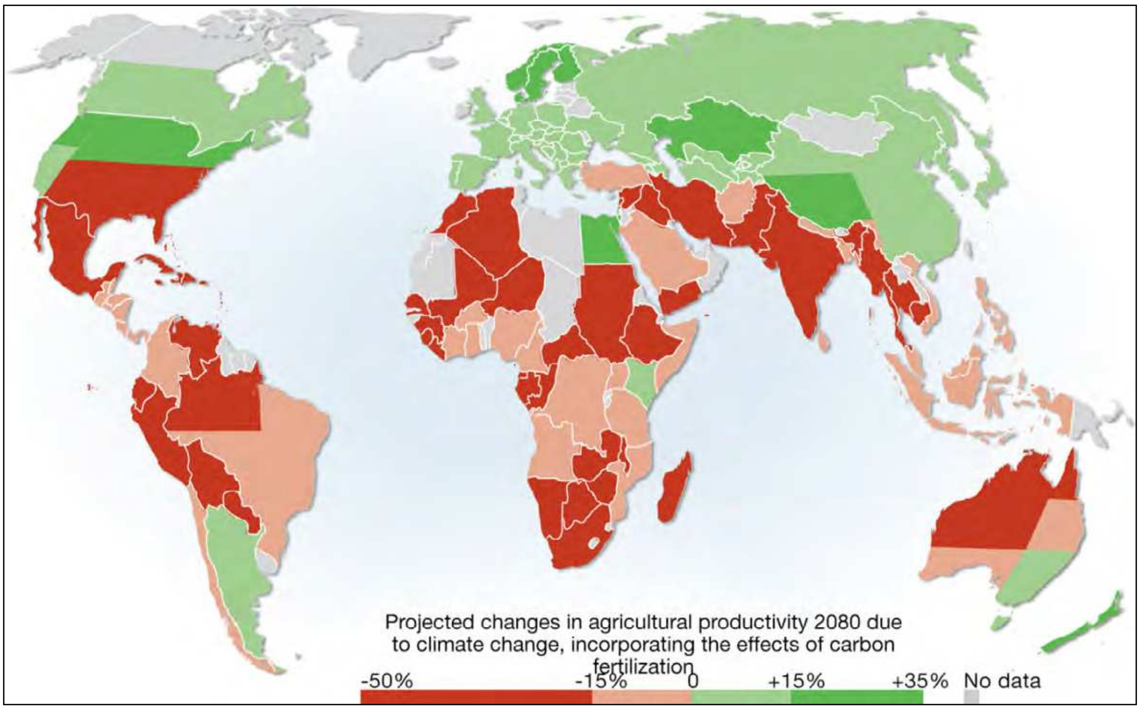
http://maps.grida.no/go/graphic/freshwater_stress_and_scarcity_in_africa_by_2025

Plate 13 Impacts of climate change on cereal output in Africa



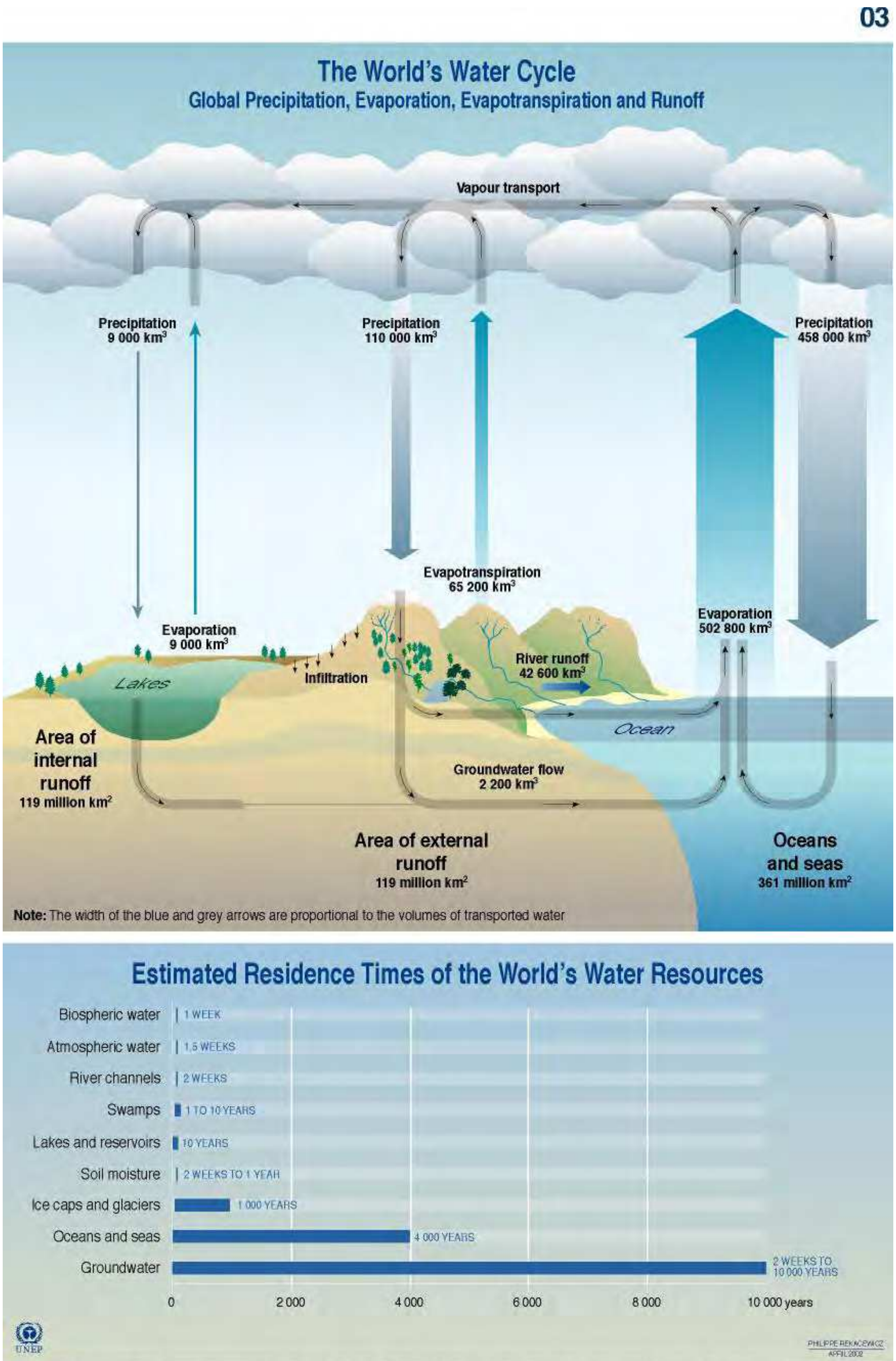
http://maps.grida.no/go/graphic/impacts-of-climate-change-on-cereal-output-in-africa

Plate 14 Projected agriculture in 2080 due to climate change



http://maps.grida.no/go/graphic/projected-agriculture-in-2080-due-to-climate-change

Plate 15 The Global Water Cycle



Source: Igor A. Shiklomanov, State Hydrological Institute (SHI, St. Petersburg) and United Nations Educational, Scientific and Cultural Organisation (UNESCO, Paris), 1999; Max Planck, Institute for Meteorology, Hamburg, 1994; Freeze, Allen, John, Cherry, *Groundwater*, Prentice-Hall: Engle wood Cliffs NJ, 1979.

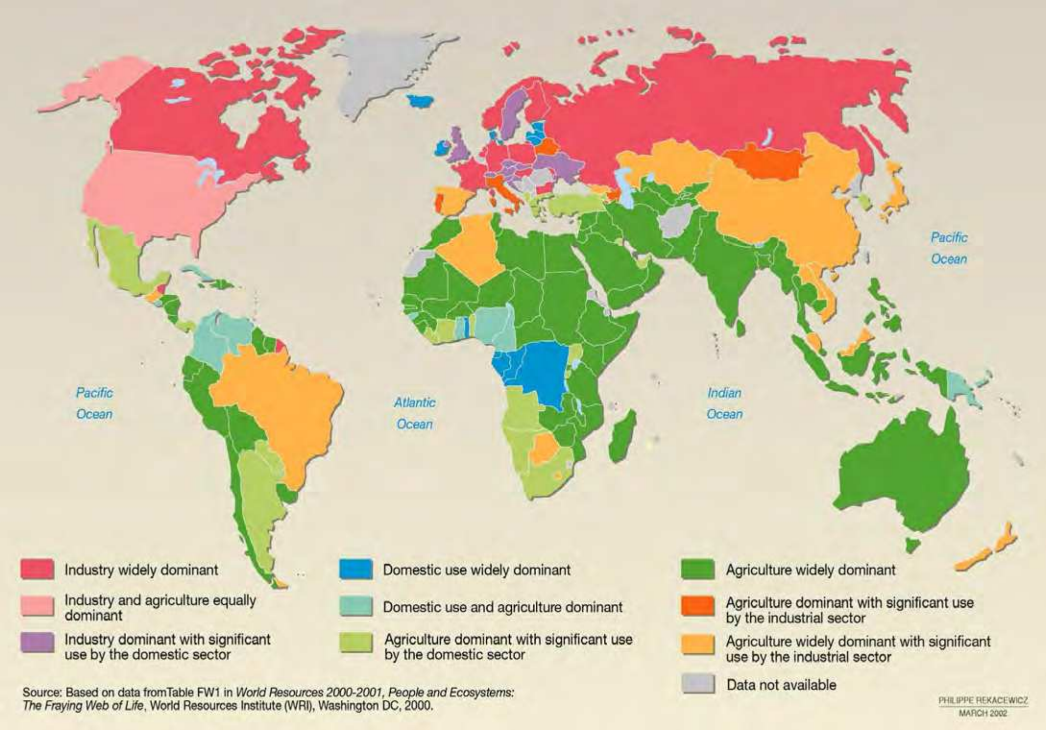
http://maps.grida.no/go/graphic/world_s_water_cycle_schematic_and_residence_time

Plate 16 Distribution of water across the globe

Location	Volume (10^3 km^3)	% of total volume in hydrosphere	% of freshwater	Volume recycled annually (km^3)	Renewal period years
Ocean	1.338.000	96.5		505.000	2.500
Groundwater (gravity and capillary)	23.400	1.7		16.700	1.400
Predominantly fresh ground-water	10.530	0.76	30.1		
Soil moisture	16.5	0.001	0.05	16.500	1
Glaciers and permanent snow cover	24.064	1.74	68.7		
Antarctica	21.600	1.56	61.7		
Greenland	2.340	0.17	6.68	2.477	9.700
Arctic lands	83.5	0.006	0.24		
Mountainous regions	40.6	0.003	0.12	25	1.600
Ground ice (permafrost)	300	0.022	0.86	30	10.000
Water in lakes	176.4	0.013		10.376	17
Fresh	91.0	0.007	0.26		
Salt	85.4	0.006			
Marshes and swamps	11.5	0.0008	0.03	2.294	5
River water	2.12	0.0002	0.006	43.000	16 days
Biological water	1.12	0.0001	0.003		
Water in the atmosphere	12.9	0.001	0.04	600.000	8 days
Total volume in the hydrosphere	1.386.000	100			
Total freshwater	35.029.2	2.53	100		

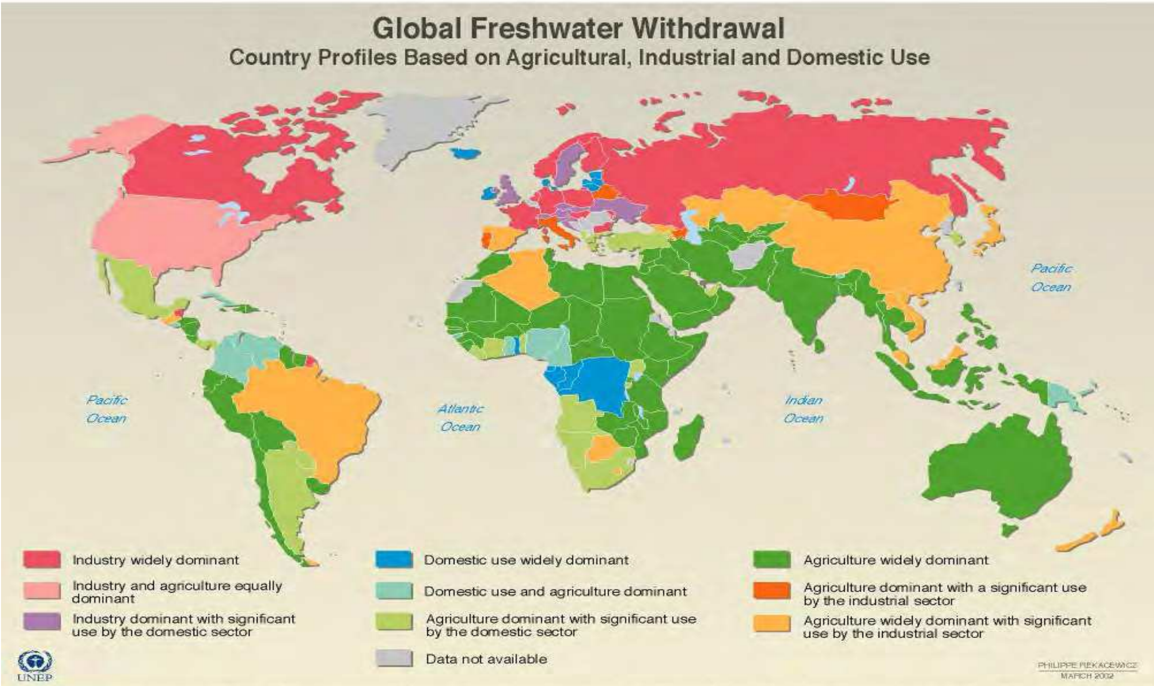
(WWAP, 2003, p. 68).

Plate 17 **Freshwater use by sector at the beginning of the 2000s**



http://maps.grida.no/go/graphic/freshwater-use-by-sector-at-the-beginning-of-the-2000s

Plate 18 Global Freshwater Withdrawal (Country Profiles base on Agricultural, Industrial and Domestic Use)



Source: Based on data fromTable FW1 in *World Resources 2000-2001, People and Ecosystems: The Fraying Web of Life*, World Resources Institute (WRI), Washington DC, 2000.

http://maps.grida.no/go/graphic/global_freshwater_withdrawal_agricultural_industrial_and_domestic_use

Plate 19 Water content of things I

The table shows some estimates of the water needed to produce a range of agrarian products.

