The importance of forest protected areas to drinking water

Running**Pure**

A research report by the World Bank / WWF Alliance for Forest Conservation and Sustainable Use

Running Pure: The importance of forest protected areas to drinking water

A research report for the World Bank / WWF Alliance for Forest Conservation and Sustainable Use

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Preface

Three years ago, WWF and IUCN's World Commission on Protected Areas organised a conference on management effectiveness of protected areas in Bangkok. One of its major conclusions was that, if protected areas are to be maintained in the long term, their essential roles and broader services, beyond biodiversity conservation, need to be emphasised. Many governments are finding it increasingly difficult to justify the maintenance of protected areas, if the wider benefits for local communities and the society at large cannot be demonstrated.

This report represents an early attempt to develop wider arguments for protection, focusing on one narrow but important issue – the potential role of protected areas in helping to maintain water supply to major cities.

It is a good time to look at the links between water and protected areas. The United Nations has proclaimed 2003 as the *International Year of Freshwater*, to help promote new and existing water resource initiatives. IUCN's *World Parks Congress (WPC)* in September 2003 provides a once-in-a-decade global focus on protected areas and their importance. The role, definitions, boundaries and management of protected areas are receiving particular attention from governments and non-governmental organisations, corporate bodies and development agencies. Two key issues have been prominent in the discussions leading up to the WPC: the need to stress the arguments for protected areas away from a narrow focus on biodiversity into other values (the congress is named *Benefits beyond Boundaries*) and the importance of securing enough resources to manage protected areas effectively. The links between protected areas and drinking water thus touches some of the most central natural resource management issues in the world today.

Water, as we shall show, provides a powerful argument for protection. Through payment for environmental services it can also help to defray the costs of managing protected areas if, as is increasingly the case, governments introduce charges for pure water coming from forests protected by the state.

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Contents

Executive summary

Well managed natural forests provide benefits to urban populations in terms of high quality drinking water:

- Well managed natural forests almost always provide higher quality water, with less sediment and fewer pollutants, than water from other catchments
- Some natural forests (particularly tropical montane cloud forests and some older forests) also increase total water flow, although in other cases this is not true and under young forests and some exotic plantations net water flow can decrease
- Impacts of forests on security of supply or mitigating flooding are less certain although forests can reduce floods at a local headwater scale
- As a result of these various benefits, natural forests are being protected to maintain high quality water supplies to cities
- Protection within watersheds also provides benefits in terms of biodiversity conservation, recreational, social and economic values
- However, care is needed to ensure that the rural populations living in watersheds are not disadvantaged in the process of protection or management for water quality

Maintaining high quality water supply is an additional argument for protection:

- Many important national parks and reserves also have value in protecting watersheds that provide drinking water to towns and cities
- Sometimes this is recognised and watershed protection was a major reason for establishing the protected area – here watershed protection has sometimes bought critical time for biodiversity, by protecting natural areas around cities that would otherwise have disappeared
- In other cases, the watershed values of protected areas have remained largely unrecognised and the downstream benefits are accidental
- Where forests or other natural vegetation have benefits for both biodiversity and water supply, arguments for protection are strengthened with a wider group of stakeholders
- In some cases, full protection may not be possible and here a range of other forest management options are also available including best practice management (for example through a forest management certification system) and restoration

The watershed benefits of forest protected areas could help to pay for protection:

- The economic value of watersheds is almost always under-estimated or unrecognised
- It is possible to collect user fees from people and companies benefiting from drinking water to help pay for the catchment protection benefits provided by protected area management – although only in certain circumstances
- Payment for water services can also be one important way of helping negotiations with people living in or using watersheds to develop land-use mosaics that are conducive to maintaining high quality drinking water supplies

Many of the world's largest cities rely on drinking water from protected areas:

- Around a third (33 out of 105) of the world's largest cities obtain a significant proportion of their drinking water directly from protected areas
- At least five other cities obtain water from sources that originate in distant watersheds that also include protected areas
- In addition, at least eight more obtain water from forests that are managed in a way that gives priority to their functions in providing water
- Several other cities are currently suffering problems in water supply because of problems in watersheds, or draw water from forests that are being considered for protection because of their values to water supply

