# The Water Challenge[1]

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## *1. Characteristics of the water challenge*

There has been much talk about a "world water crisis" among water experts for several decades now and among policymakers and the public at large for the last five to ten years. What is this crisis? Is the world running out of water? Has there not been enough investment to make water available to people? In the twentieth century there has been massive investment in water resources development[3]. The world population tripled in the last century, but water use[4] grew six-fold. The governments of the United States and Australia, for example, constructed some five thousand cubic meter of water storage infrastructure for each and every of their citizens. Most of this infrastructure is meant to produce hydro-electricity and to irrigate farm land, while some is meant to control floods and store water for domestic water supply for urban areas. Even more money has been invested in water distribution infrastructure, treatment plants, sewerage and waste water treatment. Water resources development has been a major part of the investments in

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[3] A rough estimate of the annual investments in the water sector around the turn of the century was 70-80 billion US$/year (Cosgrove and Rijsberman, 2000). That was estimated to be considerably below the high point of irrigation subsector investments in the 70s and 80s.

[4] That is, the use of renewable water resources (i.e. the water flowing in rivers plus the annual recharge into groundwater aquifers which is roughly 40% or 40 thousand cubic kilometers of annual rainfall) for human purposes grew to about 4 thousand cubic kilometers in the year 2000.

developing countries – a key component of bilateral aid, World Bank lending, and domestic investment – and the subject of a water supply and sanitation investment drive called "the water decade" in the 1980s. With all this investment, why is there still a crisis?

For many people "the water crisis" is defined by the lack of access to safe and affordable water for over a billion people and lack of access to safe and affordable sanitation for close to half the world population. As a result poor people suffer diarrhoeal diseases that kill some two million people each year, over ninety percent children under the age of five. For others, the crisis is that poor and malnourished people in rural areas do not have access to water to grow their food and sustain their livelihoods. Some three quarters of the 1.2 billion poor and the 800 million malnourished people in the world live in rural areas, with subsistence agriculture as their sole or primary source of food and income There is clearly enough water in the world for domestic purposes, industry and even to produce food, but these water resources are distributed very unevenly and there are large, densely populated areas that have either scarce water resources, or water falling very unevenly during the year[5]. In these areas, making water available requires considerable investments. The problem is not so much that there are no water resources, but that the unserved do not have access to capital (financial or political) to make it available to them. In short, both urban and rural poor people that do not have access to safe and affordable drinking water and sanitation are exposed to severe health risks, and people in rural areas that do not have access to water for productive purposes tend to be poor and malnourished. Providing access to poor people for domestic and productive purposes is the challenge addressed in this paper.

The total amounts of water required for domestic purposes are small, compared to the water required for other basic needs. Poor people that do not have washing machines, cars to wash or gardens to water need twenty to fifty liters of water per person per day for domestic purposes. People in Europe generally use some two hundred liters per person per day while in the United States this is about four hundred liters. In addition, all these people require thousands of liters of water per day to produce their food, depending on their diet and lifestyle. To produce one kilogram of cereal grains requires about one cubic meter ($m^3$), or a thousand litres, of crop evapotranspiration[6]. However, one kilogram of meat requires much more water to produce – depending on how much feed[7] is given to the animals versus animals that graze on rainfed pastures. In California for example, about 13.5 $m^3$ of water is used to produce one kilogram of beef. Renault and Wallender (2000) estimate that a typical diet of a person from USA requires about 5.4 $m^3$ water in the form of evapotranspiration. On the other hand a vegetarian diet with approximately the same nutritional value is responsible for the consumption of 2.6 $m^3$ of water per day. In other words, it takes roughly seventy[8] times more water to grow food for people than

[5] In monsoon Asia up to 90% of the annual rainfall comes in several large rainstorms in less than 100 hours – leading to the risk of floods at some periods and severe drought during a large part of the year.
[6] Evapotranspiration is a measure of the amount of water consumed during the growing process of plants, either transpired through the plants' stomata or evaporated directly from the soil.
[7] For instance animal fodder grown under irrigated conditions.
[8] Based on a domestic requirement of 50 litres per person per day and a food requirement of 3,500 litres per person per day.

people use directly for domestic purposes[9] . In addition, the large majority of the water provided to people for domestic purposes (up to 90%) is returned after use as wastewater and can be recycled, while most of the water provided to agriculture to grow food (40 to 90%) is consumed (evapotranspirated) and cannot be re-used.

The water supply and sanitation challenge has everything to do with providing reliable and affordable "water services", but for all but the largest cities and their immediate environment, it has little to do with the development and management of water resources. Scarcity is not the issue for all but the largest cities in dry areas[10]. The water for productive purposes challenge, or water for food as we shall call it from here on, has the potential to use all the water in a river basin (or "dry up rivers"). There is, then, no real competition for water between domestic water supply and other uses, both because the amounts involved are small and because water for domestic purposes is of such high value and clear priority that it takes precedence over other uses[11]. Cities do tend to have a major impact on the water sources in their immediate vicinity. Rivers running through cities often come out severely polluted. An environmental success story in developed countries is that the investments in waste water treatment have by and large solved this problem, but most cities in developing countries still cause massive water pollution.

There is real competition in quantitative terms for water resources among other uses, particularly water for agriculture and water for the environment. The enormous investments in water resources development, in developed countries and in Asia, have led to rivers running dry or not reaching the sea anymore and to groundwater levels falling as much as a fifty to a hundred meters in key aquifers. The water resources that are "developed" for agriculture were not "wasted" before their development[12]. Inland water systems, such as wetlands lakes and river floodplains, forests, grazing lands and coastal ecosystems all provide environmental good and services in their natural state that are

[9] And roughly one thousand times more than people need drink. What complicates matters is that roughly sixty percent of the world's food grains are grown under rainfed conditions. This also uses water, but since this is rainfall that enters into the soil and is directly evapotranspirated back into atmosphere without entering the surface water (rivers) or groundwater – this water is not counted in the traditional definitions of the world's water resources. For this reason some authors prefer to refer to the renewable resources in rivers and groundwater as "blue water", and to the rainall that is evapotranspirated directly back into the atmosphere as green water. Blue water is 40% or 40 thousand cubic kilometers of the total hydrological cycle, while green water forms the other 60%.

[10] Such as Los Angeles, where the development of the city was intricately linked to the development of water supplies over large distances, see Kahrl (1982). For those large cities, if they are situated on the coast, the water challenge has been largely solved by the development of desalination technologies that are affordable for developed country economies. Cities such as Singapore and Tampa Bay, Florida, have awarded large contracts for desal plants in recent years that have effectively put the provision of water in the same category as the provision of electric energy.

[11] Globally, roughly 10% of all water diverted for human purposes is used for domestic purposes, 20% for industrial uses and 70% for agriculture. In the developed countries the amount used for industry is higher (up to 50% in Europe) both because agriculture plays a smaller role in the economy and because agriculture in temperate zones needs less irrigation, i.e. uses more green water and less blue water. The water used for industrial purposes is dominated by cooling water for thermal power plants and process water. Only a small portion is incorporated in products (e.g. food and drinks) – the remainder turns out to be highly price-elastic (i.e. can be reduced drastically as water gets more costly). Water used for industry is generally not considered a problem and not discussed here. It is clear, however, that industry does cause a considerable share of the urban water pollution.

[12] A popular expression (or myth) among agriculturalists and engineers when discussing the water resources available for development is that "X amount of water is running to the sea wasted". In fact, all water in the hydrological cycle supports ecosystem services, from wetlands to coastal fisheries and none of it is wasted. While awareness of environmental functions and services has increased in recent decades, this is still a prevailing attitude in some parts of the world.

highly dependent on water. Environmental goods and services have only recently been more widely recognized as having high values. In some areas, such as California, where the awareness of the value of environmental goods and services is highly developed, water is re-allocated out of agriculture and back to ecosystems in a number of cases. In the major river basin for agriculture in Australia, the total diversions have been capped to reserve the remainder for the environment[13]. The fall in groundwater levels, particularly in China and India, threatens the livelihoods of the farmers in these areas as well as the food supply for a significant share of the world population. The assessment of values produced by natural systems has been hampered by lack of data and comparative analysis, but their have been a few famous documented cases (e.g. Acreman, 2000) where large public investments in the development of irrigated agriculture created a system that produced lower values than the wetlands it replaced.

In the challenge to provide water for productive purposes, food and livelihoods, the effective and efficient delivery of services also plays a key role, but the focus (compared with water supply and sanitation) is primarily on the management of the resource. In short, the water challenge has two crucial dimensions; one is the aspect of service delivery comparable to that of other utility services and the other is the aspect of (renewable) natural resources management. Both aspects are important and they are linked in most every real life situation, but they should be recognized as distinct, with distinct solutions. Instead in the popular discussion of "the water crisis" they are often confused[14].

## 2. The case for government involvement in water

Throughout history, water resources development as well as water service provision has generally been treated as a government task[15]. Water is often viewed as a public good, requiring government investment and management for various reasons:

1. a certain amount of water for drinking and domestic purposes is considered a basic need and has been recognized as a human right[16], requiring governments to make it available to their citizens;

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[13] As recently as November 2003 the first decisions to reduce water to agriculture and re-allocate water to restore ecosystem functions have been taken for the Murray-Darling basin too.

[14] The most widespread confusion is probably the highly controversial case of "water pricing". What is proposed by proponents of water pricing is in almost all cases the pricing of the water services, not the resource. While pricing of the scarcity value of the resource is theoretically desirable, most water pricing proposals aim to achieve cost-recovery for the services. Those against "water pricing" usually argue that the water (resource) should be free (because it is provided free by God, as is held in many Islamic countries) or should not be commoditized (but held as a public good by governments for the benefit of all and not the profit of a few, as is the argument of many environmentalists in developed and developing countries).

[15] There are numerous examples of major public investments in water projects, from the Roman aqueducts to the irrigation works developed 1500 years ago by Sri Lankan kings, closely linked with the development of major cities and the development of civilizations throughout history.

[16] The General Comment on the right to water, adopted by the United Nations Covenant on Economic, Social and Cultural Rights (CESCR) in November 2002, is the first time water is explicitly recognized as a fundamental human right. The 145 countries which have ratified the CESCR will now be compelled to progressively ensure that everyone has access to safe and secure drinking water, equitably and without discrimination.
The General Comment states that "the human right to water entitles everyone to sufficient, affordable, physically accessible, safe and acceptable water for personal and domestic uses". It requires governments to adopt national strategies and plans of action which will allow them to "move expeditiously and effectively towards the full realization

2. in addition to the "rights" based approach mentioned under (1) there is the general case for public investments that potential net-benefits to society would not be captured by private investors, which has been argued for water supply and sanitation as well as irrigated agriculture;
3. investments in surface water developments also require large or lumpy investments, beyond the capacity of private investors, which provides an additional rationale for public investments (often local, municipal government, rather than national government) in development projects such as dams, large canals, treatment plants or distribution systems;
4. surface water resources such as streams and lakes are often managed by communities as common property resource because the partial public good nature of the resource, allowing to some degree (non- or partially consumptive) use by one individual upstream that does not impair the ability of individuals downstream to enjoy the same use (apart from the degradation in quality that often is associated with various forms of use)[17];
5. provision of piped water services often has characteristics of a monopoly[18] and this provides a rational for governments to be involved in service provision, or management of the water services as well;
6. water development and use often imposes significant externalities on other users downstream, either in reduced availability of the resource or in terms of reduced quality, requiring government regulation or control.