Item	Litre	Comments
Beverages (per litre)		
Glass of beer	300	includes growing barley
Bottled Water	3 to 4	Processing and water to make the plastic bottle
Malt beverages (processing)	50	Processing only
Milk	1.000	for the cow and processing
Cup of coffee	1.120	
Cup of tea	120	
Glass of wine	960	includes producing the grapes
Glass of apple juice	950	Includes growing the apples
Assorted produced goods (per kg)		
Roasted coffee	21.000	to grow
Tea	9.200	to grow
Bread	1.300	
Cheese	5.000	
Cotton textile finished	11.000	assumes 45% crop use; 41% unproductive evaporation; 14% processing and wastewater
Sheet paper	125	Not including the water to grow tree
Potato chips	925	
Hamburger	16.000	
Leather shoes	16.600	
Assorted crops (per kg)		To grow; depends on climate; depends on weight of finished crop versus total yield
Barley	1.300	
Coconut	2.500	
Maize	1.000 to 1.800	
Sugar	1.500	
Apple	700	
Potato	500 to 1.500	
Wheat	900 to 2.000	
Alfalfa	900 to 2.000	
Sorghum	1.100 to 1.800	
Rice	1.900 to 5.000	
Soybeans	1.100 to 2.000	

http://www.worldwater.org/data20082009/Table19.pdf

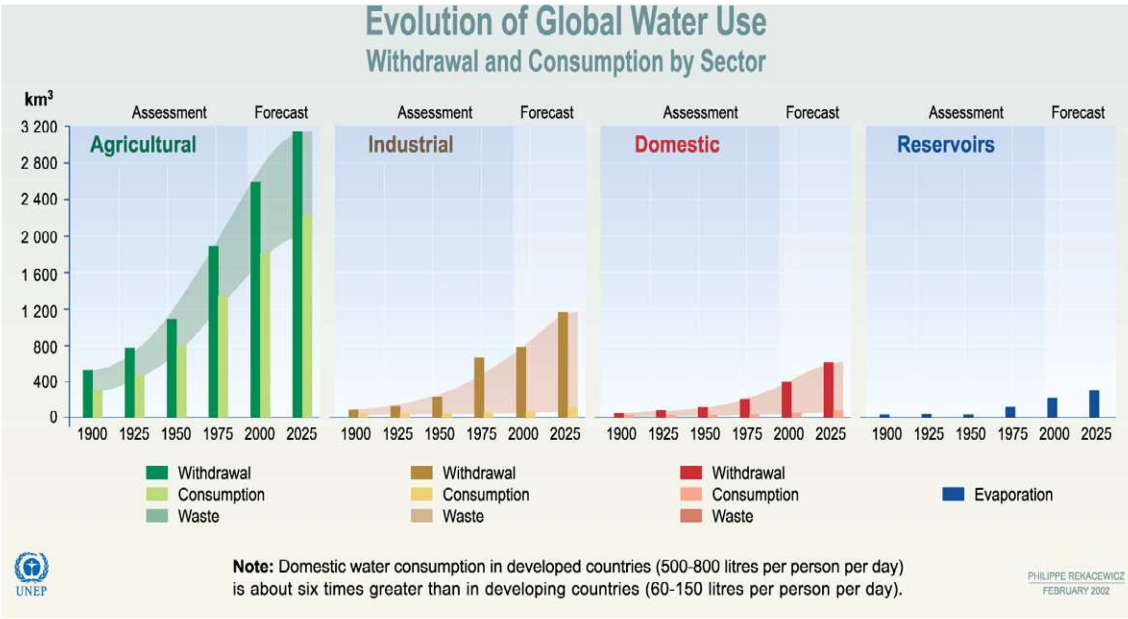
Plate 20 Water content of things II

The table shows some estimates of the water needed to produce a range of agrarian products and manufactured goods.

Item	Litre	Comments
Assorted animals (per kg of meat)		Includes water for all feed
Sheep	6.100	
Goat	4.000	
Beef	15.000 to 70.000	
Chicken	3.500 to 5.700	
Eggs	3.300	
Assorted industrial products (per kg)		Processing water; there is great variation depending on process
Steel	260	
Primary Copper	440	
Primary Aluminium	410	
Phosphatic fertilizer	150	
Nitrogenous fertilizer	120	
Synthetic rubber	460	

http://www.worldwater.org/data20082009/Table19.pdf

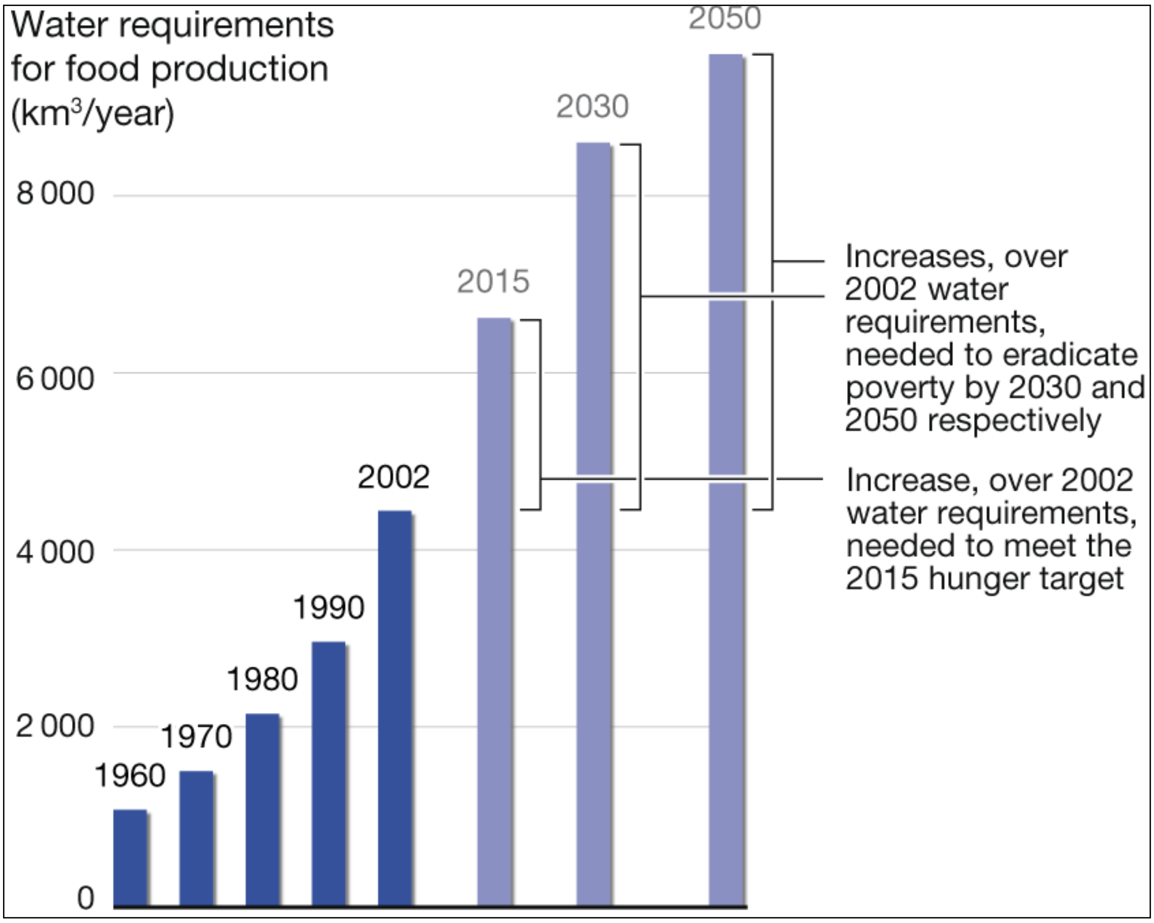
Plate 21 **Trends and forecasts in water use, by sector**



Source: Igor A. Shiklomanov, State Hydrological Institute (SHI, St. Petersburg) and United Nations Educational,Scientific and Cultural Organisation (UNESCO, Paris), 1999.

http://maps.grida.no/go/graphic/trends-and-forecasts-in-water-use-by-sector

Plate 22 Water requirement for food production



http://maps.grida.no/go/graphic/water-requirements-for-food-production-1960-2050

Plate 23 Types of water pollutants and some of their effect

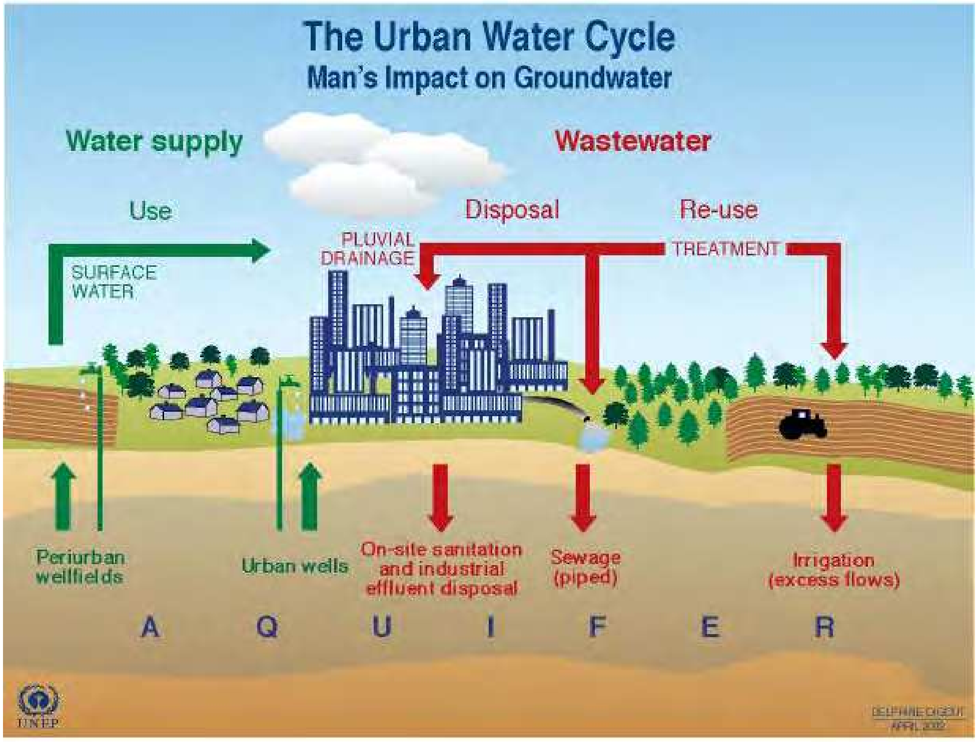
Pollutant	Anthropogenic sources	Natural sources	General effect	Effect on biota	Effect on water supplies
Heat	Power generation, steel plants	Unlikely	Increase in metabolism of living organisms, decrease of concentration of dissolved oxygen	Possible reduction in the ability to breed and growth rate	None
Suspended Solids	Quarrying, paper mills, run-off from roads	Soil erosion, storms, floods	An increase in turbidity and therefore a reduction in light penetration, covering or blanketing bottom after settling	Reduction in ability of plants to photosynthesis, clogging gills of fish, blanketing of bottom-living plants and animals	Blocks filtering systems, needs to treat water to remove solids
Surfactants	Detergents, oil	Unlikely	Formation of foam which could prevent oxygen and carbon dioxide exchange, changes surface tension of water	Reduction in dissolved oxygen, life cycle of some insects affected	Interfere with treatment process, may need extra treatment if particularly stable foams formed
Biodegradable wastes	Domestic sewage, animal wastes from farms, food processing companies	Run-off and seepage through the soil	Oxygen demand increases, provide food for organisms lower down in the food chain	Can be useful to organisms as food source, if too much, can reduce oxygen to fatal levels	Will need extra treatment
Nitrates, phosphates and other possible plant nutrients	Detergents, fertilizers, tanneries, intensive animal husbandry, ammonia-containing industrial wastes	Nitrogen cycle	Excessive plant growth	Heavy demand on dissolved oxygen	Will need extra treatment
Inorganic chemicals (acids, alkalis, salts)	Steel, chemical and textile industries, coal and salt mining	Naturally acid or alkaline rocks	Raise or lower pH	Plants and animals can only tolerate a narrow range of pH	Corrosion of equipment and pipes, silting
Toxic chemicals (heavy metals like mercury and lead) phenols (PCBs, etc.)	Detergents, pesticides, tanneries, pharmaceuticals, oil refineries	Rare	Poison living organisms	Can cause death in animals and humans	Water cannot be used until levels of toxic materials are at acceptable levels, may require extensive extra treatment
Pathogenic bacteria and viruses	Raw sewage	Manifold	Bacteria can cause diseases. Action of viruses uncertain	Can prove fatal	Will need extra treatment

Wright, 2003, pp. 308–309

Plate 24 The water reclamation plant in Windhoek

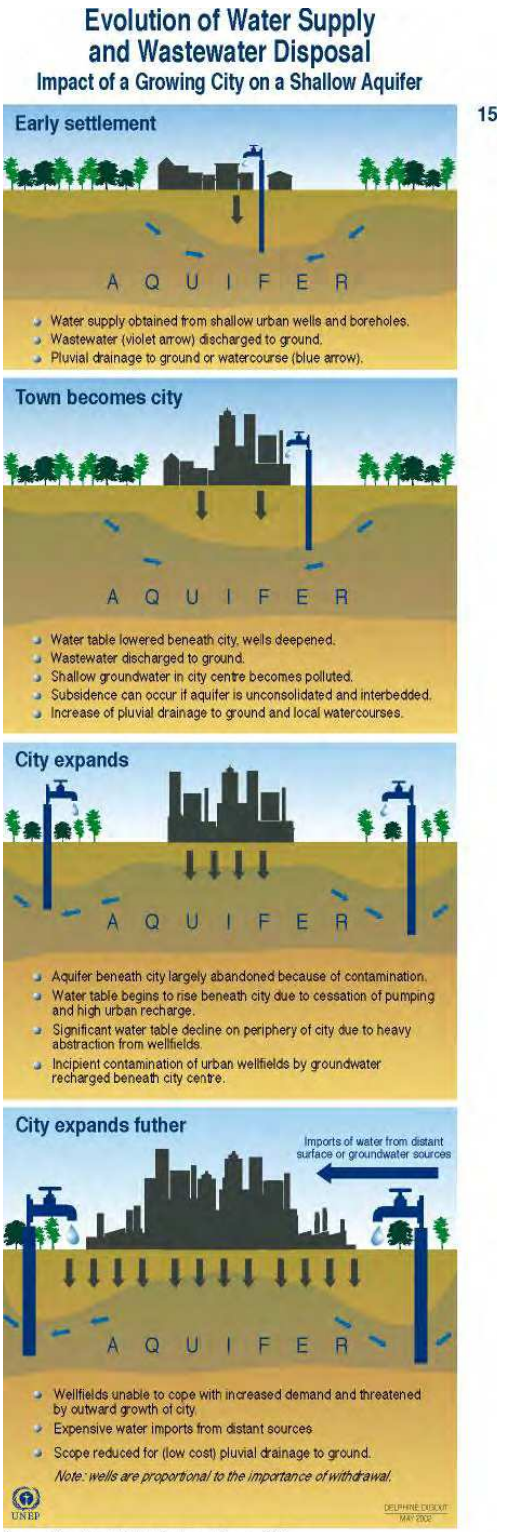
http://www.berlinwasser.net/content/language1/html/719.php

Plate 25 **The Urban Water Cycle**



http://maps.grida.no/go/graphic/urban_water_cycle

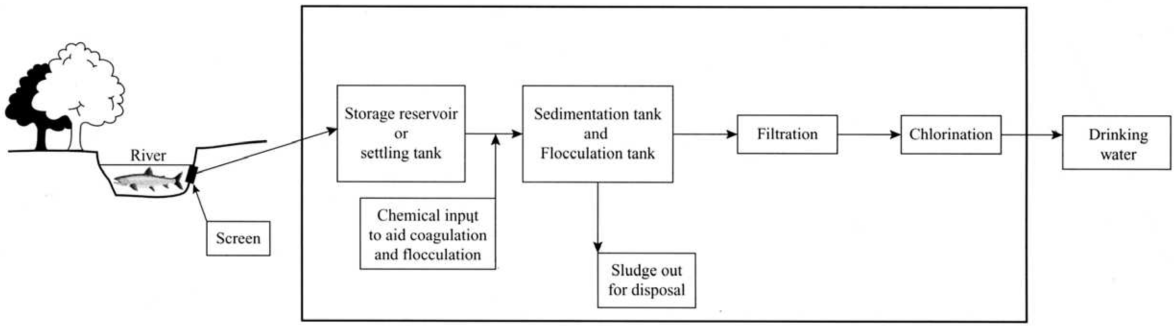
Plate 26 **Urban water supply and wastewater on a shallow aquifer**



Source: Brian Morris, British Geological Survey, 2001.