Rationale for the project

Forests and freshwater systems interact in many different ways: through soil stability and sediment load; fisheries and fish hatching; the impacts of different tree species on acidification of water; mitigation of incidence and severity of flooding from headwater catchments; management of downstream water logging and salinity; influencing the availability of water for irrigation systems; maintaining the quality of water for industrial purposes; and so on. Issues relate to the presence of forests, forest type, management systems and choices relating to afforestation and reforestation. Many of these interactions are complex and their precise nature and significance remains the subject of debate between hydrologists, natural resource economists and ecologists.

In the following report we focus on one specific interaction: the role of forests, and particularly protected forests, in maintaining quality of drinking water for large cities.

There are many reasons for this focus: many city dwellers already face a crisis of water quality, and contaminated water spreads a vast and largely unnecessary burden in terms of short and long-term health impacts including infant mortality, with knock-on effects on ability to work, industrial productivity and on already over-stretched health services. The poorest members of society, unable to afford sterilised or bottled water, suffer the greatest impacts. Similar problems affect the rural poor as well of course, and sometimes these can be even more severe. However, in a rapidly urbanising world the scale of the problem facing cities is particularly acute[1].

The issue also seems one of particular relevance to the World Bank-WWF Alliance and its targets on increasing extent and effectiveness of forest protected areas and extent of well-managed forests outside protected areas[*]. Given that both organisations also have extensive freshwater programmes, and the World Bank has a large portfolio of projects looking specifically at drinking water, linking the forest targets with water catchments is a logical next step in developing cooperation between the two institutions. In addition, the third element in the WWF *Forests for Life* programme is forest landscape restoration, an issue currently not addressed by the Alliance; one important driver for forest restoration is the need to restore functioning watersheds, so that drinking water could also provide the means for the Alliance partners to extend their work into restoration issues.

2003 has been proclaimed by the United Nations, the International Year of Freshwater, providing a platform for promoting existing activities and spearheading new initiatives in water resources at the international, regional and national levels. Currently one person in six lives without regular access to safe drinking water, and 2.4 billion people lack access to adequate sanitation. Water related diseases kill a child every eight seconds. The global focus on water is intended to accelerate implementation of the targets in the UN Millennium Development Goals, and those set by the World Summit on Sustainable Development in 2002, to: develop integrated water resources management and water efficiency plains by 2005; halve by the year 2015 the portion of people who are unable to reach or afford safe drinking water and who are without access to basic sanitation; and achieve by 2010 a significant reduction in the current rate of loss of biological diversity.

There is another specific reason to focus on forest protected areas at the moment. The occurrence of the World Parks Congress (WPC) in September 2003 provides a rare global focus on protected areas. The role, definitions, boundaries and survival of protected areas will get particular attention from governments and non-governmental organisations, corporate bodies and development agencies.

[*] The Alliance targets are, by 2005, to have created 50 million hectares of new forest protected areas around the world, increased management effectiveness on 50 million hectares of existing protected areas and developed independent certification of good forest management on 200 million hectares of managed forest by working with governments, the private sector and civil society.

Two key issues have come to the fore in the discussions leading up to the WPC: the need to extend the arguments for protected areas away from a narrow focus on biodiversity into other values (the whole congress is named "Benefits beyond Boundaries") and the need to find sustainable funding to manage protected areas effectively. Water, as we shall show in the following report, provides a powerful argument for protection in many cases. Through payment for environmental services, it can also help to defray the considerable costs of management if, as is increasingly the case, governments and other forest owners introduce charges for pure water coming from forests protected by the state. Indeed, privately managed protection forests are also starting to emerge in some parts of the world.

There was also a desire by the research team to move away from an over-reliance on case studies to argue a particular point of view. Specific case studies relating to the link between forests and freshwater have been well documented and frequently repeated and have certainly helped create interest in the issue. But how representative were these of the situation in most countries and most cities? We wanted, as far as is possible in a brief research project, to supply some statistics about how important forests are to urban water supplies. We therefore looked at the world's top 100 cities[†] and provided an overview of how many relied on water from protected areas for some or all of their drinking water supply.