That water is a public good, or has public good characteristics, does not imply that it ought to be a free good – only that there is reason for government involvement in its development and management. Some countries have changed the law recently (e.g. South Africa) to ensure that all water resources are public property and users have only use rights. How governments finance the services they provide is obviously a source of considerable debate, in the water sector as much as for various other areas of government involvement from education to health care to other utilities, and not the subject of this paper. Suffice it to say that in the water sector there is an ongoing, and often quite emotional rather than rational, debate on whether or not individuals should be charged for the amount of water they use[19].

The investments in the water sector have not always generated the benefits they were expected to produce. An important lesson learned from past mistakes is that successful water resources development and management for all but the largest projects, in

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of the right to water". These strategies should be based on human rights law and principles, cover all aspects of the right to water and the corresponding obligations of countries, define clear objectives, set targets and goals to be achieved and the timeframe for their achievement, and formulate adequate policies and corresponding indicators.

[17] Groundwater resources, by contrast, are often treated as private resources belonging to the owner of the land where the well is situated. Given that in many groundwater aquifers the use of one well-owner can lead to the drawdown of the groundwater level on a neighbor's land, or for a neighbor's well, it is clear that there are limitations to this approach.

[18] As opposed to tankered or bottled water services, obviously, where competitive markets exist.

[19] Whereas "water experts" have by and large recommended charging for water to various degrees and under various systems, for financial and economic reasons, as laid down in the Dublin Principles (Dublin Statement, 1992) or the report of the World Water Commission (2000), NGOs and citizen groups in many countries have strongly lobbied against charging for water.

developed and developing countries, have been managed by governments or communities at local or municipal levels. Users that are involved directly in these investments, either through water user associations, irrigation districts, farmer cooperatives, urban water districts, or as municipal taxpayers, have a stake in the projects and are more likely to hold the managers accountable. Users that pay for the water services that they use have an incentive to use the resource wisely and demand quality services. The more removed the investment decisions are from the user, the higher the risk is that resources are mis-allocated, and construction projects involve bribery, corruption or mismanagement. The more removed the users are from paying for the services, and the managers respond to national budget allocations, rather than fees paid by the users they serve, the higher the risk that service quality is low, users refuse to pay the fees or charges, services do not recover their costs, funding for operation and maintenance falls short, etc. A downward spiral observed for water as for many other services provided similarly. The general trend observed in the evolving government policies over the last ten to fifteen years is to decentralize the government responsibility for water and to introduce water charges[20].

The counter argument against charging users, particularly farmers, for the amount they use, rather than a fixed fee, is that for surface water irrigation systems the transaction costs of metering and charging large numbers of small users are very high (Perry, various). Shah et al (get ref) argue, for instance, that rational systems of rationing may be more efficient than individual charges.

As for the provision of other services provided by governments, from transport to education to health to electricity, the arguments for government involvement are not without counter argument. There can be private, or semi-private, large-scale investments in the water sector, as some countries such as France have demonstrated successfully, and there are many forms of service provision by various forms of semi-private (publicly held companies, parastatals) or private companies, either under a public charter or through long-term contracts with government. Wherever water services are privatized, there will still be a strong case for government involvement in, for example, setting (public health) quality standards and regulating monopolies and externalities. In most forms of water-related investments where the scale of the investment is limited, private investments are common, as is the case for groundwater used for domestic or agricultural purposes.

A further complication is that at least part of the use of water is as an economic good. That, at least, the use of water for industry or commercial scale agri-business has private, economic good characteristics will be disputed by few. The key remaining argument for government involvement is then: (a) to regulate external costs imposed by the private use; (b) to capture economies of scale; or (c) to stimulate regional economic development or to create jobs.

The discussion above is germane to this paper on the water challenge because in the following sections on costs and benefits of investments in the water sector, estimates of

[20] Governments decentralize water through: 1) establishing water user associations; and 2) establishing river basin management authorities. Governments often introduce water charges for financial reasons, i.e. because they can not afford to maintain the services, rather than for the economic reasons advanced by the experts.

future benefits that differ from observed benefits will need to be based on a sound understanding of past performance. Particularly, this paper will argue that future investments should not be focused on a narrow technology-based approach implemented primarily through national government. Instead the focus should be on a combination of interventions that combine technology, institutions and (social) marketing, implemented through decentralized organizations closely linked to, or directed by, the users.

Specifically, the case for public investments in the water sector today will rest on how much these investments can improve public health as well as reduce poverty and hunger. If so, do they generate public benefits beyond those likely to be captured by private investors. Past public investments, it is argued here, were overly focused on providing technology and infrastructure and insufficiently targeted on the poor segments of the population. As a result of the one-sided focus on technology and insufficient user involvement, investments have underperformed and not producing enough revenue to cover their operation and maintenance costs, leading to a downward spiral of deteriorating service. As a result of the lack of pro-poor targeting, sizeable sections of the population have been marginalized by the development process, even where that development process was successful.

Rijsberman (2003) reviewed the trickle-down assumption of the 60s and 70s, that assumed that infrastructure and technology provision for the relatively better off would trickle down to the poorest sections of society, and concluded that this has not worked in the water sector. In agriculture the focus on better farmers in fertile lands has benefited the target group in large parts of Asia, but left aside the poorest farmers in marginalized areas. In water supply and sanitation the public investments, or subsidies, have been effectively captured by the relatively better off in urban areas, leaving aside large sections of slum dwellers. In both cases access to water has been monopolized by the better off and this has marginalized the poor. Access to water resources is increasingly recognized as an important tool for rural poverty alleviation, however, if it is targeted and "pro-poor".

## *3. The cost of managing water resources and services badly*

In this section an effort is made to assess the costs of managing water badly, that is, to assess the key elements of the costs to society of the current "water crisis". Without trying to be complete, the following key costs are dealt with:

1. health impacts of the lack of access to safe and affordable water supply and sanitation combined with unhygienic behavior;
2. damages and deaths due to water-related natural hazards;
3. poverty and malnourishment due, in part, to lack of access to water for productive purposes, primarily in agriculture; and
4. environmental impacts due to reduced water availability and pollution.

### 3.1 Water Supply and Sanitation

Lack of access to basic water supply and sanitation services has a broad range of impacts at the household level for what are generally referred to as "the unserved". These range from the high costs the urban unserved pay to water vendors for minimal amounts of water[21], to large amounts of time spent carrying water in rural areas, or time not spent by adults on productive activities while caring for sick children suffering from water-related diseases. The water-related health impacts are well established. They can be divided into three classes:

1. Some diseases are closely correlated with the lack of access to water supply and sanitation combined with unhygienic behavior, particularly diarhoeal diseases.
2. Other diseases are water-related because the habitat for the vector transmitting the disease is closely linked to water or live in water, e.g. malaria, filariasis, schistosomiasis, guinea worm.
3. Finally, health impacts can also be caused by natural or anthropogenic low quality water or pollutants, e.g. arsenic, fluoride, heavy metals, persistent organic pollutants or endocrine disruptors.

An overview of water-related health impacts reported by the UN Task Force on Water and Sanitation (2003) provide an indication of the scale, for example:

- at any given time, close to half the population in the developing world are suffering from one or more diseases associated with inadequate provision of water and sanitation services: diarrhea, ascaris, dracunculiasis (guinea worm), hookworm, schistosomiasis (bilharzias, or snail fever) and trachoma;
- over 2 billion people are infected by schistosomiasis and soil-transmitted helminthes, of whom 300 million suffer serious illness;
- there is a 77% reduction in schistosomiasis from well-designed water and sanitation interventions; and
- arsenic in drinking water affects 50 million people in Asia that drink water from deep wells.

The most complete, recent assessment of water-related health impacts was carried out by Prüss et al. (2002). They conducted a study based on WHO health statistics that analyzed deaths and the burden of disease (in Disability Adjusted Life Years, DALYs) due to water, sanitation and hygiene risks. They show that diarrhoeal diseases form the bulk of the health risk, with a total of some 4 billion cases per year that result in between 1,085,000 and 2,187,000 deaths per year and between 37,923,000 and 76,340,000 DALYs attributed, with 90% of deaths occurring among children under 5. Adding impacts of other water-associated diseases (schistosomiasis, trachoma and intestinal helminth infections) led to a total estimate of water-, sanitation-, and hygiene-related ill health of 2,213,000 deaths and 82,196,000 DALYs per year.

According to UNWWWDR (2003), this study was innovative in that it systematically analyzed transmission pathways in fourteen regions against six exposure scenarios. Combination with the data on current levels of water and sanitation services in the WHO/UNICEF Joint Monitoring Program then allows analysis of the potential decrease in morbidity and mortality for intervention scenarios, for an assessment of the cost-effectiveness of specific measures. The Prüss et al. study has significantly improved the global methodology of the water –related health impacts and also (UNWWDR, 2003):

[21] It is well documented that the price poor people in urban areas pay for drinking water purchased from private vendors is often at least a factor ten higher than what their better-off neighbours pay for the tap water into their homes.

- confirms with stronger evidence than before that water, sanitation and hygiene are key determinants of health, with substantial mortality and morbidity occurring as a result of lack of access to water and sanitation and of inadequate hygiene behavior;
- underlines how diseases related to water, sanitation and health disproportionately affect the poor; and
- illustrates the high potential for disease reduction by simple methods such as safe drinking water storage and disinfection at the household level.

While assessment of the economic cost of DALYs is controversial, if we apply a cost of US$500 per DALY[22], a low ballpark estimate of the per capita annual income of the poor in the poorest of developing countries, as a low boundary estimate, then the annual health costs attributed to low access to water and sanitation are on the order of US$40 billion.

The other major water-related disease is malaria. The disease is the leading cause of deaths in young children in Africa, where 90% of the over one million deaths from malaria occur. In 2001, the estimated global burden of disease of malaria amounted to 42.3 million DALYs (WHO, 2002). The difference between diarrhoeal diseases and malaria is that there is no known, simple, affordable and effective measure to reduce or eliminate malaria, as there is for diarhoeal diseases. The bulk of the efforts to reduce malaria focus on providing people with insecticide treated bed-nets and the development of a malaria vaccine. More limited efforts are underway at the research level to attempt to develop environmental management methods to reduce malaria, but the potential for water-related measures for the key area of the disease, Africa, appear limited.