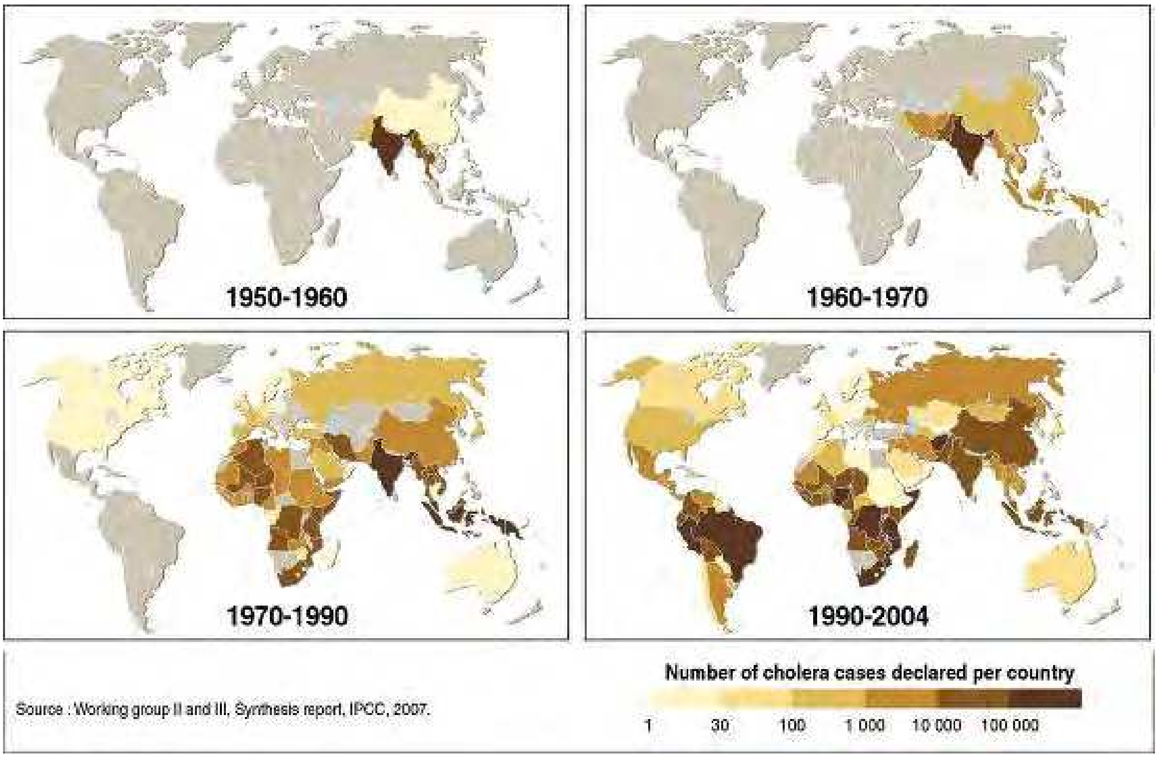
http://maps.grida.no/go/graphic/urban_water_supply_and_wastewater_on_a_shallow_aquifer

Plate 27 The water purification plant



Wright, 2003, p. 324

Plate 28 The spread of Cholera 1950–2004

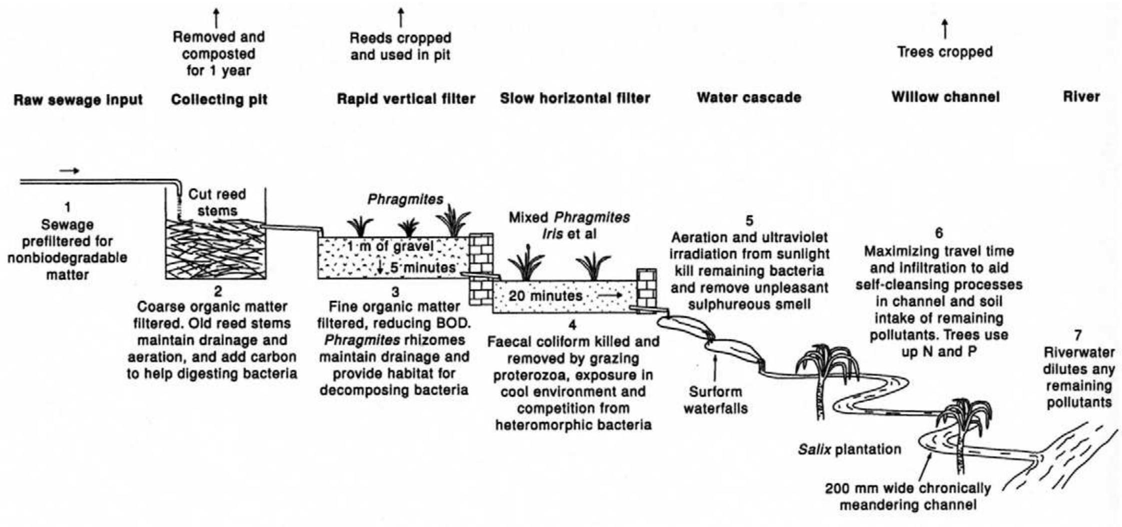


http://www.grida.no/publications/vg/water2/page/3267.aspx

Plate 29 **Women and children queuing in Harare during cholera disease in 2009 for safe water**

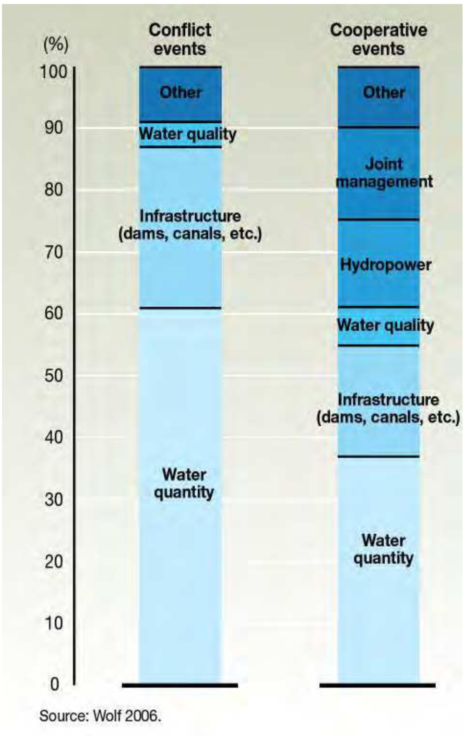
http://www.zeit.de/online/2008/51/bg-trinkwasser?3

Plate 30 **Reed beds**



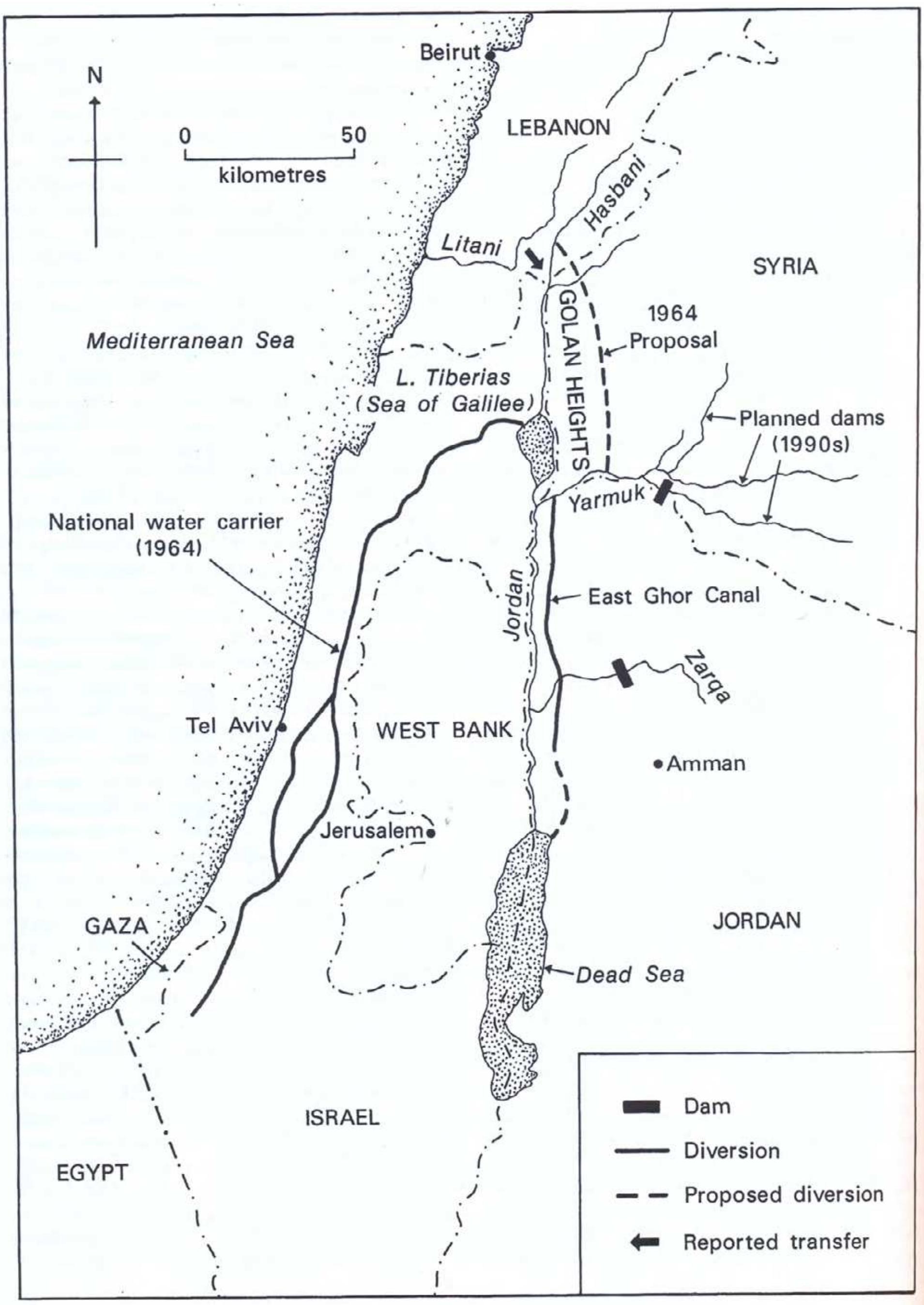
Jones, 1997, p. 268

Plate 31 **Water – cooperation or conflict?**



http://www.grida.no/publications/vg/water2/page/3264.aspx

Plate 32 The Jordan basin



Jones, 1997, p. 334

Plate 33 Aquifers in the West Bank and direction of groundwater flows

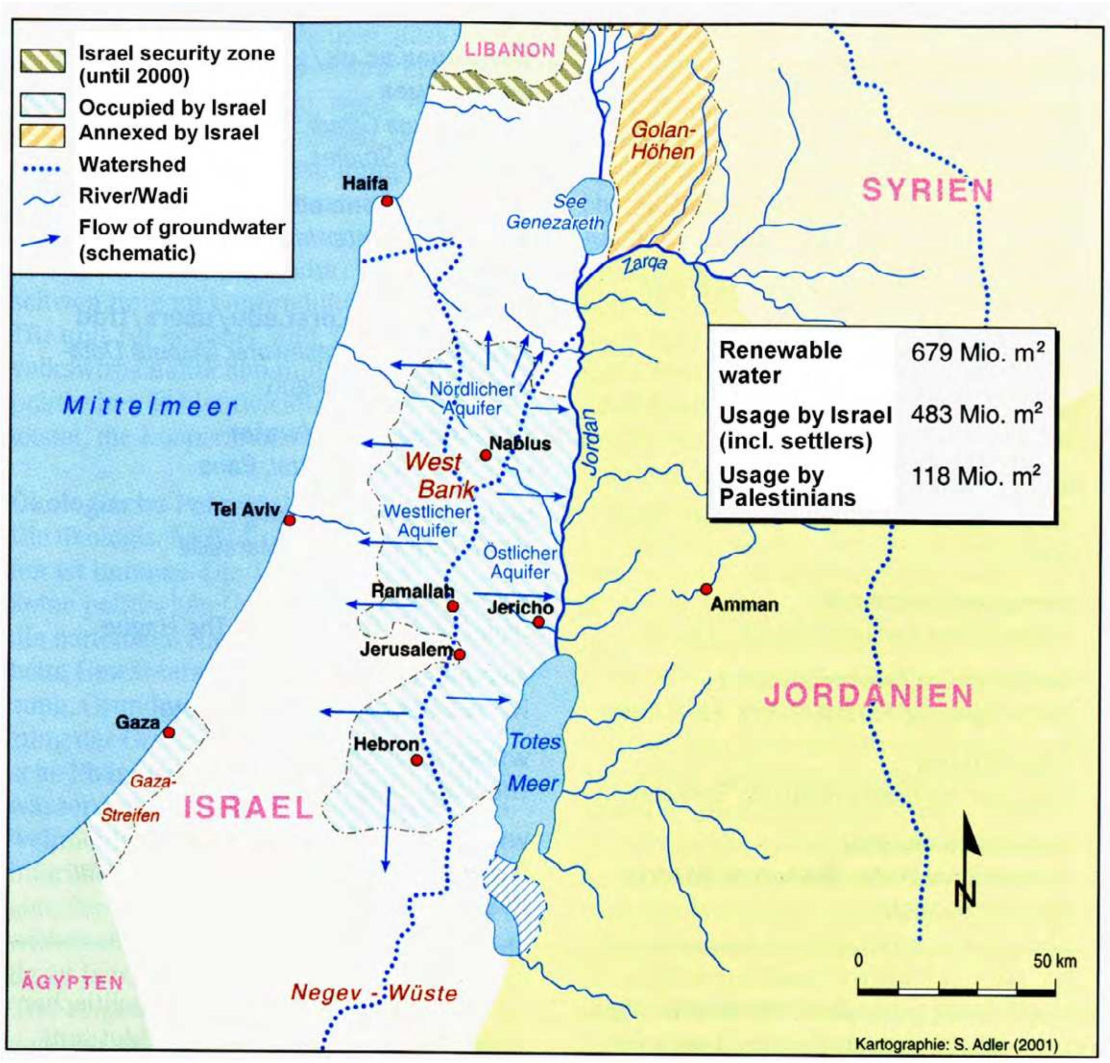
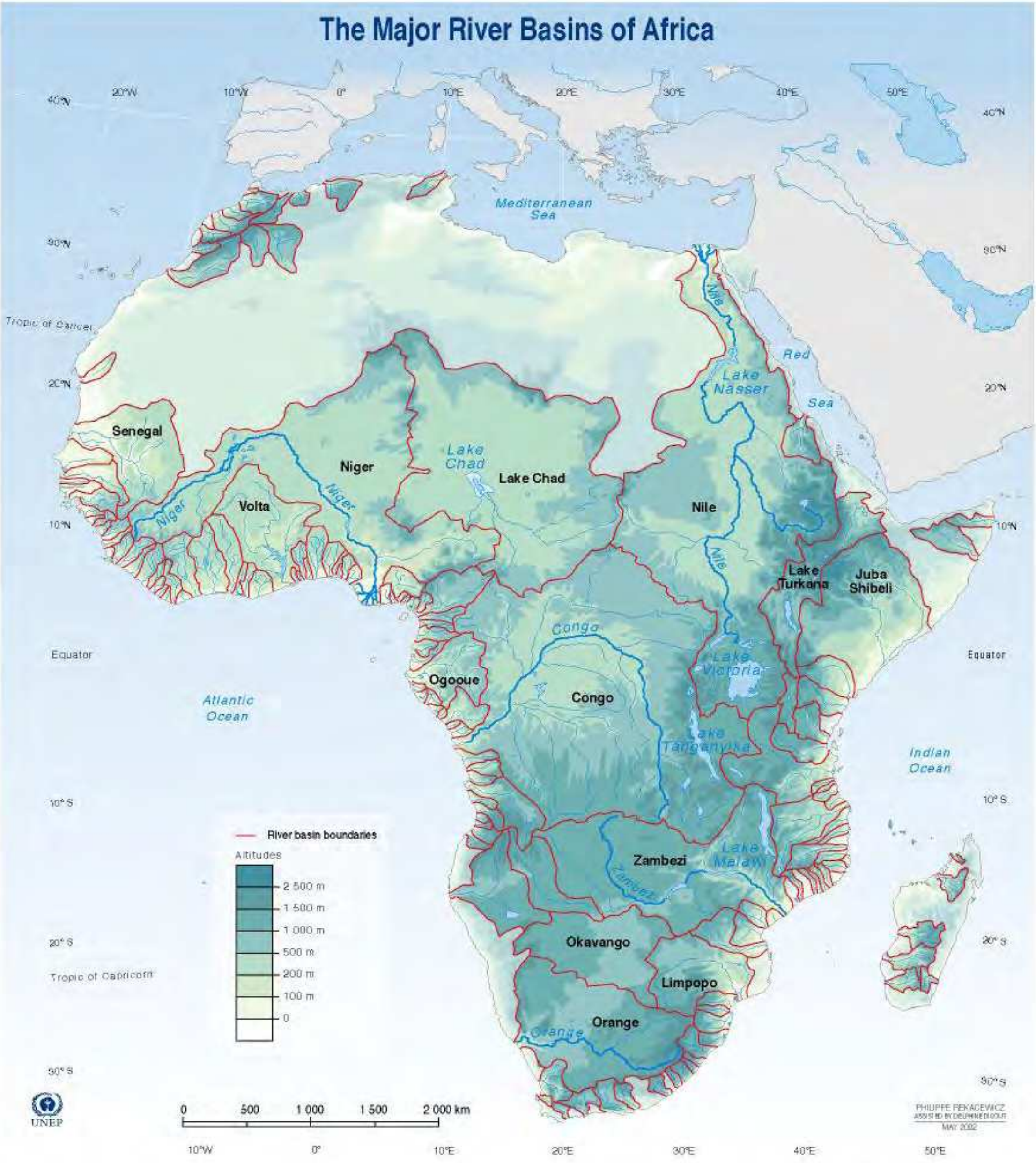