What appeared initially to be a fairly simple question became more complex in its unravelling. Finding the information proved a challenge, but also revealed many layers of complexity. What exactly constituted a forest protected area? We had assumed official protected areas, as designated by IUCN The World Conservation Union, but found many other categories of protection, some specifically aimed at watershed protection and often with their wider values only poorly understood. In some catchments (for example around Beijing), "protection" actually means integrated management, with special controls on the type of farming and other land uses rather than on protecting forests. Not all forests set aside for catchment protection also have high biodiversity values. In some areas, governments recognise the need for restoration, or have reforestation projects already underway in important catchments. It has also become clear that the role that some official protected areas play in watershed management is barely recognised by either protected area managers or water authorities.

This wider picture mirrors the development within the Alliance as well. At present, WWF is consciously attempting to integrate its work on forest protected areas, good forest management outside protected areas and forest landscape restoration into a protect-manage-restore approach at landscape level, working in priority conservation landscapes selected by an ecoregional planning process. Therefore while the main focus of the current report remains on forest protected areas, issues of management and restoration are also addressed and feature in the policy recommendations.

We are well aware that this is a preliminary study that points the way to the need for further research, rather than providing all the answers. The main report, which follows, is supplemented by three essays, written by specialists, looking at specific issues relating to hydrology, economics and social issues, in each case giving an overview but also asking some of the questions that need to be addressed when considering the use of forest protection in terms of urban water supply. The key statistics are contained in an analysis of the world's top cities and some of these examples are then examined in greater detail in a series of short assessments.

We hope that this will be the first in a series of analyses that look at wider arguments for protected areas and other forms of habitat protection.

[†] Actually the top 105 by population, divided between the Americas (25), Africa (25), Europe (25), Asia (25) and Australia (5)

Part 1: The importance of forest protected areas to drinking water

Introduction: what do city dwellers need?

In the past 100 years the world population tripled, but water use for human purposes multiplied sixfold![2]

Water is, in theory, a quintessentially renewable resource. Most of the world's surface is covered in water and over much of the world it falls, unbidden and with great regularity, from the skies. Yet, the carelessness and profligacy with which water resources have been used, the speed of human population growth and the increasing per capita demands for water together mean that provision of adequate, safe supplies of water is now a major source of concern, expense and even international tension. At the World Summit on Sustainable Development in Johannesburg in 2002, over 80 per cent of the participating decision-makers identified water as a key issue to be addressed by Heads of State from countries throughout the world[3].

Overall, the greatest human requirement for freshwater resources is for crop irrigation, particularly in places where farming takes place in arid regions and in the great rice paddy fields of Asia. Municipal water – the focus of the current study – accounts for less than a tenth of human water use[4]. But the need for clean drinking water is of critical importance to the growing proportion of the world's population that live in cities. Wherever a breakdown in water supply occurs, because of disasters like earthquakes, floods, wars or civil unrest, immediate and acute problems occur and reliance on contaminated water results in the rapid spread of diseases like cholera and infant diarrhoea.

Unfortunately, for many people there is no need for a disaster to make them dependent on unclean drinking water. Today, around half of the world's population lives in towns and cities, and of this urban population one third, an estimated one billion people, live without clean water or adequate sanitation, despite these services widely being regarded as basic prerequisites of a decent life. These one billion extreme have-nots are unevenly distributed around the world. Regionally, it has been estimated that 700 million people in urban Asia, or half the urban population, do not have adequate water supplies; nor do 150 million people in Africa, again about 50 per cent of the city dwellers; with a further 120 million people, about 30 per cent of the urban population, lacking clean water in Latin America and the Caribbean[5]. Many people die each year as a direct result. Annually, 2.2 million deaths, four per cent of all fatalities worldwide, can be attributed to inadequate supplies of clean water and sanitation[6].