## 3.2 Natural Hazards

An analysis of maco-economic impacts of natural disasters carried out for the United Nations World Water Development Report (UNWWDR, 2003, p.12) showed that between 1991 and 2000 over 665,000 people died in 2,557 natural disasters, of which 90% were water-related events and with 97% of the victims from developing countries. While such impacts are considerable, and can be catastrophic in the locations concerned as shown in Table 1, the overall scale of impacts is assessed to be an order of magnitude lower than the impacts of lack of access to water supply and sanitation.

**Table 1. Impacts of Floods and Droughts**

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| Drought in Zimbabwe during early 1990s was associated with 45% decline in agricultural production, and 11 % decline in GDP and a 60% decline in stock markets. |
| El Nino floods in Kenya in 1997-1998 caused economic losses estimated at US$1.7bn |
| Floods in Mozambique in 2000 led to a 23% decline in GDP. |
| Drought in Brazil in 2000 led to halving of projected economic growth in that year. |
| El Nino floods in Peru in 1998 cost US$2.6bn in public infrastructure damages or 5% of GDP. |
| Landslides in Venezuela in 1999 cost losses of US$10bn, or 10% of GDP. |
| Hurricane Mitch in Honduras in 199X caused damages equivalent to 79% of GDP. |

Source: Hansen and Bhatia (2004, p17).

[22] It is noted that other Challenge papers also use estimates for the value of a DALY, e.g. Mills and Shillcutt in their paper on communicable diseases propose to use the annual per capita Gross National Income of the region in which the health impacts occur, expressed in 2003 Purchasing Power Parity adjusted "international dollars" – which yields a range of int$2,000 to int$10,000. Adoption of this estimate across all challenge papers, for comparison's sake, would increase the corresponding benefits estimated here by a factor of 4 to 20.

## 3.3 Agriculture

Lipton et al. (2003) conclude in a recent overview paper that the high correlation between poverty in rural areas and the percentage of the agricultural land that is irrigated is no coincidence. In other words, lack of access to water for productive purposes in agriculture is a key determinant of rural poverty[23] and malnutrition. Lipton et al. (2003) also conclude that despite the irrigation's "bad press", it remains an important tool for poverty reduction. The main impacts of irrigation on poverty are via increased employment and lower food prices[24]. There is ample evidence that irrigation has contributed significantly to poverty reduction. Shah and Singh (2003) show that sub-districts in India with high irrigation density (irrigated area/net sown area) have significantly smaller numbers of households below the poverty line. Research carried out in India, (Bihar and Madhya Pradesh/ Chattisgarh region), Myanmar, Philippines, Thailand and Vietnam suggests that incidence, depth and severity of income poverty were substantially lower in irrigated and agriculturally developed areas compared to rain-fed and less-developed areas in all these case studies except for Myanmar (Thakur, et al., 2000; Janaiah et all, 2000; Garcia, et al.,2000; Hossain, et al, 2000; Isvilanonda, et al, 2000; and Hossain and Janaiah, 2000). Hussain and Hanrja (2003) analyzed 120 published studies on the irrigation-poverty nexus, and conducted additional household surveys in Sri Lanka and Pakistan and concluded that cropping intensity, land productivity of cereal crops, and particularly labor employment and wage rates are higher in irrigated than in rainfed agriculture. At the same time they conclude that there remains considerable poverty, not only in the rainfed, marginal lands, but also within irrigation systems due to inequitable distribution of benefits. Generally speaking, where the land distribution is inequitable, the benefits to irrigation will be inequitably distributed as well.

More land is irrigated -- and more agrarian wealth created -- in India by privately owned small groundwater pumps than by public irrigation systems (Shah, 1993). Ownership of wells is highly scale biased, however, and most marginal farmers were denied the gains of Green Revolution farming since they would be unable to invest in their own wells and pumps. Over the past several decades, a spontaneous rise of groundwater markets has opened access for South Asia's rural poor to groundwater or pump irrigation. This was facilitated by the introduction of cheaper and smaller Chinese engines, and micro- credit schemes such as those developed by the Grameen Bank and other NGOs (van Koppen and Mahmud, 1996).

In India alone surveys show that the 20 million private pump owners serve over 60 million smallholder farmers (Shah, 2000). This accounts for more area irrigated than the entire public irrigation system in the country. The scale of informal trade in pump irrigation service in India and Bangladesh might well be of the order of 3-5 billion US$ per year during mid-1990's. The drawback of the groundwater boom has been that it has been fuelled by subsidized electricity, and the state electricity boards are by and large collecting insufficient revenue to be sustainable, so energy prices are going up and are affecting the use of groundwater for irrigation. The second side-effect is that the largely

[23] Of the 1200 million people defined as dollar-poor (i.e. with a per capita household income of less than 1US$/day in 1985 Purchasing Power Parity) three quarters live in rural areas.

[24] A majority of the rural poor are not farmers, i.e. they are not net food producers, but they generate their income from employment and are net food purchasers. That makes them beneficiaries of lower food prices.

uncontrolled expansion of groundwater extraction has led, in both India and China, the two countries with by far the largest area under irrigation, to severe drawdowns of groundwater levels in key groundwater aquifers. The lowering of the groundwater table significantly increases the (energy) cost of the groundwater and eventually makes the activity uneconomical.

The development of small scale irrigation technology such as drip and micro-sprinkler irrigation systems, like groundwater, also increase the control farmers have over their water application and tends to significantly increases the value added of the water applied. The low cost varieties of the micro irrigation technology[25], originally developed for capital intensive commercial farming in places such as Israel and California, are highly labor intensive and have shorter life spans but are affordable for small farmers. Particularly suited for vegetables, fruits and other high value crops that are also labor intensive, capital investments of only one to several hundred dollars can generate significant increases in family income that pay back for the investment in one to several years.

A key part of the challenge is that the evidence of the poverty reduction impact of irrigation (including "traditional", groundwater and micro-irrigation) comes primarily from Asia and to some extent from South-America, while there are far fewer success stories from Africa. There is more evidence and data from Asia that community-based, small scale interventions that improve the access of water for productive purposes to poor people has significant impacts on poverty and malnutrition – and may have positive impacts on the environment as well. There is only scant evidence from Africa.

It is clear that lack of access to water is not the only cause of poverty in the rural areas. It is also clear that simply providing irrigation infrastructure is by itself far from a guarantee that there will be a reduction in rural poverty and malnutrition.  The argument advanced here and worked out hereafter is that providing access to water for productive purposes is one of the key opportunities in the water sector to alleviate poverty for a considerable share of the three quarters of the world's "dollar poor" that live in rural areas.

### 3.4 Environmental Impacts

All irrigated land is potentially prone to waterlogging and salinization if not managed carefully. All agriculture on sloping or steep lands is also potentially prone to soil erosion. The resulting decline in land productivity is very hard to assess but most estimates show very high shares of all land in use being affected. Hansen and Bhatia (2004) report a decline of land productivity affecting 30% of world's irrigated areas, 40% of rainfed agriculture and 70% of rangelands. Wood et al. (2000) estimated that as much as 40% of the agricultural area in the world is moderately degraded and a further 9% is strongly degraded, which may have reduced global crop yield by as much as 13%. It is clear that large areas of land are converted from natural ecosystems to agricultural use, are then more or less seriously degraded, often irreversibly, and then left. Various global (and by there very nature inaccurate) estimates of the areas of wetlands and natural grasslands that have been destroyed over the past century come up with high numbers

[25] E.g. bucket drip kits, low grade plastic "Pepsee" drip lines, treadle pumps.

such as 50% reduction in area over the last century. Only relatively recently have estimates been made of the values of the goods and services that ecosystems provide in their natural, healthy state[26]. All these estimates come up with very high estimates of the values of the natural capital that the ecosystems represent – and as a consequence very high costs to society when these systems get degraded or permanently converted into agriculture or urban use. Estimates of the cost of remediation of environmental damage due to degradation also come up with very high numbers. Jalal and Rogers (1977), for example, estimated the annual cost of remediating environmental damage in Asia alone at US$35 billion.

Not all is grim on this front, however. The major clean up of rivers in Western Europe and North America, that began with building proper sewerage systems for large cities in the 19th century and continued with major investments in waste water treatment plants from about the 1970s, has resulted in notably healthier rivers that are once again "fishable and swimmable". While this is an environmental success story, this paper has not identified opportunities for large-scale investments in water-related environmental remediation measures that would yield benefits on the scale of other opportunities identified above.

## *4. Estimating benefits of improved water management*

Water is an intermediate input to achieve desired outcomes such as health, nutrition and income and the relationship between input and outcomes is complex. In addition the dynamic nature of water, which makes its value highly dependent on timing, location and quality, poses problems for any attempt to value its contribution. Rogers (1997) proposed a framework for valuation that includes the following components:

1. direct value to the user;
2. net benefits of return flows, i.e. value to subsequent users from the fraction returned by the previous user;
3. net benefits from indirect use, e.g. the multiple use made of water in an irrigation system, not only for the primary purpose of irrigating the scheme, but for drinking, washing, fishing, watering household garden farm plots etc.;
4. adjustment for societal objectives such as employment generation, poverty alleviation, or national food security;
5. intrinsic value of the resource, to account for environmental, social and cultural values that are otherwise not accounted for (e.g. stewardship and bequest values).

While the framework serves as a reminder of the complexity of doing complete valuations, there are very few studies available that follow this or a similarly complete framework to arrive at total values at any but a micro-economic case-study scale. In short, the economic literature on the benefits of improved water management is rather sparse. The bulk of the material available addresses cost-effectiveness analysis of specific measures, assuming a set objective for the level of the service. This is the standard approach for water supply and sanitation. In addition there is an extensive literature on project level cost-benefit analysis, specifically to justify investments in irrigation and

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[26] Notably a well-known paper by Costanza et al. (1997) that estimated the value of the total global flow of environmental goods and services at US$5.254 trillion per year.

hydropower projects. An expert workshop convened by the United Nations on water economics and financing in 1998 concluded (UNDESA, 1998) that: "*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, the structural role of water in the economy and its in situ value as an environmental asset.*"

While the above quote at least expresses the belief that the disregards of economics is something to be lamented, there is also a large school in the water sector that bases itself on a human rights approach. As expressed by a recent report of the Task Force on Water and Sanitation of the UN Millennium Project[27] "*expanding access to water and sanitation is a moral and ethical imperative rooted in the cultural and religious traditions of societies around the world and enshrined in human rights instruments*" (Task Force on Water and Sanitation, 2003, p 18). It goes on to note that "*many services run on a shoe-string of hope by volunteers, religious groups or dedicated, poorly paid officials succeed because they mobilize the enthusiasm and engagement of their communities, while other projects backed by extravagant budgets and massive expertise turn to dust in a bureaucratic desert that stifles individual and community spirit*" (ibid, p 18).

At the very least this illustrates the difficulty of producing reliable economic assessments.