Plate 34 Regulation of the Tigris and the Euphrates Rivers

Source: Le Monde diplomatique, Paris, 1994, updated in 2001.

http://maps.grida.no/go/graphic/regulation_of_the_tigris_and_euphrates_rivers

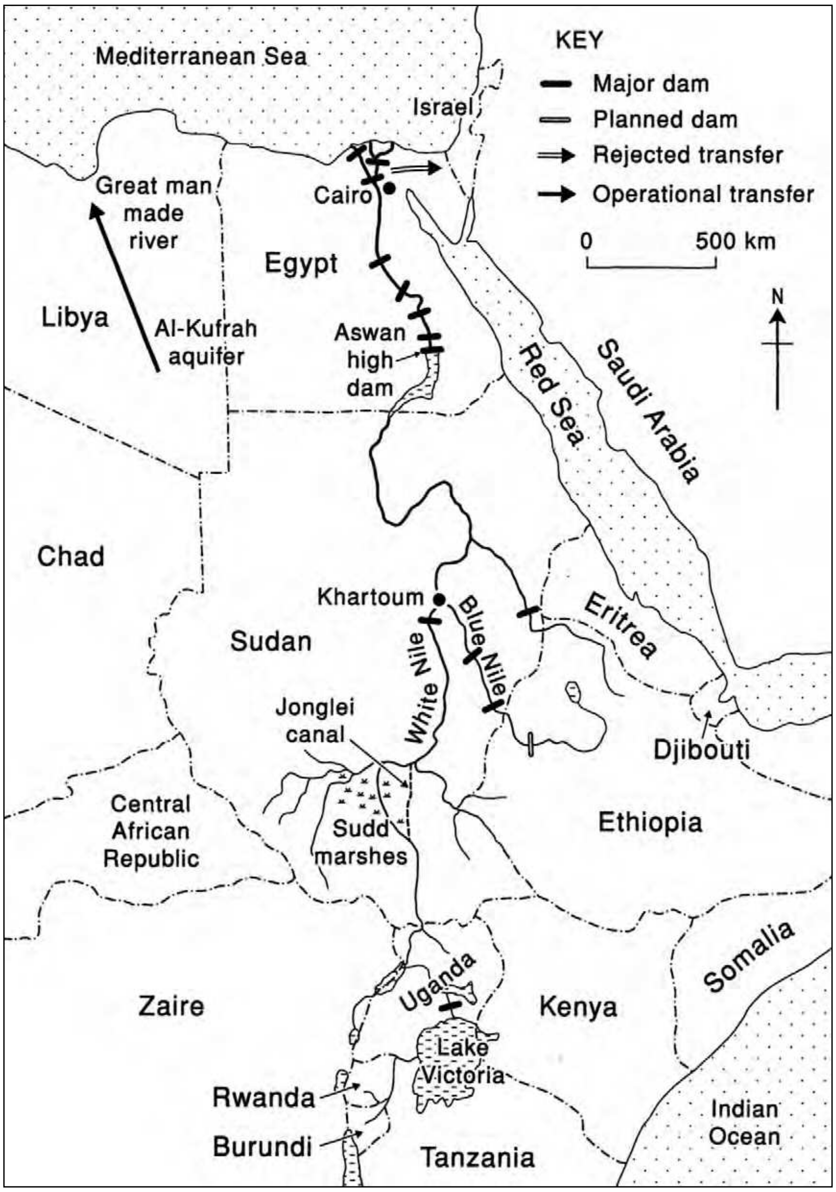
Plate 35 The major river basins of Africa



Source: Aaron T. Wolf et al., 1999; Revenga et al., *Watersheds of the World*, World Resources Institute (WRI), Washington DC, 1998; Philippe Rekacewicz, *Atlas de poche*, Livre de poche, Librairie générale française, Paris, 1996 (revised in 2001).

http://maps.grida.no/go/graphic/major-river-basins-of-africa

Plate 36 The Nile Basin



Jones, 1997, p. 335

Plate 37 Open waterhole

Siekmann, 2002, Zimbabwe

Plate 38 Access to safe water and sanitation in SADC countries

SADC Country	Population in the year 2000 (millions)	Proportion urbanised (%)	Access to safe water (%)		Access to sanitation (%)	
			Urban	Rural	Urban	Rural
Angola	12.903	31	69	15	34	8
Botswana	1.639	64	100	91	91	41
Democratic Republic of Congo	52.046	29	37	23	23	4
Lesotho	2.156	25	65	54	53	36
Malawi	10.778	14	80	32	52	24
Mozambique	19.980	35	17	40	53	15
Namibia	1.739	37	87	42	77	32
South Africa	43.265	49	80	40	79	50
Swaziland	0.928	32	61	44	66	37
Tanzania	33.744	25	67	45	74	62
Zambia	9.191	43	64	27	75	32
Zimbabwe	13.109	43	90	69	90	42
Total	201.478					

Ashton/Ramasar, 2002, p. 222

Plate 39 Broken Afridev pump

http://www.wateraid.org/documents/plugin_documents/indicatorswatermalawia.pdf

Plate 40 Afridev pump with fence

Siekmann, 2006, Malawi

Plate 41 Missing tap

Siekmann, 2006, Malawi

Plate 42 Afridev pump, secured with lock and chain

Siekmann, 2006, Malawi

Plate 43 **Different approaches, exemplified on the sanitation sector**

Poster seen in the Ministry of Water Development in Lilongwe, 2005

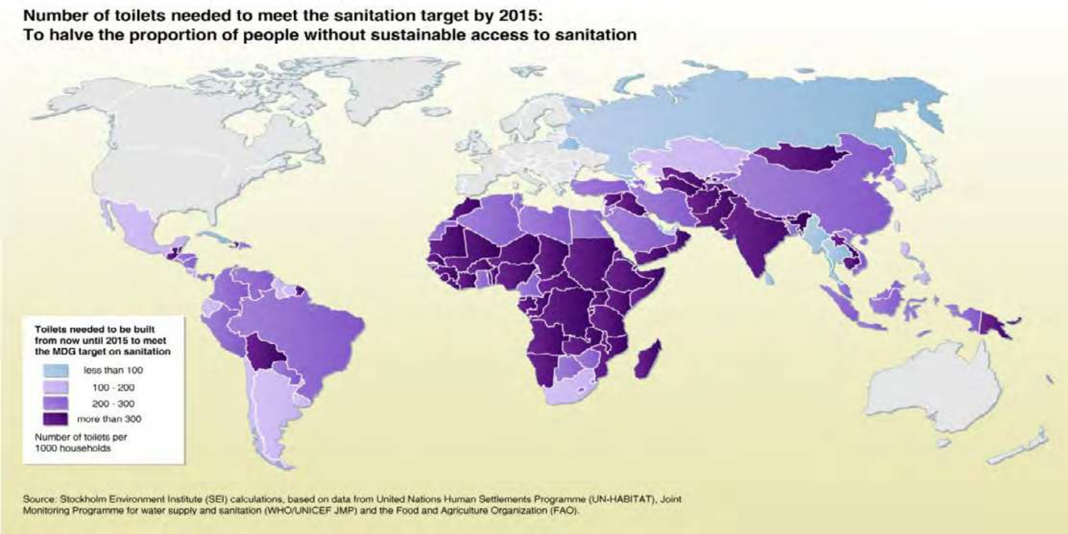
Plate 44 Different expectation of the users concerning the applied technology

Poster seen in the Ministry of Water Development in Lilongwe, 2005

Plate 45 Anti-AIDS/HIV campaign in Lilongwe/Malawi

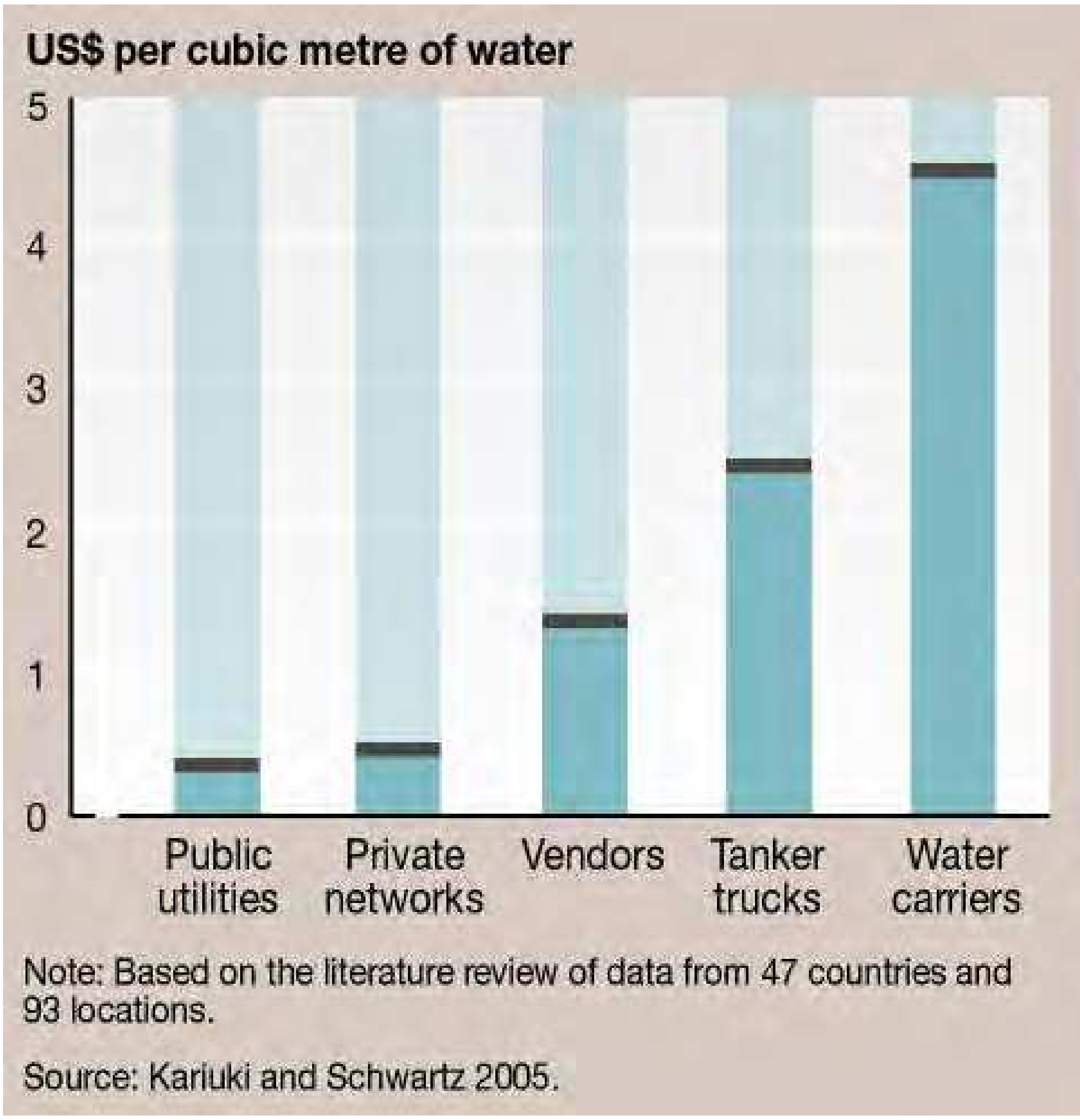
Siekmann, 2006, Malawi

Plate 46 **Number of toilets needed to meet the sanitation target by 2015**



http://maps.grida.no/go/graphic/toilets_needed_to_meet_the_mdg_sanitation_target_by_2015

Plate 47 **US $per cubic meter of water**



http://maps.grida.no/go/graphic/public-services-provide-cheaper-water

Plate 48 Efficiency of irrigation systems (example from California)

System	Cost in US $per ha	Input of hours per ha	Efficiency	Global distribution
Surface irrigation			**45%**	**90%**
Flooding	700	30		
Border strip irrigation	1.150	12		
Furrow irrigation	1.000	35		
Sprinkler irrigation			**70%**	**9%**
Carrousel, linear move	1.050–1.150	3		
Fixed sprinkler	2.650	5		
Drip or micro irrigation			**85%**	**1%**
Above surface	1.850	10		
Subsurface	1.950	10		

compiled from various sources

Plate 49 Irrigation by flooding

Lükenga, 1996, California

Plate 50 Sprinkler irrigation linear move (older system)

Lükenga, 1996, California

Plate 51 Sprinkler irrigation linear move (modern system)

Lükenga, 1996, California

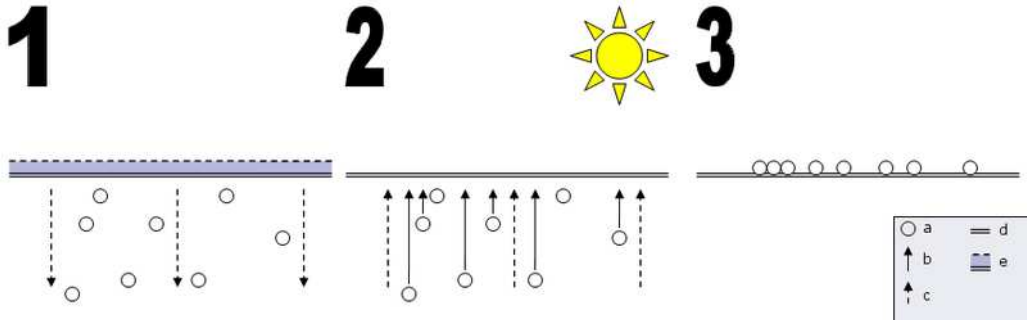
Plate 52 Feeder system for modern linear move

Lükenga, 1996, California

Plate 53 Drip irrigation of a citrus orchard yard

Lükenga, 1996, California

Plate 54 **Salinity from irrigation**



http://en.wikipedia.org/wiki/File:Salinity_from_irrigation.png

1: By irrigation, the water seeps into the floor and loosens salt.

2: Sunshine lets the water evaporate on the ground. Capillary power raises water with released salt to the surface.