These problems are likely to increase in the future as the current rapid processes of population growth and urbanisation continue. The average size of the world's 100 largest cities grew from around 0.2 million in 1800 to 6.2 million in 2000[7]. In 1900, there were estimated to be just 43 cities worldwide with a population of over half a million, by 1990 this figure had risen to around 800 cities worldwide – of which some 270 had more than one million and 14 had over 10 million[8]. These trends are likely to continue for some time. Most current estimates suggest that the world's population will grow by two billion people over the next 30 years and another billion in the following 20 years. Virtually, all of these increases will be in developing countries, the bulk of which will occur in urban areas[9]. In India, for example, World Bank forecasts are that demand for water in the urban and industrial sectors is likely to increase by 135 percent over the next 40 years[10].

In many arid countries, there is already an acute supply shortage. World water withdrawals rose six-fold over the last century. It has been estimated that humanity now uses 54 per cent of accessible runoff, a figure that could rise to 70 per cent by 2005[11]. For several countries, current reliance on non-renewable (or only very slowly renewable) groundwater sources masks a problem that could rapidly become more acute as these are exhausted. Because of population growth, the average annual per capita availability of renewable water resources is projected to fall from 6,600 cubic metres today to 4,800 cubic metres in 2025[12]. In 1998, 28 countries experienced water stress or scarcity (defined when available water is lower than 1,000 cubic meters per person per year). By 2025, this number is predicted to rise to 56[13]. As the number of people in urban areas grows, so does the demand for water, food and for irrigation in agricultural areas close to the city adding further pressures on water resources.

The demand for water, along with increasing pressures on water from pollution, urbanisation and overexploitation of aquatic resources, is also creating a biodiversity crisis in freshwaters[14].

Although future supply problems are expected, with a few notable exceptions the current shortfall in clean water for city dwellers is seldom to do with a real lack of supply but more related to poor distribution, inadequate treatment and to some extent also poor education and a lack of understanding about the problems. For example, up to 50 per cent of the urban water in many African cities is being wasted through leakage, theft or is otherwise unaccounted for[15]. (Conversely Melbourne, after a seven year period of extreme drought, is still supplying its citizens with some of the best quality drinking water in the world[16].) Efforts are being made to address these problems. Over the past 20 years for instance more than 2.4 billion people have gained access to water supply and 600 million to sanitation[17]. The United Nations Millennium Summit in 2000 agreed to reduce halve the 1.1 billion people who do not have access to safe water by 2015, as part of its Millennium Development Goals[18].

Cities therefore face immediate problems of access to clean water and sanitation and mounting problems of supply. In recent years, increasing interest has been taken in the opportunities for maintaining urban water supplies (and perhaps even more importantly water quality) through management of natural resources. Unfortunately, the links often come into focus when something goes wrong – most commonly when resource management upstream has downstream impacts in terms of changes in water supply, increased flooding and reduced water quality. The majority of the world's population live downstream of forested watersheds and therefore are susceptible to the costs of watershed degradation[19]. At the same time, 28 per cent of the world's forest areas are in mountains, and mountains are the source of some 60 to 80 per cent of the world's freshwater resources[20]. Hence the importance of this report.

The protected areas and protected forests identified below all play a role in providing drinking water for the world's biggest cities. More often than not this water also helps feed the people, through irrigation of crops, provide electricity through hydro-electric plants, and has a recreation, aesthetic and even religious function. Of course protected areas are just one tool in a range of watershed conservation models, that can have costs of their own, but it is hoped that by highlighting their role this report will add to the growing literature extolling the benefits of long-term protection to some of the world's most important resource areas.

Options for providing water

Most of the world's drinking water comes from surface waters (rivers, lakes or artificially constructed reservoirs) or from underground aquifers; an increasing number of countries are also investing in desalination plants to extract drinking water from the oceans. All sources face costs and problems, the latter including over-exploitation and pollution.