## *5. Opportunities*

This section discusses the opportunities in the water sector, in terms of specific interventions or intervention packages that, in the opinion of the author, have large potential net benefits for society. It presents the supporting evidence in terms of benefits and costs, and net benefits (in terms of Net Present Value) where possible. There is unfortunately not a neat single methodological or modeling framework to assess the costs and benefits, as these are drawn from different sources of (partial) estimates available in the literature.

The opportunities discussed in detail in the following sections are the following:

1. community-managed low-cost water supply and sanitation; and
2. small-scale water technologies for livelihoods.

These are two important opportunities for which costs and benefits are known to a degree that estimates can be made as required for this paper. They are not the only opportunities related to the sector. Other key opportunities, in the author's opinion, are the following.

3. **Re-using waste water for peri-urban agriculture**, which addresses a key aspect of the sanitation challenge as it turns the challenge of dealing with the urban waste water into an opportunity, a resource, for livelihood generation. It also addresses the poverty and malnutrition challenge for one of the most vulnerable groups of very poor people, those living in the peri-urban areas, the slums, of

[27] Established by the UN Secretary General to develop strategies to implement the Millennium Development Goals.

medium to large cities in developing countries. It even has high relevance for the health and environment challenges. It has been estimated by FAO (WWDR, 2003, p. 219) that 20 million hectare is directly or indirectly[28] irrigated with wastewater in 50 countries – close to 10% of the total irrigated area. A national survey of Pakistan showed that one third of all wastewater produced in the country is used directly, undiluted and untreated for irrigation[29] and an estimated quarter of all vegetables grown in the country are irrigated with wastewater (Ensink et al., 2004). The opportunity would refer to re-using waste water in those medium to large cities in developing countries where low-cost sewerage needs to be installed to increase access to sanitation. Domestic waste water from roughly every thousand people could sustain a farmer (therefore the number of farmers potentially affected could not be much higher than between one and two million). Costs would refer to minimal treatment to make the use of the waste water biologically safe to use for producers and consumers. The costs of treatment would be medium high, but the potential returns could be very high, both for the farmers in terms of direct income and for the environment due to prevention of the pollution that would result of the untreated discharge of the wastewater. Consequently the benefit-cost ration is potentially very high.

4. **Developing sustainable smallholder agriculture in wetlands**, as a way to maintain ecosystem services associated with wetlands (as opposed to draining them and turning them into regular arable land) while providing livelihood opportunities for poor farmers – an opportunity particularly relevant for Africa where there are small scale wetlands ("dambos") that lend themselves for agricultural production without complete reclamation[30]. If successful it would allow a critical type of ecosystem to be maintained, with services that are estimated to generate annual ecosystem services that are valued up to several thousand US$ per hectare. The total area of dambos in Africa, for example, is not well mapped but estimated to cover several thousand hectares. The total number of farmers that could derive direct income from this opportunity is relatively small; the larger share of the benefits from this opportunity would be associated with the maintenance of the environmental services of the wetlands.

5. **Research to increase the productivity of water for food production**, thereby decreasing the total water required to produce food and rural livelihoods, as a way to accommodate the rapidly increasing needs for urban and industrial water supply without further penalizing the environment. This is an intervention aimed at the heart of the matter the bulk of the water used for human purposes, i.e. increasing the crop per drop, the jobs per drop and the nutrition per drop of water used to produce food and rural livelihoods. This opportunity has recently been

[28] Direct irrigation refers to wastewater streams being applied directly, undiluted, and often untreated, to agricultural land. Indirect irrigation with waste water takes place when wastewater is discharged in streams or irrigation canals, mixed with fresh water and used for irrigation diluted.
[29] The use of untreated sewage bring considerable health risks, both in increased helminth infection of producers and diarhhea of consumers, but farmers – aware of the health risks – adopt the practice because of the high economic returns.
[30] As has been the norm in Asia, where wetlands have been turned in to paddyfields.

recognized as a top priority for the international system for agricultural research[31]. The investment costs are relatively low – in the order of US$300-400 million over a period of 10-15 years while the potential benefits are very high[32]. The benefits are hard to estimate – but earlier evaluations of the impact of the system of international agricultural research have estimated benefit-cost ratios of 15-20 (get ref – same as used in the food challenge paper).

These are important importunities for which, unfortunately, sufficient data are lacking to provide estimates of total costs and benefits. They can also be seen as important supporting elements of the first two opportunities – as it must be recognized that while the challenges and opportunities are discussed here as discrete, or even isolated, phenomena, they are of course highly interrelated.

Since it is often assumed that, with rapidly falling costs of desalination, the water challenge can be met by desalination of brackish or saline water, the following provides some perspective. The global market for desalination in 2002 stood at about 35 billion US$ (UNWWDR, 2003, p.89). In 2002 there were about 12,500 desalination plants in 120 countries (70% in the near-east, mostly Saudi Arabia, Kuwait, United Arab Emirates, Qatar and Bahrain) producing 14 million m3 per day, or less than 1% of global use. Energy costs are very high, i.e. 6 kWh per cubic meter of water desalinated for reverse osmosis technology and 80-150 kWh per cubic meter, mostly in the form of (waste) heat, for multistage flash technology[1]. Costs have come down rapidly from several dollars per m3 for most of the installed capacity to 0.5-1.0 US$/m3 for technology currently available, and are projected to fall further to possibly around 0.2 US$/m3 over the next 10-15 year (Cosgrove and Rijsberman, 2000). This makes it an attractive option for domestic and industrial use through large plants for large, wealthy sea-side cities from Singapore and Tampa Bay (Florida) to Santa Barbara (California) and in small units for tourism developments on small islands from the Caribbean to the Maldives. Small desalination units have become widely available off-the-shelf technology that has been shown to offer opportunities even for rural communities of relatively well-off farmers in dry parts of India where the only alternative source of water is deep groundwater that contains high levels of fluoride or arsenic. The price indicates, however, that it is not a large scale option for water supply for the rural poor or for poverty reduction through agriculture. In addition, both the high energy costs and the environmental problem of disposing of the brine, that is the unavoidable by-product of the process, reduce the attractiveness of the option for anything but "niche" use.

### 5.1 Community-managed low-cost water supply and sanitation

The intervention proposed in this section is a package of community-managed low-cost water supply, sanitation and hygiene education. Low-cost water supply implies standpipes and low-cost sanitation refers to latrines (ventilated, improved) in rural areas

[31] The CGIAR Challenge Program on Water and Food: www.waterandfood.org. It must be noted that the author, as the chief architect of this program, is not an independent source on the matter.
[32] The perception, at least, of the high potential benefits of the program is confirmed through the commitment of 7 donors that have underwritten the program with, to date, about US$55 million for the first 6-year phase.

and to low-cost sewerage in urban areas. Communities are assumed to be involved in the design, implementation and management of the systems, and contribute labor to reduce costs. Investment in infrastructure is linked to hygiene education, as part of a social marketing effort, and combined with micro-credit programs that increase the ability of the poor to pay (part of) the investment costs.

It is estimated that in the year 2000, 1.1 billion people lacked access to safe water and 2.4 billion lacked access to basic sanitation[33]. The Millennium Development Goal for water and sanitation, that sets out the target to halve the number of people unserved by 2015, has provided estimates of the number of people unserved by region, in both rural and urban areas, see Table 2. Since this is the number to gain access by 2015 it contains both the currently unserved and the population growth between 2000 and 2015. Just to complete the picture, reaching complete access for all of the population by 2015 would then add another 550 million people to those to whom access to water supply must be extended and another 1,200 million to whom sanitation must be extended.

**Table 2. Number of people, in millions, to whom access must be extended by 2015 in order to meet MDG targets.**

| **Regions/Country categories** | **Number of people to gain access to improved water supply by 2015** | | | **Number of people to gain access to improved sanitation by 2015** | | |
|---|---|---|---|---|---|---|
| | Urban | Rural | Total | Urban | Rural | Total |
| Sub-Saharan Africa | 175 | 184 | 359 | 178 | 185 | 363 |
| Middle-East and North Africa | 104 | 30 | 134 | 105 | 34 | 140 |
| South Asia | 243 | 201 | 444 | 263 | 451 | 714 |
| East-Asia and Pacific | 290 | 174 | 465 | 330 | 376 | 705 |
| Latin-America and Caribbean | 121 | 20 | 141 | 132 | 29 | 161 |
| CEE/CIS and Baltic States | 27 | 0 | 27 | 24 | 0 | |
| **Total** | **961** | **609** | **1,570** | **1,032** | **1,076** | **2,108** |

Source: UN Task Force on Water and Sanitation (2003, p47).

It is customary in the development literature to calculate the total cost of extending service to the unserved, compare this to the current investment levels, conclude that there is a financing gap, and call for increased development aid to meet the perceived needs (i.e. close the gap). The UN World Water Development Report (2003) reviews these approaches, and the global estimates of funding for the water sector required in the range of US$110 to 180 billion, and concludes that there is "*a massive investment gap and that the sources of finance are inadequate*" (p335). It is worth noting though, that at least one

[33] The data on the levels of access to water supply and sanitation are generally sourced from the Joint Monitoring Project (JMP), a partnership between UNICEF and WHO, that is generally acknowledged as the best, if not perfect, source of data available. The JMP data used to be based on reports provided by national governments, with all the problems that entails, but as of the assessment over the year 2000 (UNICEF-WHO, 2000) and updated in 2001 (available on the website www.wssinfo.org/en/welcome.html) the basis for the assessment has shifted to household surveys.

of those global estimates reviewed (Cosgrove and Rijsberman, 2000) in an – admittedly also crude – analysis concluded that the bulk of both current and future financing comes, and will have to come, from domestic public and private funding, not international financing through development aid. It estimated that 80-90% of current funding in the water sector comes from domestic funding, with the bulk coming from public investments (Cosgrove and Rijsberman, 2000; GWP, 2000).

In this respect possibly the best news for the current unserved populations is that roughly half the people without access to sanitation lives in China and India alone; countries whose sustained high economic growth rates makes it likely that the sources of finance necessary to "fund the gap" may be available in the national economy. The 2002 and 2003 Human Development Reports analyze the progress towards achieving the water and sanitation targets. The overall conclusion is that countries that have some 40% of the world population, and that are primarily situated in Asia, have either achieved the target or are on track towards achieving it. Another group of countries with some 30% of the world population, primarily situated in Africa, show either stalled, or reversing, progress. The conclusion is that external funding should focus on, and probably more effective, in the countries where progress is slow or stalled.

A somewhat similar approach by the UN Task Force on Water and Sanitation attempted to analyze areas where the cost-effectiveness would be greatest by identifying where current low levels of access[34] are combined with high prevalence of diarrhoeal diseases[35]. For water supply the list of high priority countries then includes Angola, Burkina Faso, Chad, Congo, Ethiopia, Eritrea, Guinea, Mauritania and Afghanistan; for sanitation the list consists of Angola, Benin, Burkina faso, Central African Republic, Chad, Congo, Ethiopia, Eritrea, Mauritania, Mozambique, Namibia, Niger, Togo, Afghanistan and Bangladesh. These may however not be the countries where the opportunities for achieving impact are greatest as the list clearly shows a high number of countries that are, or have been, engaged in conflict and the conditions may not be in place to achieve impact. This is an area where this challenge links in with the challenge paper on conflicts. It must be noted that even though countries may be on the way to achieving the MDG target, i.e. halving the number of people without access, that still leaves considerable parts of the population unserved.