3: Salt deposits on the surface and accumulates to a salt bed.

a: salt

b: way of the salt

c: way of the water

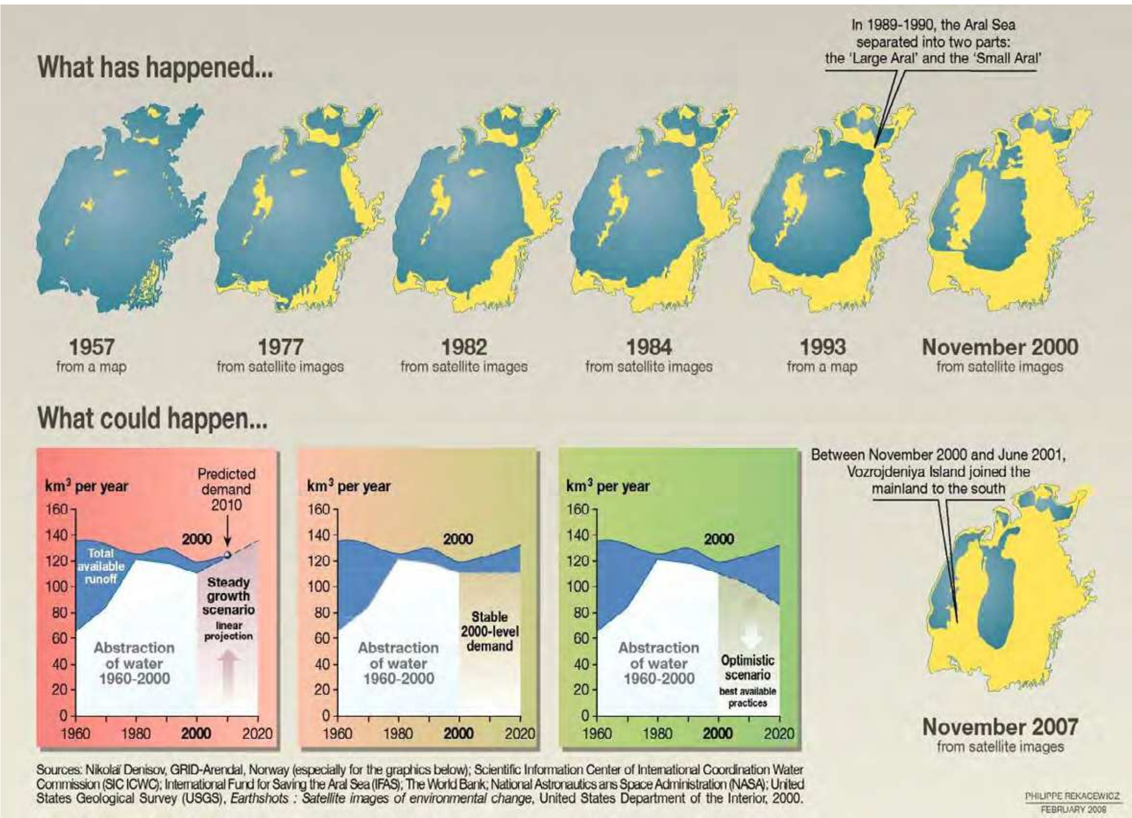
d: dry ground

e: watered ground

Irrigated saline land with poor crop stand

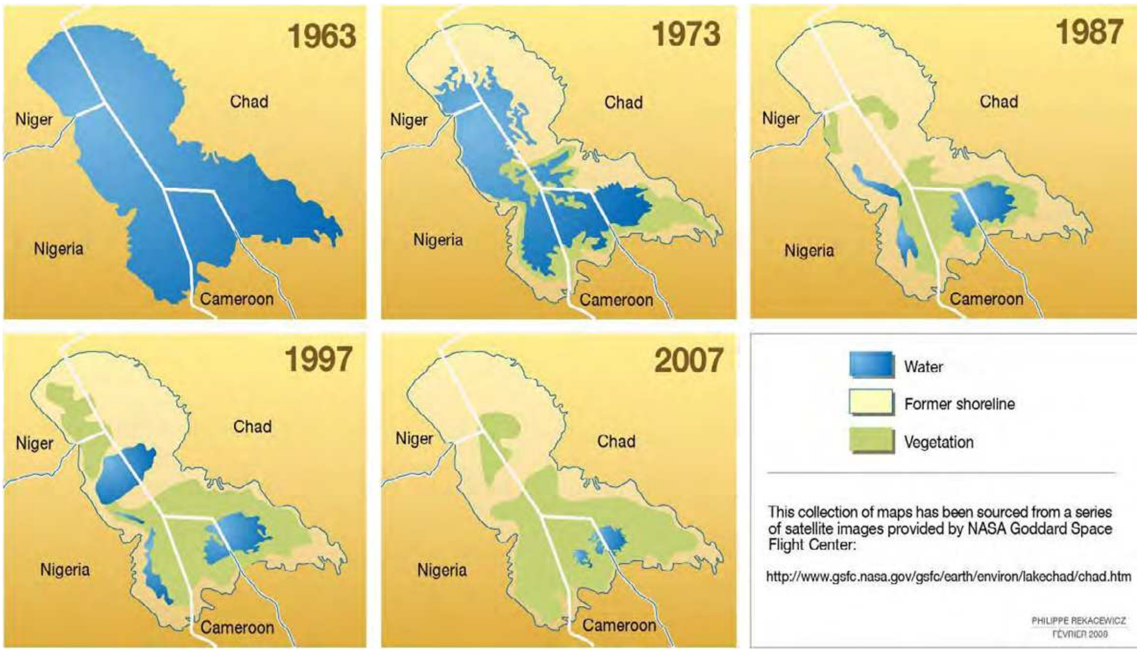
http://en.wikipedia.org/wiki/Soil_salinisation#Drainage_systems

Plate 55 The disappearance of the Aral Sea



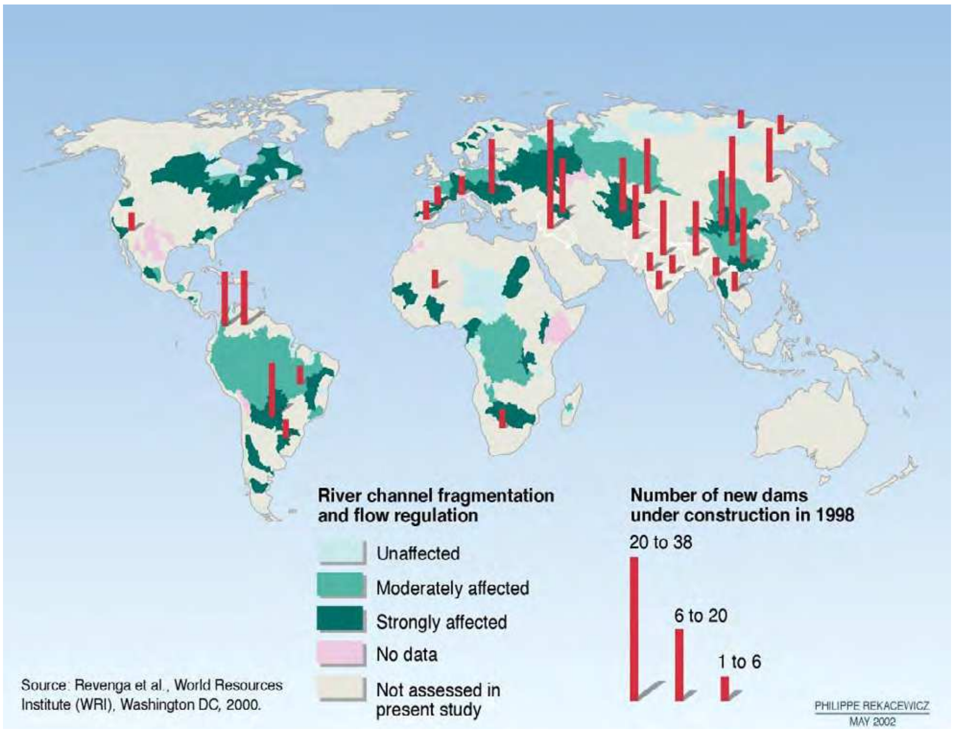
http://maps.grida.no/go/graphic/the-disappearance-of-the-aral-sea

Plate 56 Lake Chad: almost gone



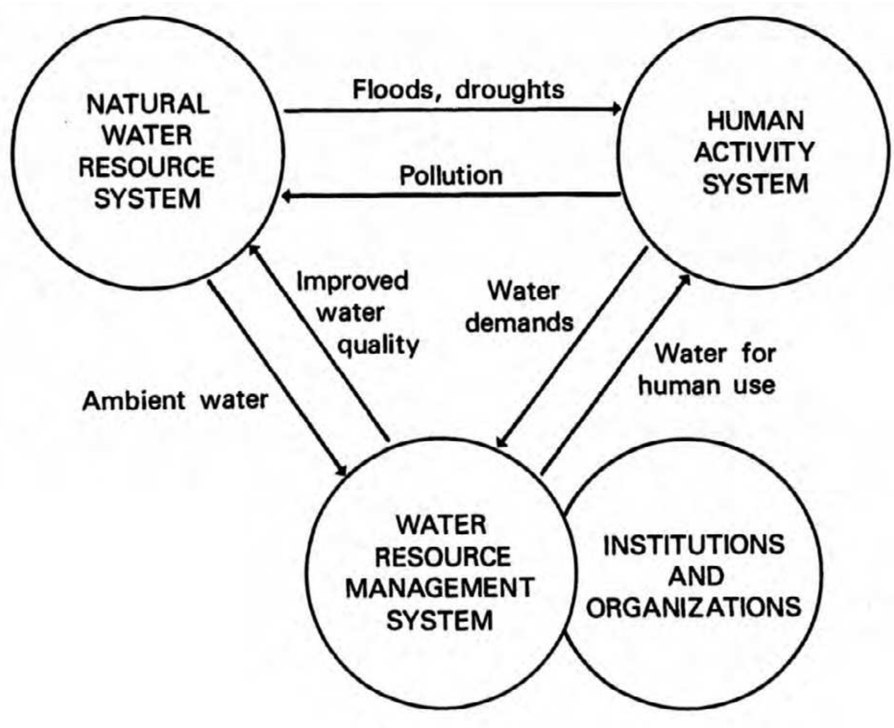
http://maps.grida.no/go/graphic/lake-chad-almost-gone

Plate 57 **Damming the world**



http://maps.grida.no/go/graphic/damming-the-world

Plate 58 The framework for integrated water resource management



Jones, 1997, p. 343

Plate 59 Integrated watershed management: rationale, implementation and problems

Rationale major aims	Implementation stages of development	Problems common causes of failure
1. Treating watershed as a functional region with interrelationships between water and land management	1. Establishing watershed management objectives	1. Lack of local participation
2. Evaluating the bio-physical linkages of upstream and downstream activities	2. Formulating and evaluating alternative resource management actions, involving institutional structures and tools for implementation	2. Inadequate technical support and guidance
3. Enabling planners/managers to consider all relevant facets of development	3. Choosing and implementing a preferred course of action	3. Inadequate management practices
4. Strong economic logic in integration	4. Evaluating performance, i.e. degree of achievement of specific objectives, by monitoring activities and outcomes	4. Delays in key inputs, especially financial
5. Allows ready assessment of environmental impacts		5. Fragmented governmental control structure
6. Can be integrated into other programmes, e.g. forestry and soil conservation		6. Ignoring downstream interests
		7. Inappropriate institutional arrangements
		8. Political boundaries unrelated to catchment boundary

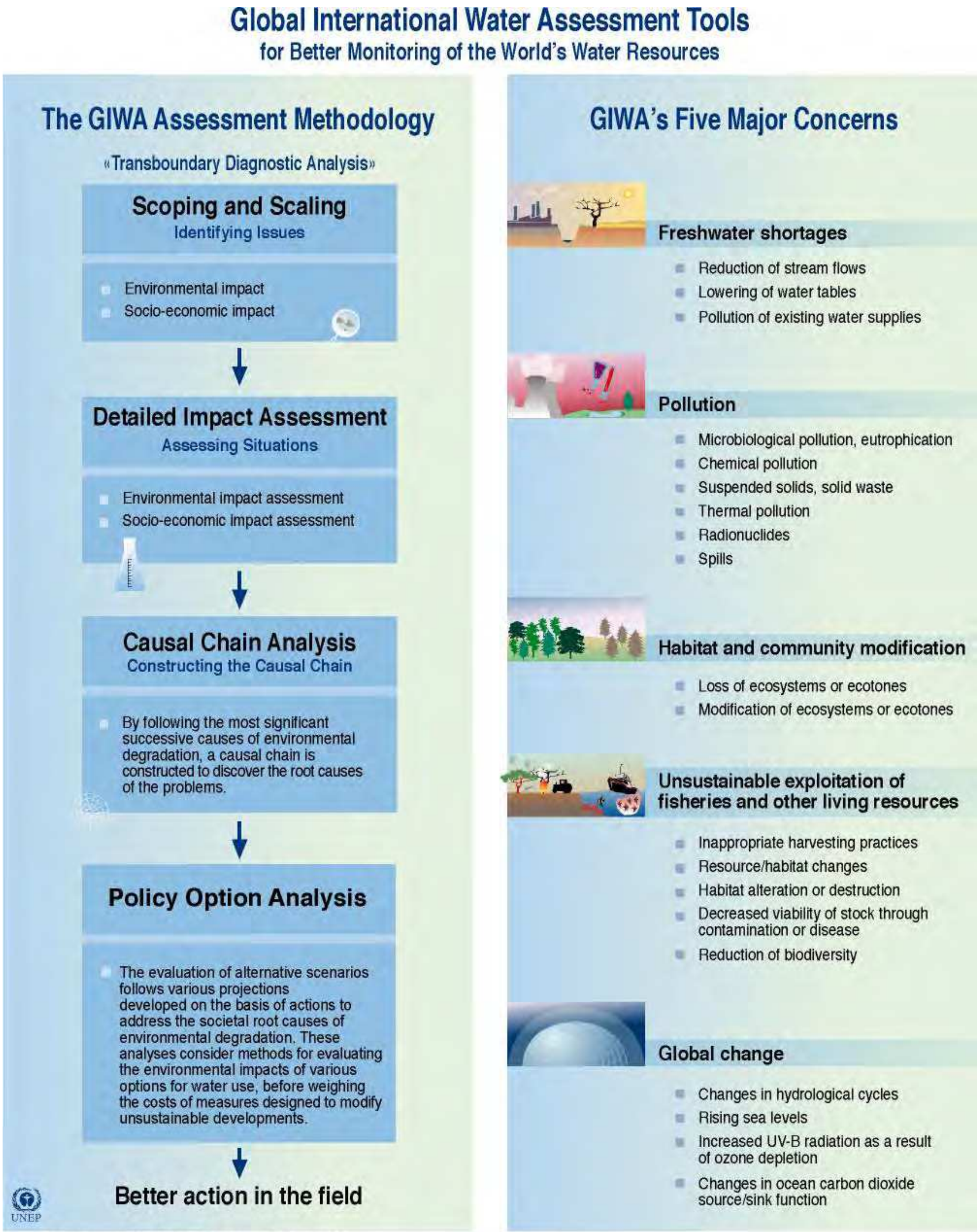
Jones, 1997, p. 343

Plate 60 **Examples of value of integrated water resource management, especially in the Developing Countries**

Problem	Major causes	Implications for integrated management
Groundwater:		
Aquifer depletion, increasing pumping costs, saltwater intrusions on coast	Unsustainable groundwater pumping rates	*Need for conjunctive groundwater–surface water management* Link timing of pumping with status of surface resources Use surplus surface water for artificial recharge
Land subsidence in urban areas	Excessive pumping of groundwater	*Need aquifer-wide regulation of pumping rates* Establish pumping permits, metering and monitoring
Floods:		
Flood risks and damages increased	Rapid urbanization and human occupancy of floodplains	*Need effective land-use planning* Floodplain zoning, flood proofing, evacuation programmes, redevelopment of flood-prone areas
Structural flood controls too expensive		*Emphasize non-structural and low-cost solutions* Use existing field or paved areas as temporary flood storage Create new low-lying areas to do this
Ineffective flood control programmes	Lack of high-level management	*Establish appropriate institutions and integrated flood management for basin*
Urban water supply:		
Many, especially poor, areas not served	Bias towards high-cost technology, shortage of investment funds, unequal distribution of infrastructure	Increase charges to present users Adopt low-cost technology Promote community involvement in management
Unreliable distribution system and high losses	Poor operation and maintenance Faulty metering and billing	Increase water charges to invest in improvements Improve organization and training Community involvement
Urban water pollution:		
Domestic sewage enters water bodies uncollected	No centralized system through lack of funds or perception of need	Low-cost sanitation techniques Community involvement in building and operating sanitation systems
Domestic sewage collected but not treated	Cost of standard treatment	Low-cost treatment like detention basins Wastewater reuse and cost-sharing
Industrial wastewater discharged untreated	Lack of regulatory controls	Recycling Incentives like subsidies for pollution control, effluent charges or fines
Major nonpoint pollution	Lack of regulatory controls Limited community understanding or commitment	Watershed management programme Community involvement in sanitation and clean-up
Centralized sewage collection and treatment too costly	Lack of funds	Low-cost technology Community involvement Cost-sharing, e.g. sewer charges
Existing sewage treatment systems poorly maintained	Lack of funds	Community involvement in operation and maintenance Improving financing, e.g. by taxes

Jones, 1997, p. 344

Plate 61 Global International Waters Assessment Tools



Source : Global International Water Assessment (GIWA), 2001.

http://maps.grida.no/go/graphic/global_international_waters_assessment_tools

Plate 62 An example of the use of biotic indices – the BMWP method

An example of the use of biotic indices – the BMWP method

Organism type	Score
Mayfly nymphs (e.g. *Ephemeridae*) Stonefly nymphs (all families)	10
Damselfly and dragonfly (all families) Freshwater crayfish (*Astacidae*)	8
Cased caddis larvae (all families) Caseless caddis larvae (e.g. *Rhyacophilidae*)	7
Freshwater shrimp (*Gammaridae*) Freshwater limpet (*Ancylidae*)	6
Water bugs (all families) Water beetles (all families) Flatworm (all families)	5
Alderfly larvae (*Sialidae*) Mayfly nymphs (*Baetidae* only)	4
Snails (e.g. *Lymnaediae*) Leeches (all families) Water mites (all families)	3
Fly larvae (*Chironomidae* only)	2
True worms (all families) Fly larvae (e.g. *Culicidae*)	1

In the above table a particular family of a species is identified in some cases, e.g. the two types of fly larvae. This is indicative of how sensitive different families are to the presence of pollution.