Municipal authorities have a variety of ways of supplying drinking water, depending on where they are located, how much resources they can afford to devote to water supply and on issues relating to social and political structure and the willingness of the population to practice water conservation measures. The vast majority of cities rely on the collection and diversion of existing freshwater sources, with minor amounts, on a global scale, extracted directly from rainwater or from the seas. Key supply routes are outlined below:

- **Direct extraction from natural surface waters, including lakes, river and streams**: such sources are amongst the most straightforward in terms of supply but in many situations require considerable processing to remove contaminants. Inhabitants of the city of Paris, for example, mainly drink water extracted from the Seine while Londoners rely on the River Thames (and it is estimated that most water from the taps has already been drunk and recycled 6-7 times).

- **Direct extraction from underground aquifers**: including both those that are renewed regularly and seasonally, and those where renewal is far slower and extraction is therefore, in the short-term, non-renewable. Currently, for example, many Middle Eastern countries rely heavily on non-renewable aquifers while the city of Milan extracts water from aquifers that are refilled more regularly. Groundwater supplies about one third of the world's population; an estimated 65 per cent of public water supplies in Europe come from groundwater sources and withdrawal in the European Union rose by 35 per cent between 1970 and 1985[21].

- **Collection of water in surface reservoirs**: either near to a city or further away; in the later case transportation becomes costly. Establishment of dams and reservoirs has become enormously controversial, both in terms of loss of land and because stemming natural water flow affects people, countries further downstream and aquatic life[22]. From a water supply perspective however, such dams often result in relatively pure water that needs comparatively little treatment: ultimately purity depends on land use within the catchments. Most cities rely on some form of reservoir, near or far.

- **Desalination plants**: the world's oceans are the largest source of water, but with too high a salt content to drink. Some countries with low freshwater supplies and abundant energy sources (fossil fuel or solar) have developed desalinisation plants to provide drinking water; this is currently a major source in Saudi Arabia for example and around the world 11,000 desalination plants contribute to drinking water supplies in 120 countries[23].

- **Rainwater harvesting**: smaller scale options also exist, including working with communities to develop direct methods of rainwater harvesting through individual or community reservoirs, collecting water from roofs, temporary streams and other easily accessible sources. Direct collection of rainwater, if practised correctly, can result in high quality water with little need for further treatment, but is obviously dependent on seasonal climatic conditions and is a source likely to be particularly vulnerable to climate change. China has developed rainwater harvesting in Gansu province and it is important in north-east Thailand; interest is not confined to developing countries and for example subsidies are available to encourage construction of rainwater tanks and seepage wells in Germany[24].

- **Water recycling**: re-use of water is encouraged in many areas, although not usually for drinking; recycling and re-use can however take the pressure off piped water supplies and thus reduce overall need for water. Re-use of drainage water can be a major supply source in areas where intensive surface irrigation is currently practised and is important for instance in the eastern Nile delta of Egypt, the north China plains, the Arkansas valley in Colorado and in Australia[25].

- **Bottled supplies**: in many of the world's cities, bottled water has become increasingly popular, in part due to fashion and good marketing and in part to genuine concerns about quality of tap water. Many of those who can afford to buy bottled water in the cities of Africa and Asia choose to do so, even if they have access to piped water, because of fears of contamination. Bottled water has become increasingly popular in Europe and North America, and worldwide sales have reached $22 billion. In part this is because of concern about pollution by nitrate, with human activities having increased the load in rivers by a factor of 2-4[26], although the relative health impacts are unclear and bottled water can have a higher bacterial contamination than tap water in these areas and far higher resource and energy costs[27].

All major water supplies have a variety of problems. Some countries are facing genuine shortages although in many others the problems relate more to access and transport: about 50 developing countries, mainly in Africa, still use less than 1 per cent of their available freshwater resources[28]. Withdrawal of water from riverine transboundary sources, such as the Nile or rivers in the Middle East are creating actual or potential political tensions and are also causing many rivers to dry up far from their outlets to the sea, with a range of ecological and economic consequences. For example, there have been long term tensions between Turkey, Iraq and Syria relating to extraction from the Euphrates-Tigris basin[29] and between Afghanistan and Iran regarding access to water from the Helmand River.