The estimates reported in Table 2 are only relatively rough estimates for several reasons. First, while the analysis in Table 2 assumes that all people born between 2000 and 2015 need to be served with new infrastructure, Hutton and Haller (2004, cited in Evans Hutton and Haller, 2004, note 13) assume that the percentage coverage in 2000 applies to the new population as well and arrives at an estimate of the total population to be served with sanitation to meet the MDG of 1.47 billion. Second, one must also analyze what it is implied in the various definitions of access. The data in the UNICEF/WHO Joint Monitoring Program (as reported in Table 2 above) report access to "improved" water supply and "improved" sanitation. This is a definition based on the availability of infrastructure, see Table 3, not on the outcome in terms of access to water and sanitation.

[34] Less than 50%.
[35] Prevalence of 20-40%.

For this reason UN-HABITAT prefers to define the number unserved in terms "adequate" access to water and sanitation (e.g. UNWWDR, 2003). It concludes that for urban areas, particularly, improved water and sanitation does not need to imply adequate access. In its analysis of the number unserved in urban areas, on the basis of the "adequate" definition, the numbers go up. The MDGs, on the other hand, speak about access to "safe" water (without defining safe) and access to basic sanitation. The latter is understood to be a definition that focuses more on the outcome of sanitary conditions that include hygienic behavior and focus less on the technology used. An important problem with the focus on the availability of infrastructure is that past experience shows that the availability of infrastructure is poorly correlated with the level of service provided.

**Table 3. Improved versus non-improved water supply and sanitation**

| | **Improved** | **Non-improved** |
|---|---|---|
| **Water supply** | • Household connection<br>• Public standpipe<br>• Borehole<br>• Protected dug well<br>• Protected spring water<br>• Rainwater collection | • Unprotected well<br>• Unprotected spring<br>• Vendor-provided water<br>• Bottled water[1]<br>• Tanker-truck provided |
| **Sanitation** | • Connection to a public sewer<br>• Connection to a septic system<br>• Pour-flush latrine<br>• Simple pit latrine<br>• Ventilated improved pit latrine | • Service or bucket latrines[2]<br>• Public latrines<br>• Latrines with open pit |

1 Considered as "non-improved" because of quantity rather than quality of supplied water.

2 Latrines from where excreta are manually removed.

Source: UNWWDR (2003, p113).

Investments in infrastructure have often not led to the intended increase in access because, particularly, inadequate levels of operation and maintenance in rural as well as urban systems have led to large amounts of installed infrastructure being de-facto non-operational or functioning poorly. Reasons for the poor performance of these investments are: a) donor-driven, top-down and technology focused projects, that failed to involve the users directly, tend to be poorly maintained and break down after a limited period of use; this has been the fate of a very large number of hand-pumps installed in rural areas; b) low levels of financial recovery in urban systems, not covering operation and maintenance, sooner or later lead to badly functioning and badly managed systems with low service and high losses.

The widely accepted lessons learned from this past experience, based also on an analysis of success stories, is that successful water supply projects should be community managed. They should involve the community from the start of the project, mobilize community resources in terms of labor contributed, and pay attention to the development of institutions that will manage the infrastructure once in place.

While past projects often focused on providing improved water supply systems as stand-alone projects, the benefits in terms of improved public health are only partially realized by providing access to clean water in sufficient amounts alone. A review of 144 linking sanitation and water supply with public health found that the "role [of water quality] in diarrhoeal disease control was less important than that of sanitation and hygiene" (Esrey et al., 1991). The greatest impact is obtained when water supply, sanitation and hygiene education are combined, however. The opportunity discussed here is therefore to combine water supply and sanitation in a single investment.

While Esrey's findings suggests that sanitation may be more important to achieving health impacts than water supply, Evans et al. (2004) report that JMP data suggest that sanitation investments make up only 20% of the total water and sanitation sub-sector investments in developing countries (12% in Africa, 15% in Asia, 38% in Latin America). While these data may under-report the household expenditures, the number does suggest why the lack of access to sanitation facilities is so much greater than that to water supply. Given findings from a multi-country study, also conducted by Esrey (1996), that providing access to improved sanitation facilities to an unserved population leads to an observed reduction of 37.5% in diarrhoeal disease, investment in low cost sanitation presents a major water investment opportunity. In other words, to capture some of the key benefits of providing water supply related health benefits, it is necessary to provide water supply and sanitation, together with a basic hygiene public awareness campaign.

Low cost sanitation for rural populations consists essentially of pit latrines, costing US$30-60 per capita in initial investment (Evans et al. 2004). Low cost sanitation for dense urban areas, where latrines are not an option, may consist of septic tanks or shallow, small-bore sewerage[36] combined with low cost treatment, costing US$60-140 per capita in initial investment, with so-called simplified or condominial sewer costs starting as low as US$30/capita (Evans et al., 2004; Mara, pers. comm., 2004).

To assess the overall benefits of extending access to water supply and sanitation there are two approaches available, both reported in Evans et al. (2004).

1. A micro-scale intervention analysis conducted by Hutton (reported in Evans et al. 2004) of the costs and benefits of meeting the MDG on sanitation by 2015, scaled up to global coverage. This involves an analysis of the costs of initial investment and recurrent costs per capita for a range of low-cost technologies, with costs varying for Africa, Asia and Latin America[37] and the benefits in terms of (a) health sector treatment cost avoided; (b) patient health seeking costs avoided; and (c) the annual value of time gained.
2. A macro cost-effectiveness analysis conducted by WHO that maps transmission pathways of feacal-oral diseases, and offsets the six WHO regions[38] distinguished in the global burden of disease statistics against six globally important exposure

[36] Also referred to as low-cost sewerage.
[37] Costs adapted by Evans et al. (2004) based on UNEP/GPA Financing Domestic Wastewater Collection and Treatment in Relation to the WSSD Target on Water and Sanitation (forthcoming) and the UNICEF/WHO (2000) gloabal assessment of water and sanitation.
[38] Subdivided into 14 regions on the basis of child and adult mortality levels.

scenarios. It assesses exposure risks as derived from literature-based intervention reports, to arrive at relative risks for different scenarios, constructed on the basis of the WHO/UNICEF Joint Monitoring Program data. It then assesses the cost of moving from one scenario to another and the benefits, in terms of reductions in DALYs, of moving from exposure scenarios with lower levels of safe access to water supply and sanitation to higher level scenarios. The analysis then reports the cost-effectiveness of each of the scenarios, in terms of the cost per DALY averted.

Fore the first approach, the detailed costs and benefits analyses (Evans et al, 2004) are reported in Annex 1. The conclusions are provided in Table 4. The strategy is based on providing access to low-cost technologies, generally speaking public standpipes for water supply and pit latrines in rural areas and low cost sewerage in urban areas for sanitation. The costs refer to both the costs of providing low cost water supply, through community managed projects (i.e. assuming considerable contributions through the community and low implementation costs) and the cost of providing low-cost sanitation in a similar manner. These costs are in line with (and based on) estimates made by the Water Supply and Sanitation Collaborative Council in their Vision 21 process, and by the UNEP GPA program – but they are considerably lower than other estimates that assume "conventional" technologies and implementation.

**Table 4. Costs and benefits of meeting the MDGs on water and sanitation through community managed low cost water supply and sanitation (US$ million)**

| Region | Water Supply annual investm. and recurrent cost | Sanitation annual investm. and recurrent cost | Sanitation benefits | Cost Benefit Ratios san.ben. over total costs | NPV 5% | NPV 10% |
|---|---|---|---|---|---|---|
| SS Africa | 491 | 1,531 | 16,183 | 8.0 | 130,000 | 102,000 |
| Latin America | 171 | 617 | 7,325 | 9.3 | 60,000 | 47,000 |
| East Mediterranean & North-Africa | 57 | 206 | 5,865 | 22.3 | 51,000 | 40,000 |
| Central & Eastern Europe | 60 | 198 | 2,508 | 9.7 | 21,000 | 16,000 |
| South and SE Asia | 403 | 3,692 | 11,104 | 2.7 | 64,000 | 50,000 |
| West Pacific developing countries | 566 | 3,056 | 11,619 | 3.2 | 74,000 | 57,000 |
| **Total** | **1,748** | **9,300** | **54,604** | **4.9** | **400,000** | **312,000** |

Adapted from Evans et al. (2004).

The benefits included in Table 4 are benefits assessed in detail for sanitation by Hutton as reported in Evans et al. (2004)[39], assumed to be responsible for the lion's share of the reduction in diarrhoeal diseases. As there are obviously other benefits associated with better water supply, such as the reduced time spent to obtaining the water, which are not assessed, this can be considered a lower boundary of the overall benefits. At the same time it is worth noting that the bulk of the benefits reported in Table 4, are associated with estimated annual value of time gained. Time is gained due to: (a) closer access to sanitation services; and (b) less days off work and school due to diarrhea averted[40], valued at the minimum wage in each country; and (c) less days lost caring for sick babies (valued at 50% of the minimum wage in each country). Benefits associated with "health sector costs avoided" and "patient health seeking costs avoided" were also estimated but amounted to only about 10% of total benefits.

The strategy evaluated in Table 4 assumes that water and sanitation is provided to 50% of the people currently unserved, as well as the growth in population, between 2004 and 20015 (which is the MDG target). For the analysis of net present value (NPV) the annual costs and benefits have been taken into account for that period (discounted at 5 and 10%). This is also a lower estimate as it can be assumed that the benefits continue, while the investment costs would diminish; recurrent costs would remain however, and the low cost technologies assumed to be used do not have a very long life time and would need to be replaced at some point, therefore neither costs nor benefits are projected beyond 2015.

The cost-benefit ratio is highest in the East Mediterranean and North African region because the value of time gained is higher here (because minimum wage is higher in the region). The total number of cases of diarrhea averted is estimated to be highest in South and South-East Asia, while the overall NPV is highest for Africa because of both low current service rates and high prevalence of diarrhea[41].

This analysis shows that global welfare would be increased by US$300-400 billion through provision of low-cost, community managed water supply and sanitation to about 50% of the people currently unserved. It would also leave another 550 million people without access to safe water supply and 1.2 billion people without access to basic sanitation. If providing water and sanitation is as beneficial as suggested in Table 4 then it would make good sense to provide universal access – and that would, by simple extrapolation[42], increase the total NPV by roughly half as much again – or up to US$ 450-600 billion. In practice this is not a linear process, of course, as there are locations where providing the service is easier and therefore cheaper and there are areas where current diarrhea prevalence is high and the benefits are therefore higher. Finally there are areas that are troubled by civil war, or very remote etc., where costs would be so high that economic benefits, as estimated here, would not arise.