Assume that a sample of water and sediment is taken from the bottom of a lake. The species found in this sample together with their respective scores are shown below:

Mayfly nymphs from the *Ephemeridae* and *Baetidae* families	10 and 4
4 types of stonefly nymphs	$10 \times 4 = 40$
Freshwater crayfish	8
1 type of cased caddis larvae	7
Freshwater shrimps	6
3 types of snails	$3 \times 3 = 9$
Fly larvae from the *Culicidae* family	1

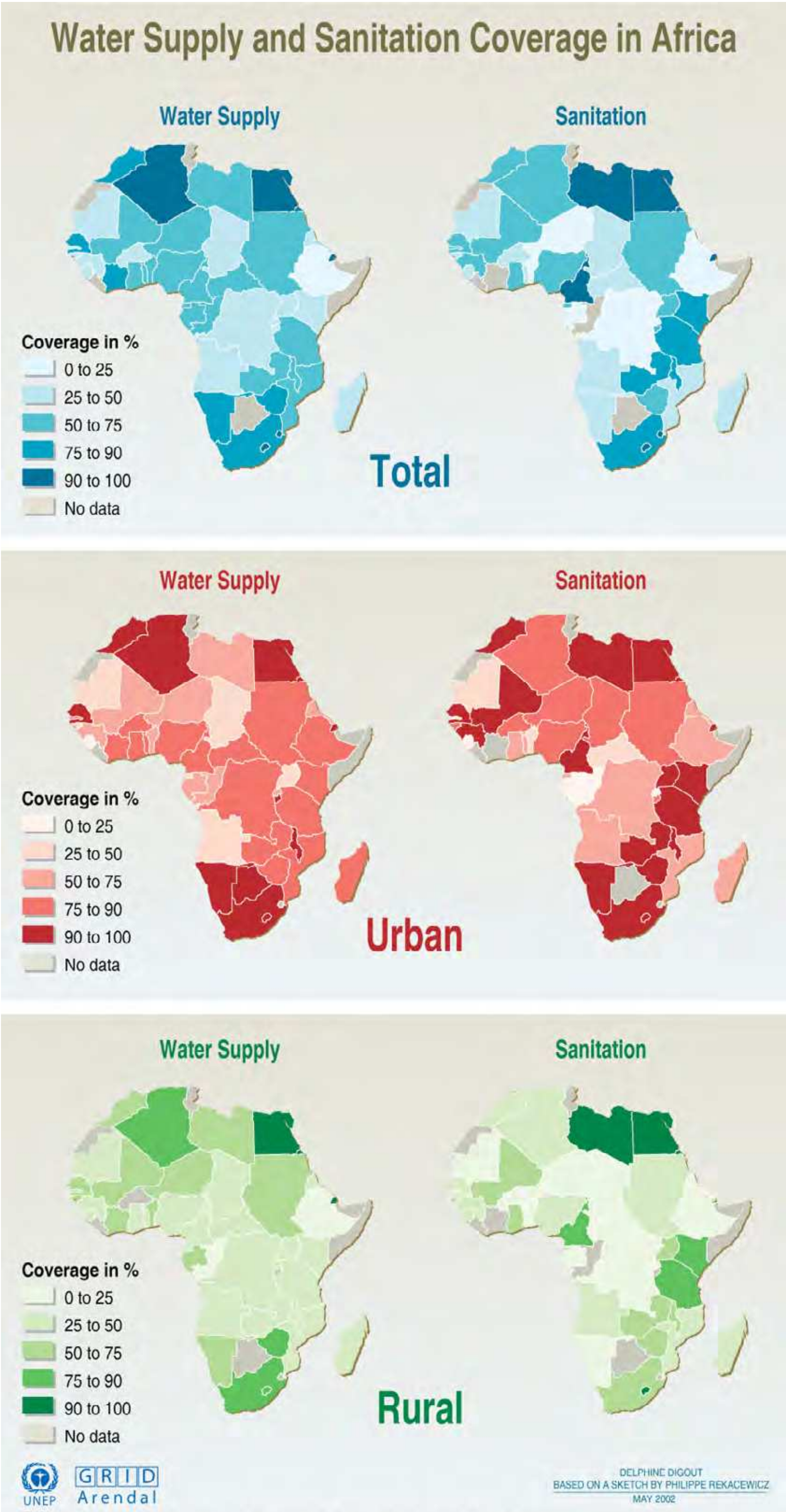
The total score is therefore $10 + 4 + 40 + 8 + 7 + 6 + 9 + 1 = 85$

Such a high score would indicate that the water was clean.

The above shows how biotic indices may be used to calculate an overall score. There are other types of biotic indices apart from the one listed here.

Wright, 2003, p. 312

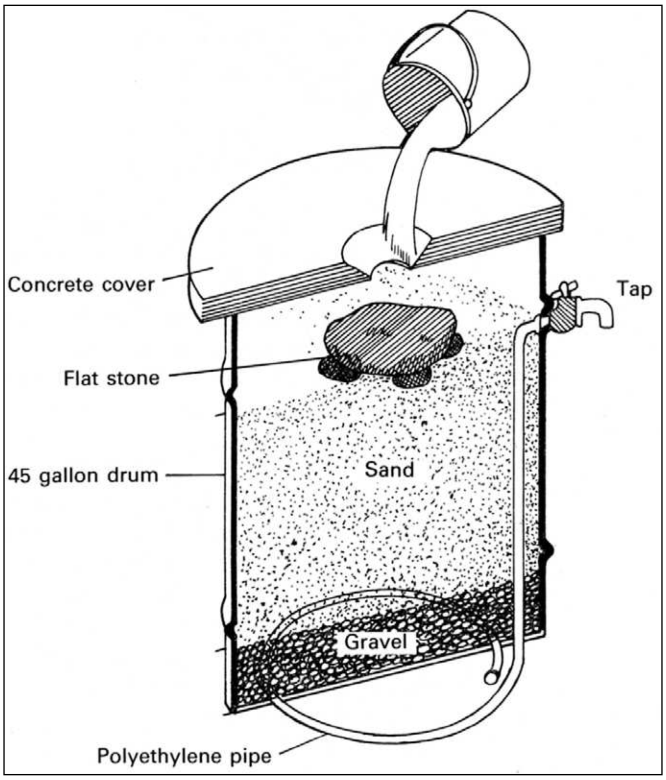
Plate 63 Water Supply and Sanitation Coverage in Africa



Source: *Global Water Supply and Sanitation Assessment 2000 Report.*

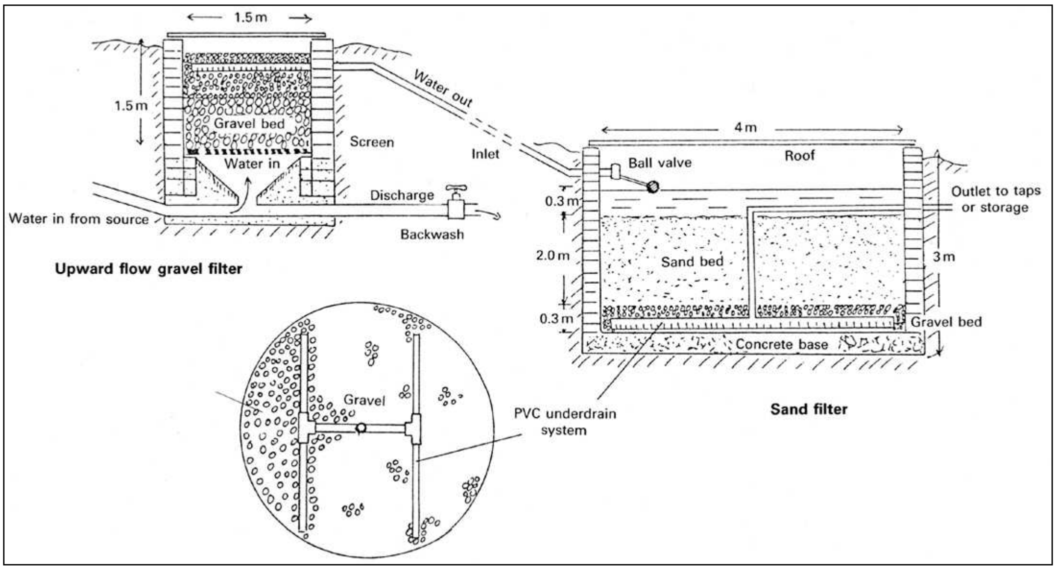
http://maps.grida.no/go/graphic/water-supply-and-sanitation-coverage-in-africa

Plate 64 Family sand filter



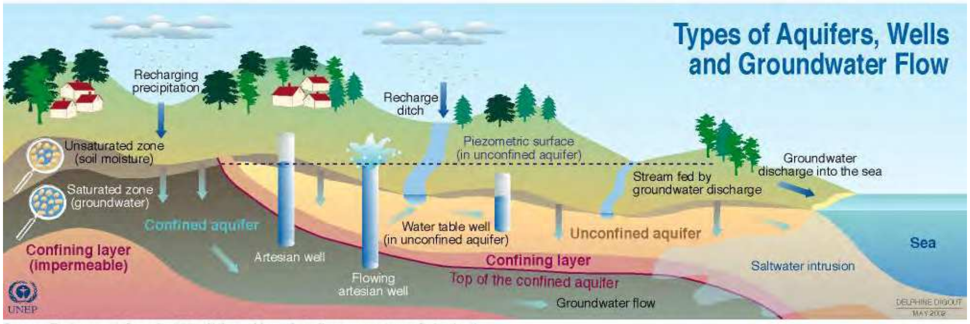
Morgan 1990, p. 259

Plate 65 A community sand filter



Morgan, 1990, p. 262

Plate 66 Groundwater: aquifers, wells and circulation



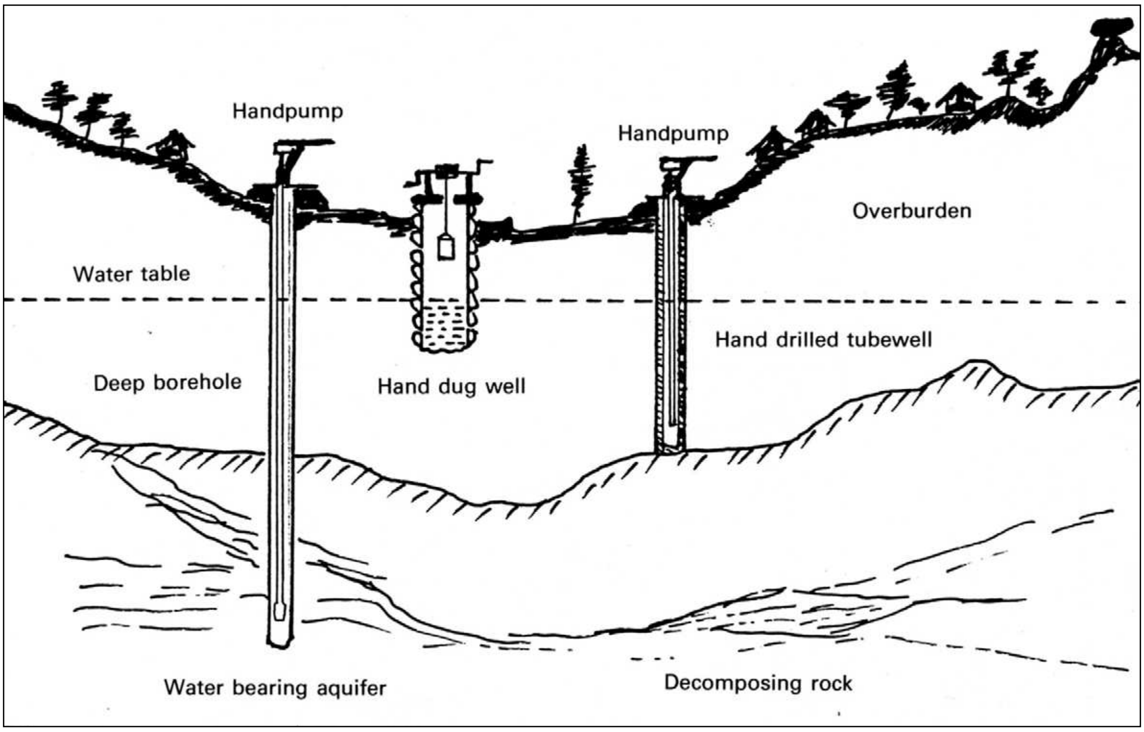
Source: Environment Canada, 2001 (Adapted from: http://www.ec.ca/water/index.htm).