Over-exploitation of groundwater resources is a major problem in many developed and developing countries – for example in the American Great Plains, China, India, Mexico and the southern states of Central Asia – resulting in water tables falling in some cases tens of metres because underground aquifers are being drawn down too quickly to be replenished. Saline intrusion into groundwater sources is a problem for many coastal cities, such as Jacksonville, Florida, Dakar in Senegal and several Chinese cities[30] and over-extraction can also lead to subsidence.

Pollution of all water sources provides major problems, both in terms of cost and health, with pollutants coming mainly from agriculture, sewage, industry and resource activities such as mining[31].

Until recently, the main focus of efforts to improve urban water sanitation and supply have focused within the cities themselves, on better distribution systems, treatment plants and sewage disposal. However, throughout the world, municipal authorities are now increasingly looking up into the hills towards the forested watersheds that supply their precious drinking water and at ways in which improvements can be made at source.

What forests can provide

*Much of the world's drinking water comes from catchments that are or would naturally be forested. There appears to be a clear link between forests and the **quality** of water coming out of a catchment, a much more sporadic link between forests and the **quantity** of water available and a variable link between forests depending on type and age and the **constancy** of flow. Forests therefore often provide the basis for integrated management of water resources, although precise effects vary from place to place and have been the subject of dispute amongst hydrologists. Knowledge of the type and age of trees, soil conditions and user needs can help determine what kind of forest management policies will be most beneficial.*

> *The loss of forest cover and conversion to other land uses can adversely affect freshwater supplies, threatening the survival of millions of people and damaging the environment[32].*
>
> UN Food and Agriculture Organization
>
> *Integrated water resources management is based on the perception of water as an integral part of the ecosystem, a natural resource and a social and economic good, whose quantity and quality determine the nature of its utilization. To this end, water resources have to be protected, taking into account the functioning of aquatic ecosystems and the perenniality of the resource, in order to satisfy and reconcile needs for water in human activities[33].*
>
> "Agenda 21"

Quantity, quality and regularity

There is a widespread assumption that forests provide useful ecosystem functions in maintaining constant supplies of good quality water. Loss of forests has been blamed for everything from flooding to aridity and for catastrophic losses to water quality.

In fact, the hydrological role of forests remains the subject of a debate. The impacts of land use on water resources depend on many ecological and socio-economic factors, making generalisations difficult. Natural factors include climate, topography and soil structure, while socioeconomic factors include economic ability and awareness of the farmers, management practices, and the development of infrastructure[34]. The precise impact of forested catchments on water supply therefore varies dramatically between places and can also vary in one place depending on such factors as the age and composition of the forest.

For the present report, we have been lucky enough to have a specially–prepared analysis by Professor Lawrence Hamilton, with David Cassells of the World Bank, which goes a long way to addressing the myths on both sides and to providing an overview that will be of use to those charged with making policy about drinking water. But no-one should assume that there is consensus as yet. The following section draws both on the Hamilton essay and recently published material by FAO and others.

*There appears to be a clear link between forests and the **quality** of water coming out of a catchment, a much more sporadic link between forests and the **quantity** of water available and a variable link between forests and the **constancy** of flow.*

Quality: forests in watersheds generally result in higher quality water than alternative land uses, if only because virtually all alternatives – agriculture, industry and settlement – are likely to increase the amounts of pollutants entering headwaters and also because in some cases forests help to regulate soil erosion and hence reduce sediment load (although the extent and significance of this will vary[35]). While there are some contaminants that forests are less able to control – the parasite *Giardia* for example – which is spreading gradually throughout North America as an invasive species, in most cases presence of forests will substantially reduce the need for treatment. Where municipalities have protected forests to protect water supply, it is issues of water quality that have generally been the primary driving forces and this is the focus of much of our report.

If forests are managed other than for protection, the type of management has significant impacts on water quality. There have been many studies of the impacts of forest management on water quality[36], which have generally shown that sediment yield increases after timber harvesting[37], but also that changes in management practices can help reduce this damage[38]. Applying fertilizer without using best management practices can also result in water pollution[39] and governments have addressed the impacts of these and other forestry practices through legislation, such as the Clean Water Act in the USA[40].