[39] And updated by Hutton, one of the authors, for this paper.
[40] An estimated total of 391 million cases of diarrhoea avoided per year, out of a total 5,388 million, see Annex 1.
[41] And note that these are also, by and large, where the high priority countries are located as identified by the UNDP Human Development Report 2003.
[42] Presuming for simplicity here that all services would be provided in the same period – even though that is not likely to be practically implementable.

In practice, of course, the water supply and sanitation challenge can not be divorced from the other challenges. Living in Sri Lanka, as the author does, it is all too clear that an end to civil war, and a stable institutional and financial system, is a pre-condition for making progress on many other fronts. Solid economic growth, that is then more likely to follow, is then the basis for dealing with many other challenges, including water supply and sanitation. That is why universal access, domestically funded, is more likely to be a realistic medium term goal in e.g. China and India[43], presuming their economic growth holds. If the case is a prioritization of external assistance, in the absence of stability and economic growth, if that can be sustainable at all, then a target of making "significant progress" – such as the MDG target to reduce by 50% – may be a more useful goal.

The second approach is based on WHO-led cost-effectiveness analysis (see Annex 2) to reduce the burden of disease. As discussed earlier, the total burden of disease associated with water is estimated at about 82 million DALYs annually. If we assume a value per DALY of US$500, and discount at 10 and 5%, then the NPV of that burden of disease is US$400-800 billion, respectively. This is roughly in line with the NPV of providing universal access arrived at above. Assuming a higher value per DALY, as done elsewhere in the challenge papers, obviously increases this value. The WHO analysis shows that chlorination of water at the point of use was most cost-effective with a cost of US$25-150 per DALY averted. Assume for a moment that all water-related disease could be resolved through this method, then the maximum NPV associated with this, at US$500 per DALY and discounted 10 and 5%, would be in the range of US$280[44] to 760[45] billion.

The method with the highest chance to actually reduce the burden of disease to close to zero is to provide universal access (assumed to be 98%) to piped water and sewerage connection, but the estimated cost of this strategy is US$850 to US$7,800 per DALY averted. In other words, for an assumed value of US$500 per DALY there would not be any net present value, or no gain in welfare. This is not surprising, since it is another way of saying that for the dollar-poor, for whom the US$500 per DALY is assumed as an estimate of the income lost per DALY, conventional piped water supply and sewerage connections are not affordable. Or in other words, it suggests that for conventional piped water supply and sewerage connections to have any economic benefit on improved health, income levels would have to be above US$850 to US$7,800[46].

The intermediate option in the WHO analysis is to provide low-cost technologies (standpipes and latrines, as opposed to individually piped water sewerage connections) at a cost of US$650 – 5,600 per DALY averted. It is interesting to note that according to this WHO study the cost effectiveness of this strategy improves to US$280 – 2,600 per

[43] Or, for that matter, Asia as a whole, where indeed the HDR 2003 reports satisfactory progress towards reaching the MDG on water and sanitation.
[44] A cost of US$150/DALY, benefits discounted at 10%.
[45] A cost of US$25/DALY, benefits discounted at 5%.
[46] Note that in the challenge paper on communicable diseases a range of int$2,000 to int$10,000 is used as the value per DALY averted; the same approach would yield net benefits for piped water supply and sewerage connections.

DALY averted if disinfection (chlorination) at the point of use is added in[47]. It is also worth noting that –contrary to what is concluded in the WHO-analysis that is discussed here - experience with low cost (condominial) sewerage in Brazil has shown that individual (low cost) house sewerage connections become more efficient (cheaper) than latrines at relatively low levels of density.

### 5.2 Small-scale water technology for livelihoods

The second opportunity assessed here is the dissemination of small-scale water technology for productive purposes, primarily to provide livelihoods to small and landless farmers. There is a range of technologies available that can be used depending on the agro-climatic and socio-economic conditions, ranging from rainwater harvesting in dry areas to the use of manual pumps to access shallow groundwater. As for the first opportunity, what needs to be recognized is that successful adoption by a large number of people depends less on the technology than on: (a) the social marketing of the technology; (b) the availability of micro-credit programs; or (c) the institutional support through NGO networks or community based organizations to provide training and technical support.

The target group consists of the 800 million dollar poor in the rural areas, as well as a subset of the poor in peri-urban areas, whose livelihoods depend on agriculture (growing crops as well as tending livestock), fisheries, agro-forestry, and aquaculture and for whom access to water for productive purposes is a key constraint of not the key constraint.

The main public investments have been in large scale publicly managed infrastructure, particularly large dams[48] for hydropower and irrigation. While these currently suffer from a rather bad press, and have certainly underperformed in a number of cases, national governments in key countries[49] maintain a high priority for these investments. Carruthers (1996), as discussed in Lipton et al. (2003), reviewed 192 World Bank funded irrigation projects implemented between 1950 and 1993 and concluded that 67% performed satisfactorily at evaluation with an average internal rate of return[50] of 15%. A recent World Bank review (2004) of 11 Brazilian publicly-funded irrigation schemes in the semi-arid areas, with a total public investment of about US$2 billion in 200 thousand hectares of irrigated land, showed an economic rate of return of 14 to 25%, with 4 out of the 11 projects exceeding a social discount rate of 16-19%[51]. The study also concludes that the main poverty impact of the projects is their job-generation or employment effect,

[47] This increases costs by a relatively small amount, but is estimated, according to WHO, to more than double the impact on the reduction in diarrhoeal diseases.
[48] Defined as dams higher than 15 meter, of which there are now over 48 thousand, with a total value of some 2 trillion US$.
[49] Notably China, India, Turkey and Brazil.
[50] That is, the discount rate that would result in a zero net present value.
[51] The social discount rate is defined in this study as reflecting the opportunity cost of capital in the economy at the time the capital was used, in the study area ranging from an average high of 19% in the 70s to about 16% in the 90s.

with each job created in the irrigation sector costing US$5.000 to 6.000, compared to an average of US$44.000 in other sectors (World Bank, 2004, p11)[52].

More recently, there has been an upsurge in the adoption of water technologies for smallholders such as low-cost small electric and diesel pumps, manual devices such as treadle pumps, low-cost bucket and drip lines, sustainable land management practices such as low or zero-till agriculture, supplemental irrigation, groundwater recharge and water harvesting systems. Emerging evidence suggests that access to water for agriculture through these technologies has a major potential to improve the livelihoods of the poorest farmers. Identification and promotion of these technologies therefore offers significant opportunities for poverty reduction. The technologies are particularly suited to smallholders, poor and even landless households as they self-select the poor and have a strong land and water-augmentation effect. Hereafter two examples are given of low cost drip irrigation and treadle pumps.

Drip irrigation is promoted to help farmers in water scarce areas. The advantages of drip systems are that they minimise water losses and increase yields. Drip irrigation is part of the family of precision irrigation technologies that aim to deliver the right quantity of water at the right time (IWMI, 2000). It can increase yields from 20% to 70%, while using less water than traditional methods (IWMI, 2000). Water savings are reported to be around 60% over flood irrigation (Shah and Keller, 2002).

Drip irrigation is usually applied by commercial farmers who cultivate larger land areas than possessed by a typical smallholder farmer and are too expensive for poor farmers. Cheap, small scale bucket-and-drip kits (e.g. The Chapin bucket-kits in Kenya) have been developed, however, for vegetable cultivation on small plots that do have potential for poor smallholders. (Shah and Keller, 2002; Sijali and Okumu, 2002). Research by IWMI in Nepal evaluated the economic impact of drip irrigation kits for small farmers (RITI, 2001). The cost of each drip kit promoted by IDE in mountain range of Nepal is US$13, with a life cycle of 3 years. The IWMI study shows that for a small farmer producing vegetables, one set is adequate for irrigation of 125 square meters. A farmer can irrigate 1,000 sq. meter of land with 8 such drip kits at a total cost of US$104. The total net benefits, subtracting all costs except labor, obtained by each farm household were US$210 per 1000 $M^2$ per year by growing two crops of cauliflower and cucumber (RITI, 2001). Thus, the total NPV for 3 years (@ 10 % discounting rate) would be US$570 per farmer.

The costs of these systems are dropping dramatically. A recent innovation introduced in India , for example, is the 'Pepsee' kit, a locally developed "disposable[53]" micro-irrigation kit made of low-grade plastic tubes. The technology was introduced in 1998-99. Initially, it was confined to the cotton growing areas of Madhya Pradesh and Maharashtra. Over the years its use has spread to grow other crops such as sugarcane and vegetables. The popularity of the Pepsee system is its low cost. The initial investment in a

[52] The projects in semi-arid Brazil focused on labor-intensive high value crops, primarily fruits, with a significant share for export markets.
[53] Disposable, in this context, refers to the fact that the cost of the drip system is so low that the farmers can afford to use it for a single cropping season only; instead of an investment it becomes a consumable, much like fertilizer.

Pepsee system to irrigate an acre of cotton is estimated to be US$ 93 which, is about half the investment required for micro-tubes (US$ 158) and nearly 25% of the capital required for conventional drips (Verma, et al, 2003). Farmers who adopted the technology claimed that it led to significant water savings at the farm level. A recent IWMI study in two districts in Madhya Pradesh (West Nimar) and Maharashtra (Jalgaon) showed that the cotton yield realized by farmers who had adopted Pepsee irrigation was comparable to yields obtained by farmers using conventional drip irrigation systems and was almost double the yield of non-adopters (Verma et al, 2003). The same study showed that farmers were able to increase the area under irrigation and also enabled them to cultivate crops in the dry (Rabi) season. The growing popularity of the Pepsee technology clearly demonstrates the tremendous scope for appropriate, low cost, grass-root level technologies that are within easy reach of poor farmers. IWMI research in India shows that farmers use the low-cost technology as a stepping stone to switch to more conventional technology after several seasons.

Another example is the treadle pump, a foot-operated device that uses bamboo or flexible pipe for suction to pump water from shallow aquifers or surface water bodies. Since it can be attached to a flexible hose, a treadle pump is useful for lifting water at shallow depths from ponds, tanks, canals or catchment basins, tubewells and other sources up to a maximum height of 7 meters. It performs best at a pumping head of 3.0-3.5 m, delivering 1.0-1.2 l/s.

IWMI research found that treadle pump technology has had a significant impact in improving the livelihoods of the poor in eastern India, the Nepal Terai and Bangladesh (the heartland of the Ganga-Brahmaputra-Meghna basin), South Asia's, so-called "poverty square" (Shah et al, 2000). This region, which contains 500 million of the world's poorest people and is characterized by tiny land holdings, is underlain by one of the world's best groundwater resources, available at a depth of 1.5-3.5 m.