http://maps.grida.no/go/graphic/groundwater_aquifers_wells_and_circulation

Plate 67 Unprotected well

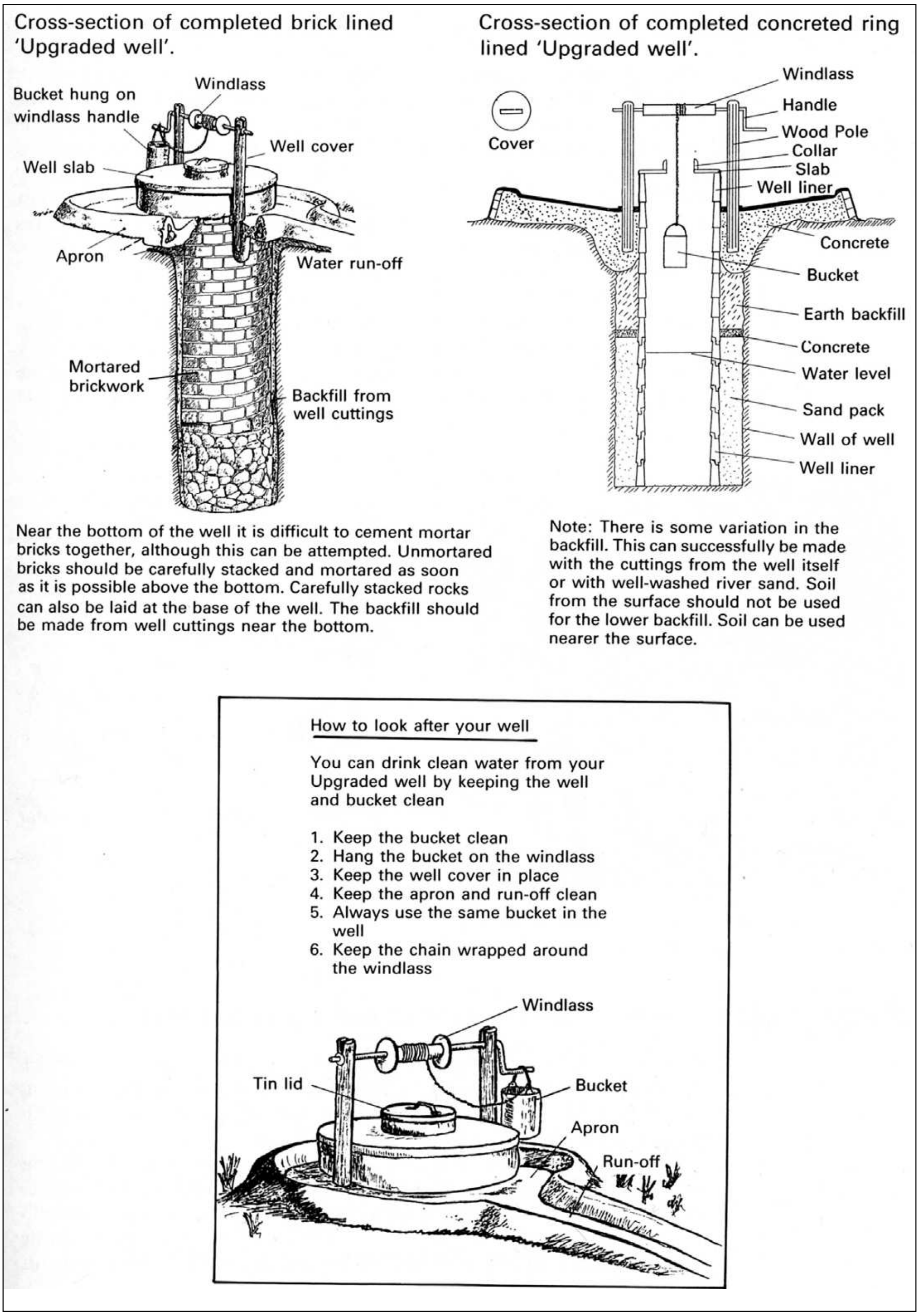
Siekmann, 2006, Malawi

Plate 68 Methods of tapping groundwater



Morgan, 1990, p. 14

Plate 69 Cross section of an upgraded well

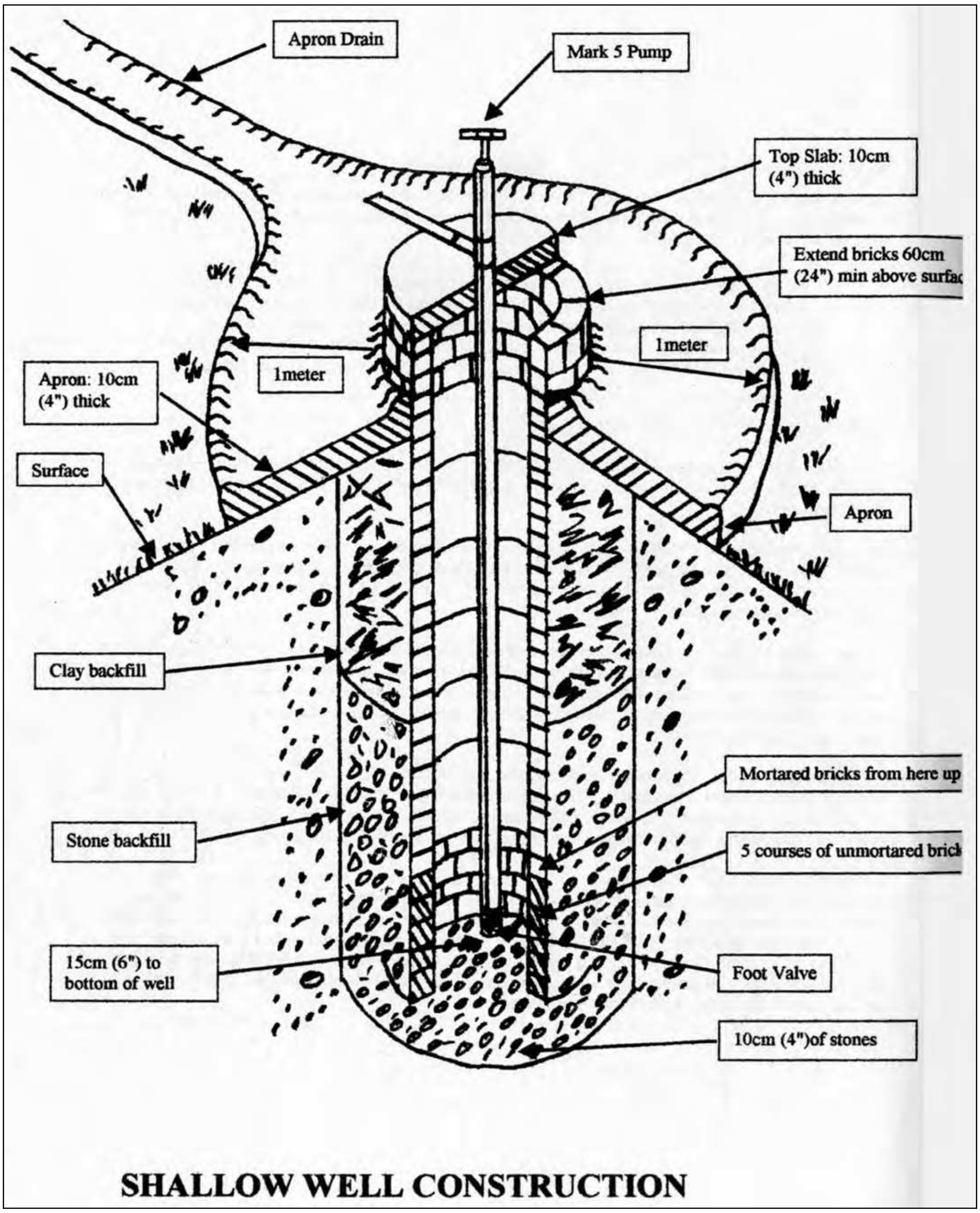


Morgan, 1990, p. 41

Plate 70 **Protected well with windlass**

Lükenga, 1994, Zimbabwe

Plate 71 Cross section of a shallow well

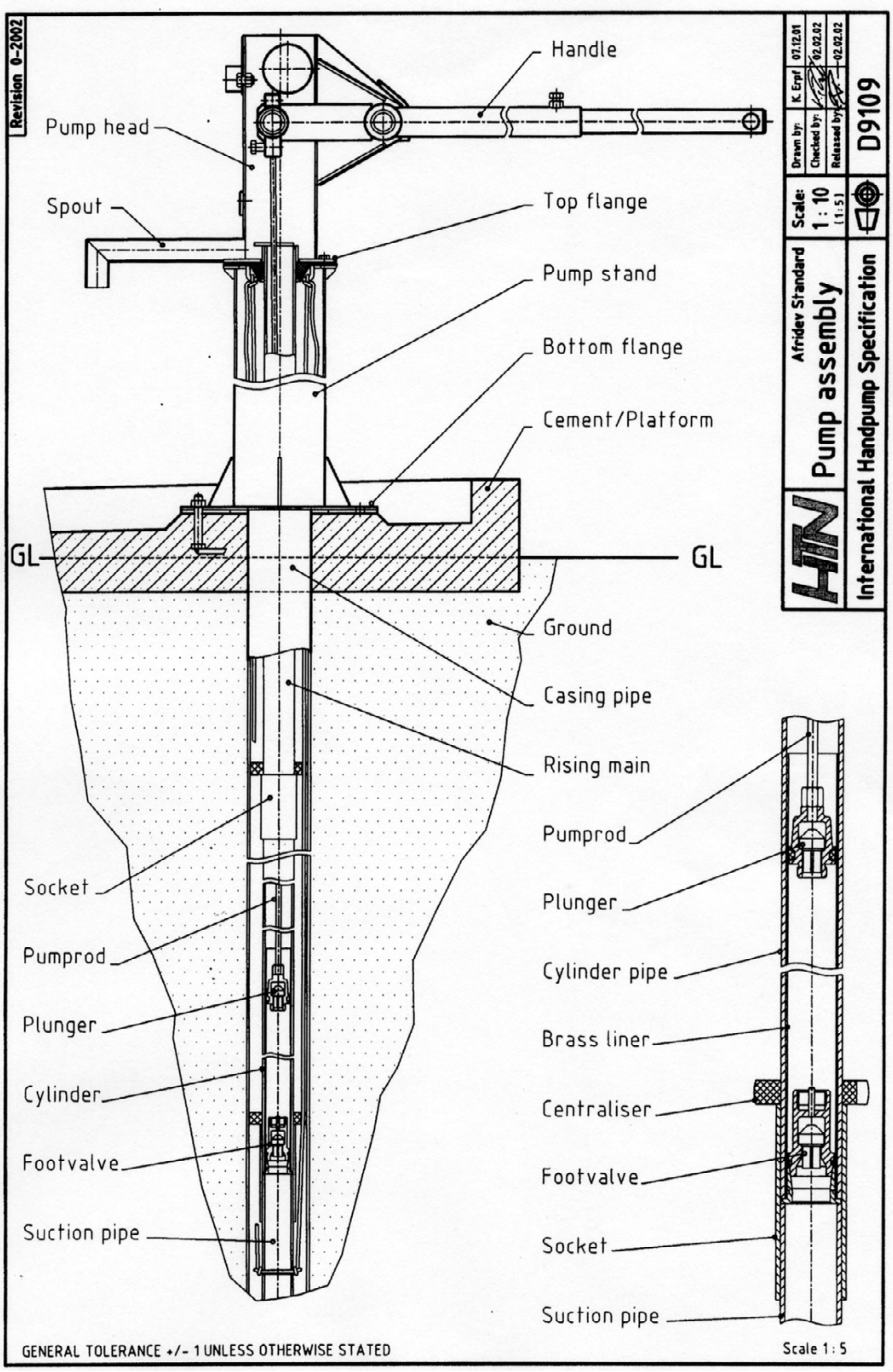


Synode of Livingstonia & Marion Medical Mission, 2001, p. 11

Plate 72 Afridev pump on borehole

Siekmann, 2006, Malawi

Plate 73 Cross section of an Afridev pump



SKAT Foundation, 2002, p. 5

Plate 74 Model of a Mark V pump

Siekmann, 2003, Malawi

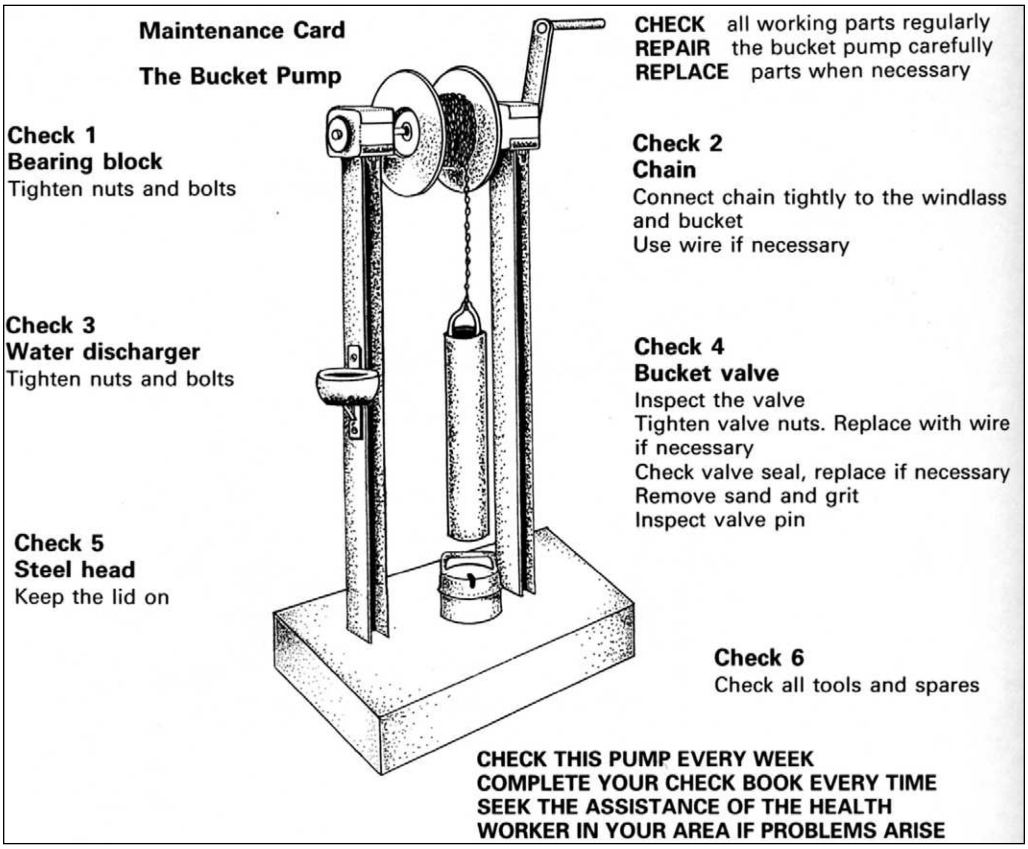
Plate 75 Mark V pump on a shallow well

Siekmann, 2003, Malawi

Plate 76 Bush pump

Lükenga, 1994, Zimbabwe

Plate 77 Bucket pump



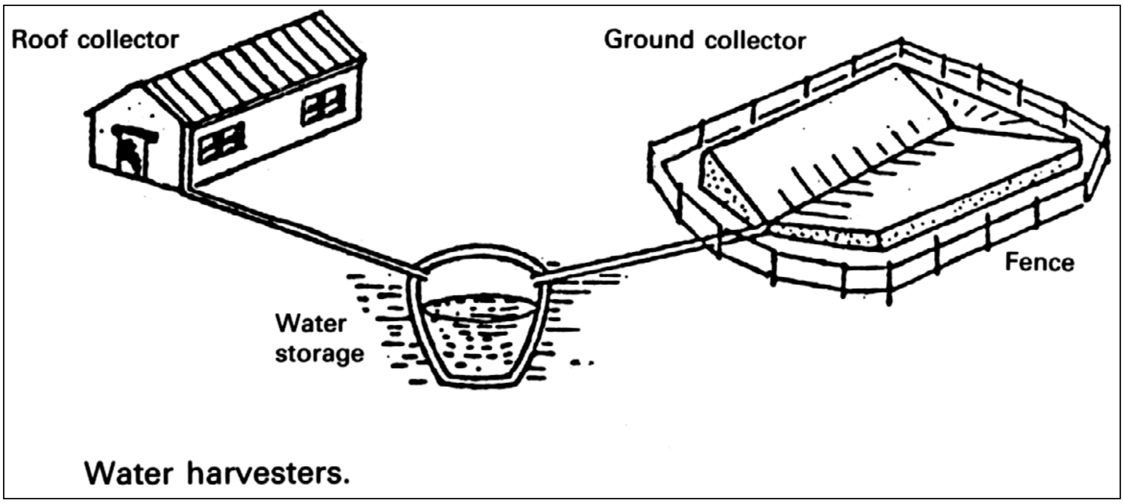
Morgan, 1990, p. 108

Plate 78 Bacteriological quality of water taken from wells

Source	Mean number of Escherichia coli Bacteria per 100 ml
Open water holes	> 1.000
Poorly protected wells	266
Upgrade wells	65
Bucket pump	23
Blair pump	26
Bush pump or Afridev pump	6
European standard of drinking water	0