Quantity: the situation with regard to the flow of water from catchments is more complex. Despite years of catchment experiments, the precise interactions between different tree species and ages, different soil types and management regimes are still poorly understood in many situations, making accurate predictions difficult. The impact of land use on runoff depends on many variables, the most important being the water regime of the plant cover in terms of evapotranspiration, the ability of the soil to hold water (infiltration capacity), and the ability of the plant cover to intercept moisture[41].

In contrast to popular understanding, many studies suggest that both in very wet and very dry forests, evaporation is likely to be greater from forests than from land covered with other sorts of vegetation, leading to a decrease in water from forested catchments as compared with, for example, grassland or crops[42], although there are important exceptions to this as outlined below. For example, a review of 94 catchment experiments concluded that the establishment of forest cover on sparsely vegetated land decreases water yield, due to higher evapotranspiration[43].

Planting new forests, particularly of species with high evapotranspiration rates, can often lead to reduced water flow. The debate about the hydrological impacts of eucalypts has continued for many years[44] and prompted a review by the Food and Agricultural Organisation of the United Nations[45], which concluded that eucalypts are likely to reduce water yield and that in the humid tropics, young eucalyptus plantations may consume more water and regulate flow less well than natural forests. A number of observations from South Africa indicate that increased dry period transpiration following forestation with pine or eucalyptus species will significantly reduce low season water flows[46]. Planting *Eucalyptus grandis* in the Mokobulaan research catchments resulted in streams drying up completely nine years after planting. When the eucalypts were clear-felled after 16 years, perennial stream flow did not return for a further five years, the long lag time being thought to be due to very deep soil moisture deficits generated by the eucalypts, which required many years of rainfall before field capacity conditions could be re-established[47]. In the Mae Thang watershed in Thailand, afforestation programmes also led to water shortages downstream, which resulted in a seasonal closure of a water treatment plant and lower availability for irrigation[48]. In Fiji, large-scale pine afforestation in watersheds previously covered by grassland led to reductions in dry-season flow of 50-60 percent, putting the operation of a hydro-electric plant and drinking water supply at risk[49]. Research in Nepal suggests that it is only several decades after tree planting that the rainfall absorption capacity of a once degraded soil starts to come anywhere near its former value under natural forest conditions[50].

Natural forests have a more complicated relationship with water flow and some appear to increase flow rates. The most significant example is cloud forest, where leaves collect water from clouds and this additional water may exceed transpiration losses. Recent work in northern Costa Rica suggests that the pattern of cloud formation above forested and cleared areas differs[51]. In addition, some very old forests also apparently increase available water, for instance research suggests that mountain ash (*Eucalyptus regnans*) of 200 years or more in Australia increases water flow[52] and depending on the species, old forests may consume less water than the vegetation that establishes itself after clear-cutting[53].

In general, the evidence seems to suggest that cloud forests and some older natural forests can increase net water flow, but that some other types of forests – including particularly young forests and plantations, are likely to have the reverse effect. Local variations may change these general tendencies.

Regularity: as important as total water is constancy of flow, both in terms of maintaining dry season flow and reducing sudden surges in water and resulting flooding during periods of heavy rain. Here opinion remains divided and examples of very different responses can be found: in some cases dry season flow is depressed by the presence of trees while in other cases it is increased. There are differences between natural forests and plantations, but again these differences do not show a constant trend. There is also little evidence that forests regulate major floods, although flooding was the reason for introducing logging bans in, for example, Thailand and parts of China. One important exception to this general rule is flooded forests, which do appear to have a role in regulating water supply, both lowland forests such as the Varzea forests on the Amazon and swamps in the uplands. Furthermore forested catchments can have important local impacts in regulating water flow, so for example are an important components in the landscape for people and communities in upland areas.