The treadle pump is cheap and affordable, with costs ranging from US$12-30, is easy to install, operate and maintain and has no fuel costs. The labor-intensive treadle pump self-selects the poor that have under-utilized time to work the pumps. Shah et al. (2000) suggest that: (1) for poor small holders constrained by limited land, treadle pump technology works as a land augmenting intervention, enabling users to raise crops in both summer and winter thereby increasing overall cropping intensity; (2) treadle pump technology enables farmers to grow high-yielding and high value crops (such as china rice, a high-yielding variety, and high value crops such as vegetables); and (3) the technology increases crop yields[54], (for example). The study estimates that farmers using treadle pump technology see an average increase of US$ 100 per year in annual net income with gross incomes of US$300-400 per acre quite common. Net incomes did vary across households and regions, however. International Development Enterprise (IDE), a US-based NGO that developed and promoted the technology, estimates to have sold 1.3 million pumps since the mid-1980s in Bangladesh, and 200,000 in eastern India and the Nepal Terai since the mid-1990s. IDE indicates that, 'eastern India and the Nepal Terai have an ultimate market potential for some 10 million treadle pumps.

[54] In Uttar Pradesh and north Bihar, treadle pump users had potato yields of 16-17 ton per hectare, 60-70 percent higher than diesel pump users.

Assuming average investment costs of US$20 for low-cost treadle pumps, with a life of three years, and an average annual gain in net income of US$100, the total NPV for a treadle pump adopter, assuming the person will stick with the technology indefinitely, is US$900 to 1,900 (discounted at 10 and 5%, respectively) For the 1.5 million adopters of the treadle pump technology the total NPV then is US$1.4 to 2.8 billion and for the estimated market in Eastern India and the Nepal Terai the NPV amounts to US$9-19 billion.

In addition to drip irrigation and treadle pumps (combined with low cost sprinkler or drip, often) there is a host of small scale technologies that aim to conserve rainfall, either in the field directly, or in small structures[55]. Collectively referred to as rainwater harvesting, they have been actively promoted by NGOs and civil society organizations in India, particularly, but elsewhere as well. Contrary to large scale public investments that often take 10-30 years to get from the drawing board to implementation, the rainwater harvesting technologies have seen astounding adoption rates, on the order of several hundred thousand villages over several years in parts of India.

IWMI has conducted research over the last 3-4 years to evaluate the impact of these technologies. Since these technologies are evolved by local NGOs or 'barefoot hydrologists' to suit each socio-ecological context, one finds enormous variety in type, scale, costs, benefits, adoption rates and management approaches, making it difficult to work out economics that represent all of them. In India, for instance, these range from farm ponds—whose costs and benefits are concentrated on each small holder—to individual check dams or tanks benefiting a section of a village to a network of check dams built by a basin or sub-basin community. Construction costs range from US$ 0.4-0.5/$m^3$ for earthen structures (such as farm ponds in Gujarat's *Sujalam Sufalam* scheme or the so called '5% technology popular in east-Indian plateau[56]) and US$ 0.7-0.9/$m^3$ when bricks, cement and concrete structures are involved. Some of the larger structures can support some winter crop irrigation; however, the key benefit that drives India's rural communities to invest in these is to ensure one or two life-saving irrigations to the main monsoon crop during frequent dry spells that ruin standing crops. The value of irrigation water during these dry spells is very high and varies from US $ 0.1-0.8/$m^3$ depending on the losses the dry spell imposes on the farmer. For average construction cost taken at US $ 0.5/$m^3$ of storage, implicit value productivity of water at US $ 0.2/$m^3$ of dry-spell supplemental irrigation and average life of the structure at 10 years, the NPV for a water harvesting structure of 1000 $m^3$ costing US $ 500 works out to around US $ 800 at a social discount rate of 10%/year.

[55] Technologies range from creating small ridges along the contour line (by placing stones) or creating tiny basins of, say 2 by 2 meter, to concentrate rainfall towards the roots of a single plant or tree, as practiced in the dry areas, to technologies such as digging a pond on 5% of the land to store water within a farmer's field, to recharging groundwater wells with excess rainfall, creating underground barriers to create underground storage, to building small check-dams that create small reservoirs or tanks at village level. Some of these technologies hark back to traditional, indigenous technologies such as practiced in South-Asia over centuries, while others are based on, or combined with, modern technology.

[56] 5% technology, popularized by PRADAN, an Indian NGO involves making a 3.5 feet deep pit over an area equal to 5% of the farm size on its upstream end to capture run off and store water to save the main monsoon crop from the dry spell.

Numerous local studies suggest investment in small water harvesting structures far more attractive (see, e.g. Raju, 2004). Most of these refer to a village or a small area but analysis of large regional programs suggest high rates of return as well. In an evaluation of Gujarat Government's Sardar Patel Participatory Water Conservation Program under which 10,708 check dams were constructed in Saurashtra and Kutch regions, Shingi and Asopa (2002) noted that "*within a period of three years, an initial investment of Rs. 1,58,000 (US $3511*[57]*) on an average check dam fetched total benefits worth Rs 251,582 (US $ 5591)*." And that "*The investment becomes more attractive if one recognizes that the government had to in fact invest only 60 per cent of the average figure of Rs 1,58,000 under the 60:40 scheme*". Of Gujarat's 4.2 million ha of cultivated land, 2.2 million is rainfed and critically dependent upon supplemental irrigation sustained by small water harvesting and recharge structures. According to M S Patel, Gujarat's Secretary for water resources, the value of the main monsoon crop on these 2.2 m ha can increase from Rs 10-15 billion now (US $ 0.22-33 billion) to Rs 50 billion (US $ 1.1 billion) provided there is a check dam per square kilometer (Shah, 2003). India as a whole has over 80 million ha of rain fed farming area which can benefit greatly from crop-saving supplemental irrigation in terms of increase in the value of monsoon crop output from US $ 36-54 billion/year to US $ 180 billion/year; but this would require creating small water harvesting capacity and storage equivalent to some 2 million check dams costing US $ 7 billion.

IDE and Winrock estimated a global potential of 30 million smallholder families, or about 150 million people, that could potentially benefit from the adoption of low-cost, affordable water control systems, essentially "micro-irrigation"[58] (get ref). For sub-Saharan Africa, using the total (1999) population of 625 million for the 46 SSA countries, 65% of this is rural. Using a 1998 rural poverty threshold, about 59% of the rural population in SSA were estimated to be poor families, i.e. about 240 million people or 50 million families. The IDE-Winrock project estimates that at least 4 million smallholder families in SSA would have the basic pre-condition to engage in high-value crop production.

In summary, the potential for adoption of small-scale water technology[59] in Africa and Asia is estimated at about 100 million farmers (or families), with an average annual direct net benefit[60] of US$100[61] per farmer. Discounted at 10 and 5% respectively this yields an NPV estimate of US$100 (C-B=150-50) to 200 (C-B=300-100)billion in terms of direct benefit to the users.

[57] US $ = Indian Rs 45 in early 2004.

[58] Projections made for the IDE/Winrock Smallholder Irrigation Market Initiative (SIWI) project.

[59] Combining rainwater harvesting potential in India alone of 80 million ha, with the estimate of 30 million farmers that have micro-irrigation potential, the 100 million farmer, or half a billion people, estimate is considered a low estimate, given the potential for rainwater harvesting in the global arid and semi-arid belt circling the globe from Brazil to North-Africa, Central Asia, South Asia and Western China.

[60] That is, the increase in income minus the costs of the technology, both investment and recurrent.

[61] Assuming annualized investment plus recurrent costs of US$50 per farmer, yielding an increase in income of US$150.

On top of the direct benefits to farmers there are indirect benefits, particularly in terms of employment downstream in the economy.  A number of studies have reported multipliers (the ratio of total, i.e. direct plus indirect, over direct benefits) ranging from 2 – 6. An irrigation impact study in Alberta province of Canada reported that only about 20 percent of the total benefits of irrigation development have been captured by the farming sector in termed of increased agricultural production with the remaining incremental benefits accrued to the wider sections of the Canadian society (AIPA, 1993; Hill, and Tollefson, 1996). These wide spread benefits of irrigation included rural employment impact, and induced economic activities in the region. Powel at al. (1985) have reported irrigation multiplier values of 6 for irrigation in New South Wales, Australia. A comprehensive economic impact study, (Bell, et al. 1982) reported that the Muda irrigation project, Malaysia, had produced substantial indirect effects through expansion of other sectors of the regional economy e.g.  it had contributed over 95% in agricultural machinery, over 70 % in construction, over 70 % in the financial sector, and about 60% in the trade sector in the region affected by the project. The study reported that for every dollar of direct benefits, another 83 cents were generated in the form of downstream or indirect effects (i.e., a multiplier of 1.83). Likewise, Bhattarai et al (2003) study in India shows an irrigation multiplier value of 3 at all India level impact of irrigation development. Bell, et al. (1982), Powel et al. (1985), and AIPA (1993) have all used a project-level accounting framework of analysis such as an I-O (input-output) and SAM (Social Accounting Matrix) based accounting framework. However, the "irrigation multiplier" derived from constant coefficient assumptions of the accounting framework of I-O and SAM are short run values of irrigation multipliers operating in a regional economy. The value of "irrigation multipliers" derived from Computable General Equilibrium (CGE) models (or from regression based analyses) as used by Bhattarai et al. (2003) is an estimation of the long run value of the irrigation multiplier operating in the economy as these incorporate the societal substitution behavior in resources use decisions.

Table 5: Estimates of Irrigation Multipliers

| **Project (source)** | **Irrigation multiplier (total / direct effects)** |
|---|---:|
| Muda, Malaysia (Bell et al., 1982) | 1.83 |
| NSW, Australia (Powell et al., 1985) | 6 |
| Alberta, Canada (AIPA, 1993) | 5 |
| Senegal project (Delgado et al., 1994) | 1.3 – 4.6 |
| Bhakra project (World Bank, 2003) | 2 |
| All – India (Bhattarai, 2003) | 3 - 4 |

Taking such indirect effects into account with an assumed multiplier of 3 would increase the total NPV of the widespread adoption of small-scale water technology to US$300 billion (discounted at 10%) to US$ 600 billion (discounted at 5%).

## *Conclusions*

The lack of access to safe and affordable water for domestic purposes, lack of access to safe and affordable sanitation, and lack of access to water for productive or livelihoods purposes has a major impact on the 1.2 billion dollar-poor people in the world today. At any given time close to half the population in developing countries suffers from one or more water-related diseases. The total annual burden of water-related disease is about 80 million DALY. Three quarters of the dollar poor live in the rural areas with agriculture as their only way out of poverty and water as one of the key constraints to obtaining a higher return on their labor.

Providing community-managed access to low-cost water supply and sanitation is a major opportunity to increase global welfare. This requires an integrated approach to water supply, sanitation and hygiene education. The focus should be on service delivery rather than on infrastructure – and sanitation should receive at least as much attention, and more funding, than water supply. Social marketing and micro-credit programs are key ingredients of the package. The benefits to society range from improved health, particularly a reduction in diarrhoeal diseases, and reduced loss of time engaged in gaining access to water and sanitation but particularly reduction of time lost to disease. The total net benefits of making a significant progress towards increasing access, defined as MDG target 10, or halving the people without access by 2015, are estimated to be US$300-400 billion. Total benefits of providing universal access by 2015 based on the same package, although not likely to be a practical or realistic goal, could be extrapolated to US$450-600 billion.