Morgan, 1990, p. 253

Plate 79 Rain water harvesting

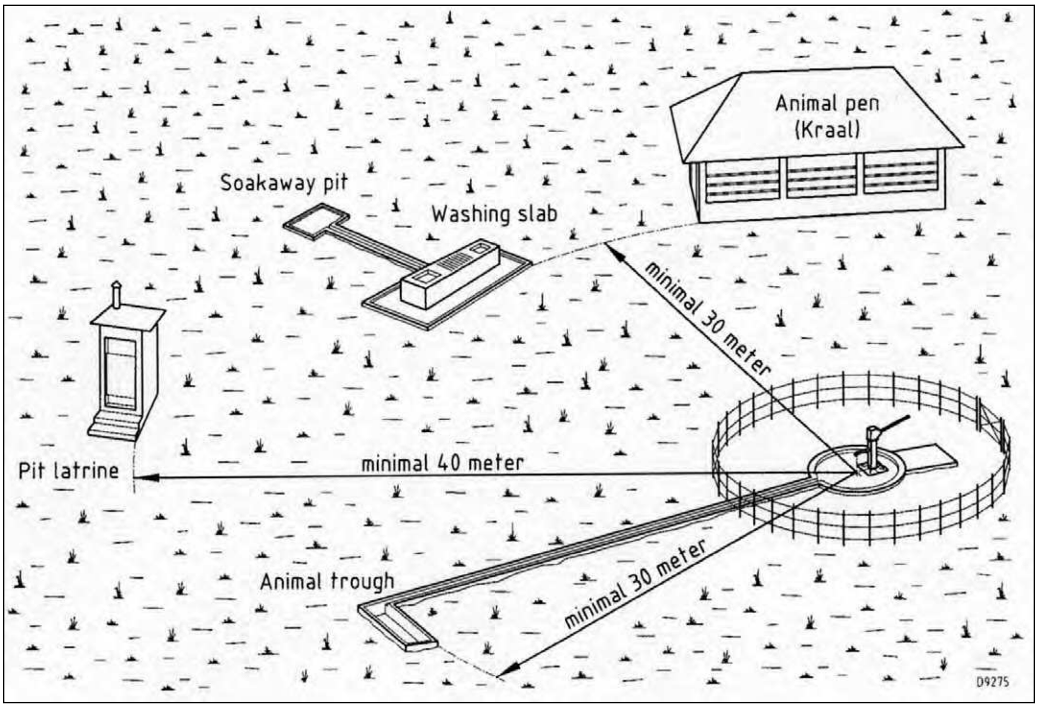


Morgan, 1990, p. 225

Plate 80 Water point with unhygienic surrounding

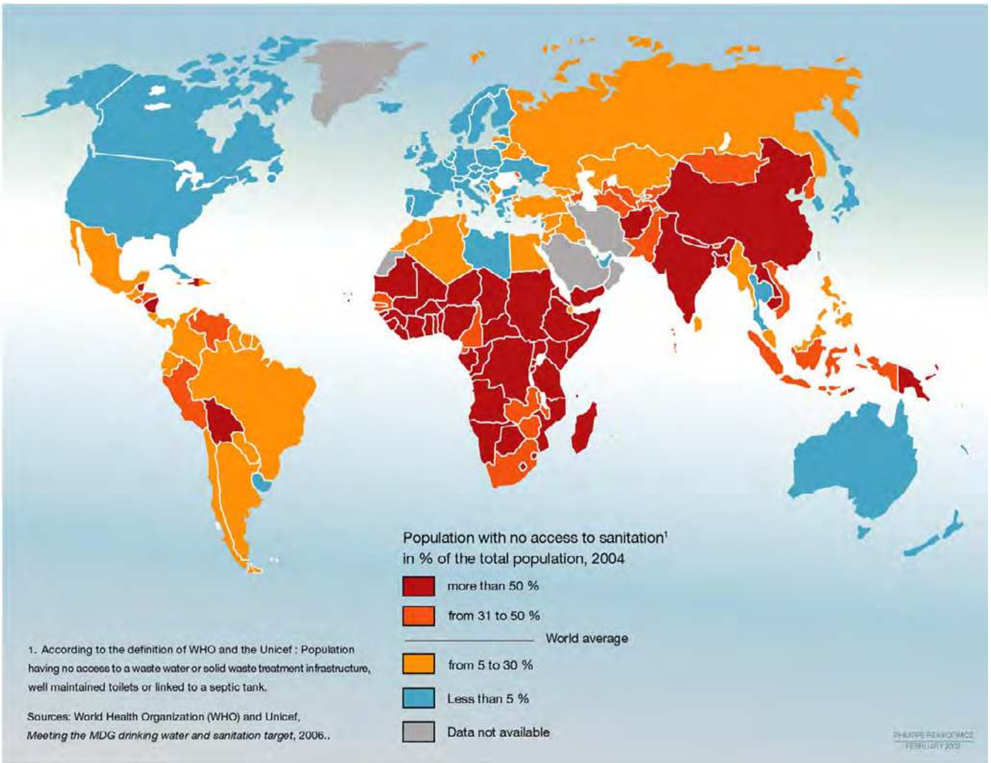
Siekmann, 2006, Malawi

Plate 81 Ideal localization of a water point



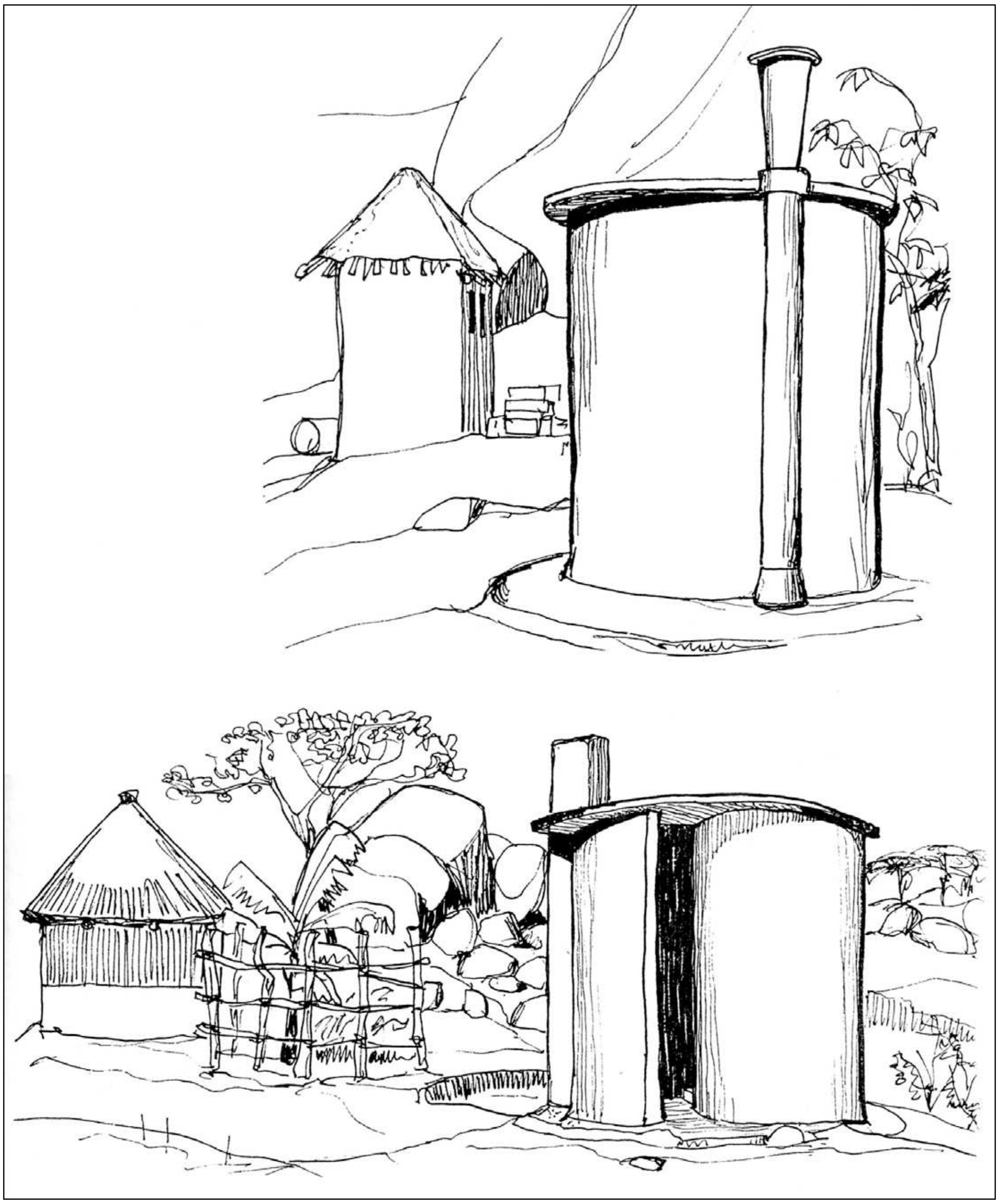
SKAT Foundation, 2002, p. 10

Plate 82 Access to sanitation in 2004 (total population)



http://maps.grida.no/go/graphic/total-population-access-to-sanitation

Plate 83 The Blair latrine in its natural habitat

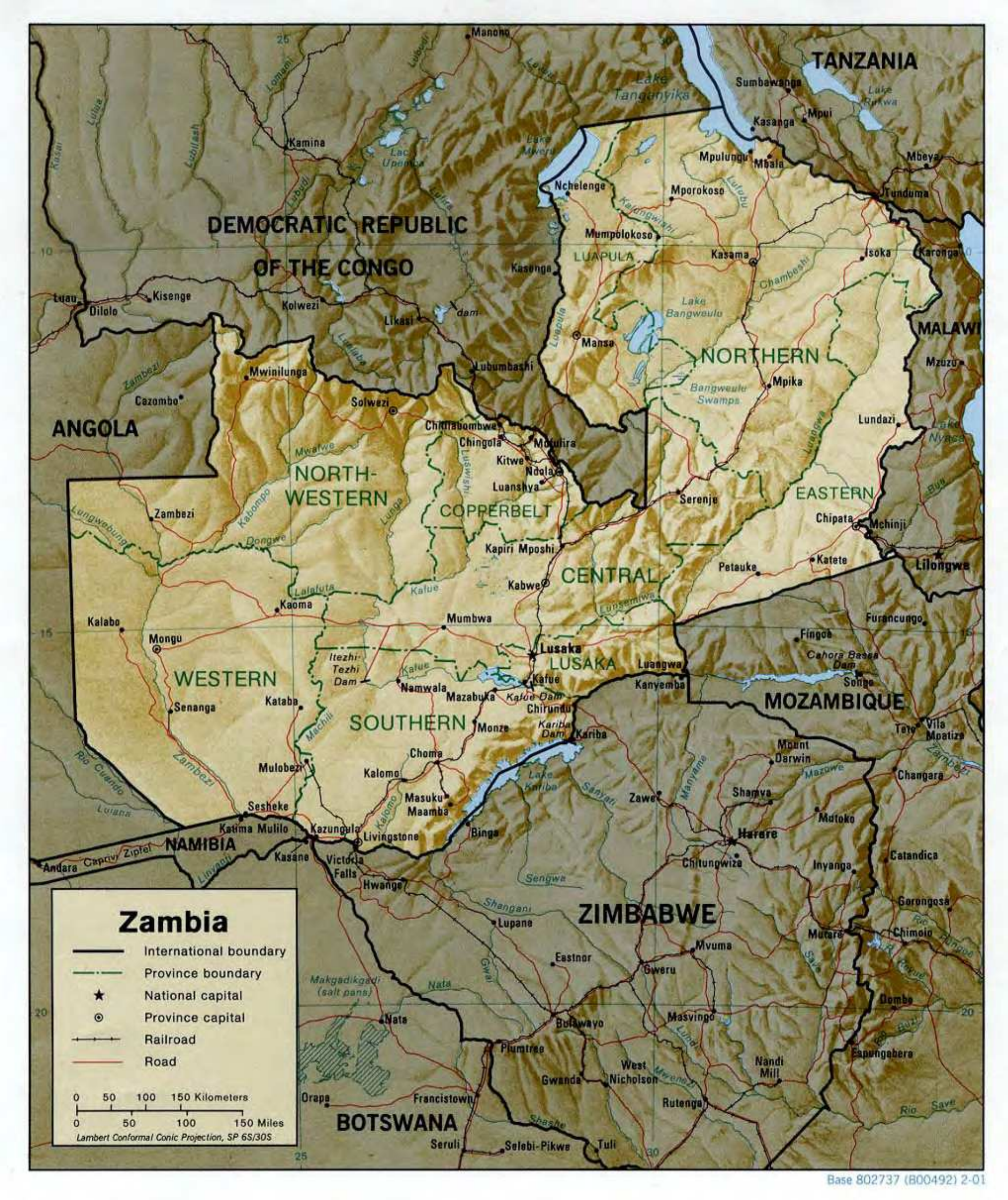


Morgan, 1990, p. 305

Plate 84 Operation and maintenance: making water supply and sanitation a sustainable reality

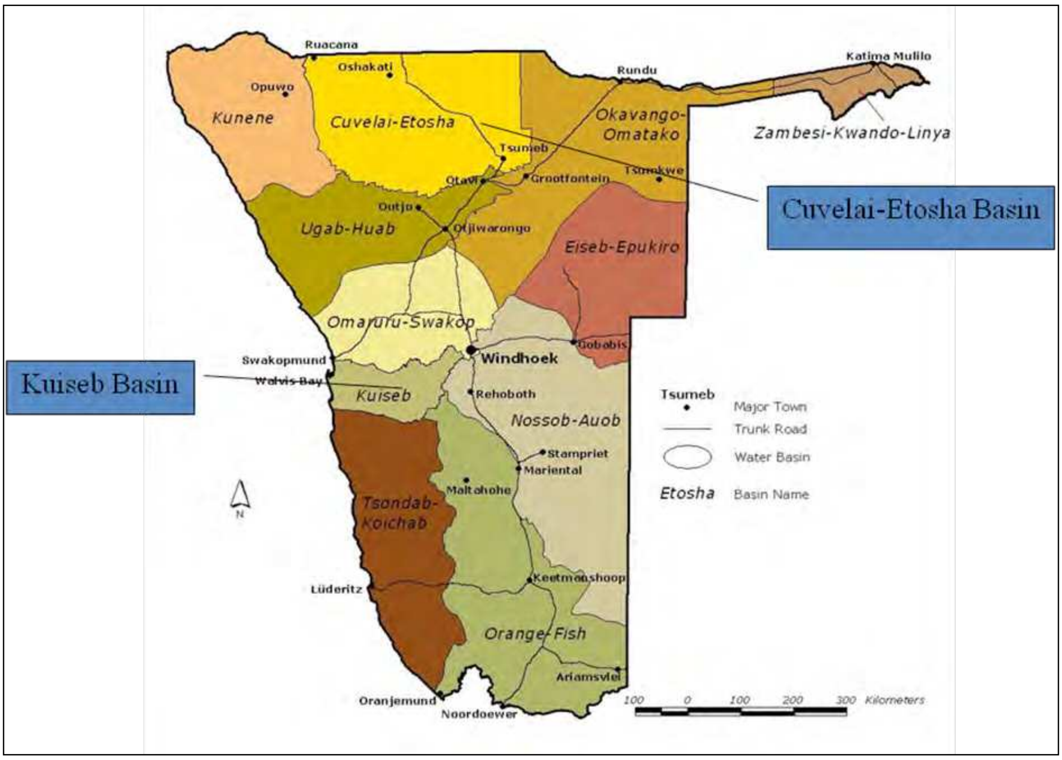
http://www.who.int/docstore/water_sanitation_health/wss/o_m.html

Plate 85 Topographic map of Zambia



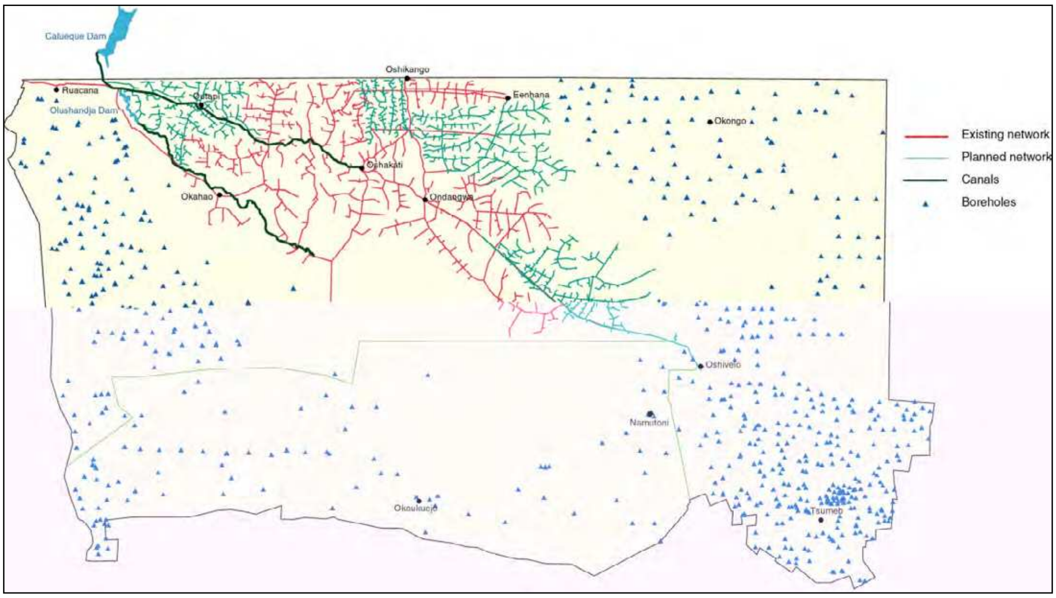
http://www.lib.utexas.edu/maps/africa/zambia_rel01.jpg

Plate 86 Localisation of Cuvelai-Etosha Basin



Amakali, 2003, p. 37

Plate 87 Cuvelai water supply system



Amakali, 2003, p. 10

Endnotes

1. The information refers to the situation on the Northern Hemisphere (Europe), where the temperatures rise in spring (March to May) and decrease in autumn (September to November).
2. http://www.unwater.org/publications/publications-detail/en/c/210593/
3. http://www.unesco.org/bpi/wwap/press/