Providing access to small-scale water technology for livelihoods purposes to smallholder and landless farmers is another major opportunity in the water sector. There is a wide variety of technologies available that range from rainwater harvesting, to small-scale electric pumps, manual treadle pumps to low-cost drip irrigation kits. The key impact of the technology is that it substitutes labor inputs for land and capital. Again, the focus should not be on development or provision of the technology, but rather on social marketing and micro-credit programs. For an estimated 100 million farmers that could adopt this technology, the direct total net benefits can be estimated to be US$100-200 billion at 10 and 5 percent discount rate, respectively. When including indirect benefits in the economy, with a multiplier of 3, the total net benefits (NPV) can increase to US$300-600 billion.

There are more water-related opportunities for which there are insufficient data to attempt estimates of total benefits, particularly: (a) re-use of urban waste water for peri-urban agriculture; (b) sustainable agriculture in wetlands; and (c) research to increase the productivity of water in food production. For these opportunities the costs and benefits have been assessed as small, medium, high and very high based on the expert judgment of the author.

Table 6 provides an overview of costs, benefits and benefit-cost ratios.

**Table 6. Costs and benefits of water-related opportunities (billion US$)**

| Water Opportunities | Total Benefits | Total Costs | Annualized B/C | Discount rate / remarks |
|---|---|---|---|---|
| Community managed low-cost water supply and sanitation[1] | 392 | 80 | 4.9 | 10% |
| | 502 | 102 | 4.9 | 5% |
| Small-scale water technology for livelihoods[2] | 350 | 50 | 7 | 10% |
| | 700 | 100 | 7 | 5% |
| Re-use of waste-water for peri-urban agriculture | Very high | Medium | Very high | |
| Sustainable agriculture in wetlands | Medium | Small | High | Focus on Africa |
| Research to increase water productivity in food production | Very high | Very small | Very high (15-20) | |

1Annualized costs, for the period 2004-2015. 2 Multiplier for indirect benefits assumed as 3.

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## *Annex 1: Costs and benefits of meeting the MDG on Sanitation.*

Source: Evans et al. (2004)

**Table 1.1: Sanitation Technology Cost Estimates (US$ 2000)**

| IMPROVEMENT | INITIAL INVESTMENT COST PER CAPITA | | | | | |
|---|---|---|---|---|---|---|
| | JMP Estimates | | | Other | Recurrent Costs | |
| | AFRICA*1 | ASIA*1 | LA&CN | Estimates | Level | Source |
| Sewer and WWT | | | | 450*1 | v. high | User fees/subsidy |
| Sewer connection | 120 | 154 | 160 | 150-260*2 | High | User fees/subsidy |
| Small bore sewer | 52 | 60 | 112 | 120*3 | Medium | User fees/household |
| Septic tank | 115 | 104 | 160 | | High | Household |
| Pour-flush | 91 | 50 | 60 | | Med/low (lumpy) | Household |
| VIP | 57 | 50 | 52 | | Low (lumpy) | Household |
| Simple pit latrine | 39 | 26 | 60 | | Low (lumpy) | Household |
| Improved trad.practice + Hygiene Promotion | | | | 10*4 | Low (US$0.60 per annum) | Household |

Source: adapted from UNEP/GPA *Financing Domestic Wastewater Collection and Treatment in Relation to the WSSD Target on water and sanitation*

Notes:

(1) Adapted from Global Water Supply & Sanitation Assessment 2000 Report (www.who.int/docstore/water_sanitation_health/Globassessment/Global3.3.htm). Unless states, figures are based on the average construction cost of sanitation facilities for Africa, Asia and Latin America & the Caribbean for the period 1990-2000 and include a small charge to account for inflation and currency fluctuations. These data were provided by member states as per of the JMP data collection exercise.

(2) Taken from Water: A World Financial Issue (PricewaterhouseCoopers, March 2001). The figure is based on a per head cost of $20/year multiplied by 13 years to reflect the timescale required for meeting the MDGs.

(3) This figure is quoted by Suez in the publication Briding the Water Divide (Suez/Ondeo, March 2002) and is based on a one-off connection cost for households in poor neighbourhoods in the Aguas Argentinas concession area and assumes the bartering of local labour in exchange for connection to a network. However, no data is given for the number of persons per household.

(4) From Sustainable Local Solutions, Popular Participation and Hygiene Education (Richard Jolly) writing in Clean Water, Safe Sanitation: An Agenda for the Kyoto World Water Forum and Beyond (Institute of Public Policy Research, February 2003). Based on the Vision 21 estimate of average external costs per person for sanitation and hygiene promotion.

**Table 1.2 Total annual benefits of meeting sanitation MDG in natural units**

| World / Region | Pop'n (m.) | Current annual diarrhoea cases (millions) | Meeting sanitation MDG (annual figures, in millions)<br>Diarrhoea cases averted | Hours gained per year due to closer access | Productive days gained (15+ age group) due to less illness | Nr of school days gained (5-14 age group) | Baby days gained due to less illness (0-4) age group) |
|---|---|---|---|---|---|---|---|
| Sub-Saharan Africa | 968 | 1,239 | 115 | 38,616 | 78 | 1,700 | 330 |
| Latin America | 624 | 552 | 25 | 9,306 | 52 | 956 | 92 |
| East Mediterranean & North Africa | 373 | 286 | 9 | 4,156 | 28 | 426 | 100 |
| Central & Eastern Europe | 460 | 130 | 3 | 3,818 | 8 | 42 | 16 |
| South and SE Asia | 2,162 | 1,795 | 135 | 28,445 | 110 | 1,150 | 270 |
| West Pacific developing countries | 1,673 | 1,317 | 102 | 39,929 | 203 | 708 | 95 |
| Developed regions | 923 | 69 | 2 | 2,253 | 47 | 89 | 44 |
| **All regions** | **7,183** | **5,388** | **391** | **126,523** | **527** | **5,071** | **947** |

Source: Hutton (as quoted in Evans et al., 2004) – calculations updated by Hutton for the Evans et al. paper.

**Table 1.3: Some economic benefits of meeting sanitation MDG, and cost-benefit ratios**

| | | Meeting sanitation MDG (annual figures, in US$ million) | | | | |
|---|---|---|---|---|---|---|
| World Region | Population (m.) | Health sector treatment costs avoided | Patient health seeking costs avoided | Annual value of time gain | Total benefits* | Cost-benefit ration* |
| Sub-Saharan Africa | 968 | 1,130 | 72 | 12,873 | 16,183 | 10.6 |
| Latin America | 624 | 514 | 16 | 5,695 | 7,325 | 11.9 |
| East Mediterranean & North Africa | 373 | 148 | 6 | 5,157 | 5,865 | 28.5 |
| Central & Eastern Europe | 460 | 60 | 2 | 2,381 | 2,508 | 12.7 |
| South and SE Asia | 2,162 | 1,378 | 84 | 8,112 | 11,104 | 3.0 |
| West Pacific developing countries | 1,673 | 1,645 | 64 | 8,905 | 11,619 | 3.8 |
| **All regions (incl. developed regions)** | **7,183** | **4,955** | **244** | **51,525** | **63,269** | **6.6** |

Source: Hutton (as quoted in Evans et al., 2004) – calculations updated by Hutton for the Evans et al. paper.

Note*: Total benefits Includes time savings due to closer sanitation facilities, productive and educational time gain due to less ill from diarrhoea, and health sector and patient savings due to less treatment for diarrhoeal disease. Time savings per person were day from closer access to sanitation services was assumed to be 30 minutes. Days off work and school were assumed to be 2 and 3 days per case of diarrhoea, respectively, which were valued at the minimum wage for each country. A baby was assumed to be ill from a case of diarrhoea for 5 days, at a value of 50% of the minimum wage to take into account the opportunity cost of the carer. The economic benefits of reduced mortality were not included in the calculations of total economic benefit.

It is important to note that health sector costs are not actual costs saved, as the calculations includes health sector infrastructure and staff time, which are not saved in a real sense when a diarrhoeal case does not show up. This figure reflects the opportunity cost: in settings where services are used to 100% capacity, if someone does not show up with diarrhoea, then someone else with another disease can be treated.

## *Annex 2: WHO Cost-effective analysis of improved water supply and sanitation.*

**Source: Evans et al. (2004)**

**Table 2.1: Average CER by WHO Region (US$ per DALY averted)**

| | AFRO D | AFRO E | AMRO D | SEARO B | SEARO D | WPRO B |
|---|---|---|---|---|---|---|
| Halve pop without access to improved WS | 338.8 | 498.3 | 954.9 | 3,362.0 | 427.4 | 2,611.1 |
| Halve pop without access to improved WS&S | 686.0 | 822.5 | 1,898.4 | 5,654.0 | 1,117.0 | 5,618.6 |
| Disinfection at point of use to pop currently w/o improved WS | 23.5 | 26.0 | 94.3 | 156.8 | 25.7 | 156.8 |
| Universal access (98%) to improved water supply and improved sanitation (Low technologies) | 648.5 | 718.9 | 1,886.6 | 5,251.2 | 1,116.1 | 5,618.5 |
| Universal access (98%) to improved water supply and improved sanitation plus disinfection at point of use | 283.8 | 332.7 | 736.6 | 1,484.1 | 471.4 | 2,552.2 |
| Universal access (98%) to piped water supply and sewer connection (High technologies) | 852.9 | 943.6 | 1,693.7 | 7,765.0 | 1,121.7 | 4,693.2 |

Source: Haller as quoted in Evans et al. (2004).

**Notes:**

**AFRO D** Algeria, Angola, Benin, Burkina Faso, Cameroon, Cape Verde, Chad, Comoros, Equatorial Guinea, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Liberia, Madagascar, Mali, Mauritiania, Mauritius, Niger, Nigeria, Sao Tome And Principe, Senegal, Seychelles, Sierra Leone, Togo

**AFRO E** Botswana, Burundi, Central African Republic, Congo, Cote d'Ivoire, Democratic Republic Of The Congo, Eritrea, Ethiopia, Kenya, Lesotho, Malawi. Mozambique, Namibia, Rwanda, South Africa, Swaziland, Uganda, United Republic of Tanzania, Zambia, Zimbabwe.

**AMRO D** Bolivia, Ecuador, Guatemala, Haiti, Nicaragua, Peru

**SEARO B** Indonesia, Sri Lanka, Thailand

**SEARO D** Bangladesh, Bhutan, Democratic People's Republic of Korea, India, Maldives, Myanmar, Nepal

**WPRO B** Cambodia, China, Lao People's Democratic Republic, Malaysia, Mongolia, Philippines, Republic of Korea, Viet Nam