In addition, the undisturbed forest with its understory, leaf litter and organically enriched soil is the best watershed land cover for minimizing erosion by water. Any activity – such as litter collection, fire, grazing or scraping in logging – that removes this protection increases erosion. In minimizing water erosion, forests reduce the problem of sedimentation: the carrying or deposition of soil particles in water courses. Suspended soil in water supplies can render potable or irrigation water unfit for use, or greatly increase costs to make it useful.

What forests provide therefore depends to a large extent on individual conditions, species, age, soil types, climate, management regimes and needs from the catchment. Information for policy makers remains scarce and models for predicting responses in individual catchments are at best approximate.

The policy response

Towns and cities are therefore faced with a bewildering diversity of opinions on which to make hard financial and politically-charged decisions about their water supply. Not surprisingly, they have reacted in a variety of ways.

Quite a number of municipalities already cite maintenance of water supply as a reason for introducing forest protection or reforestation; for example reforestation of the Pyrenees in Spain is being promoted by the government to improve downstream water resources[54]. In a number of cases there is good evidence that forests can help maintain water flow – for example in Melbourne in Australia as discussed below (page 74) and in some cities fed by cloud forests as is the case for the Caribbean National Forest in Puerto Rico[55]; in other cases this decision is based on belief rather than hard science.

A larger number of users refer to the link between forest and water quality. In France, Perrier-Vittel, the world's largest bottler of natural mineral water, draws its most important water sources from heavily farmed watersheds where nutrient runoff and pesticides threaten the aquifers that the company relies upon. As a response, Perrier-Vittel has found that reforesting sensitive infiltration zones, financing farmers to build modern facilities, and switching to organic farming practices are cheaper than building filtration plants[56].

Some water authorities already make the link between protecting for water and protecting for nature – the link that lies at the heart of this report and which will be discussed in more detail later. In the USA, all states are required under federal law to complete a Source Water Assessment by 2003, which promotes the idea that protecting drinking water at the source is the most effective way of preventing drinking water contamination[57] and many examples of watershed protection come from there. Around 85 per cent of San Francisco's drinking water comes from the Hetch Hetchy watershed, an area located in Yosemite National Park (Category II, 308,273 ha) that captures water inflows from the watershed in the Hetch Hetchy Reservoir and snowmelt runoff from the Tuolumne River[58]. Further up the coast in Seattle, Washington, the primary sources of water are the Cedar River watershed (36,650 ha) and the South Fork Tolt watershed (5423 ha), which together serve a population of 1.2 million people with unfiltered drinking water. To protect the endangered and threatened species in its Cedar River Watershed, while maintaining stringent water quality standards, Seattle has developed a *Habitat Conservation Plan*, which includes commitments to establish an ecological reserve on about 64 per cent of the land it owns and operates; and to develop a programme to manage the commercial harvest of timber on lands not part of the ecological reserve[59]. As part of these efforts, Seattle does not permit agricultural, industrial, and recreational activities in the watersheds, and residential use of the watersheds is prohibited[60].

The city of New York is famous for its use of protected forests to maintain its high quality water supply and is described in a later case study. But other cities in the region also rely on forested catchments. The Pine Barrens ecosystem covers some 567,000 ha, making up almost 30 per cent of the state of New Jersey. The area contains a huge aquifer in the middle of New Jersey (the Cohansey aquifer containing 17 trillion gallons of water), which supplies water to hundreds of thousands of people, living in the densely populated townships south of New York and east of Philadelphia.[61] The Pinelands National Reserve is 445,500 ha; nested within this area is 378,270 ha managed by Pinelands Commission. Among the primary motivations for its protection is the desire to protect the aquifer, which is particularly vulnerable because it lies under sandy soil in an area that is expected to undergo enormous development, and the forest also maintains an important berry industry. The area contains the Category V protected area, the Pinelands National Reserve (438,210 ha).

In Europe, many forest authorities also explicitly cite watershed functions within their plans. The Bavarian alpine forest *Plan of Forest Functions* for instance identifies and maps all forest functions, and reports that site protection involves 40 per cent of forests, protection against avalanches 22 per cent and protection of water resources 46 per cent[62].

Such activities are not confined to Europe and North America. The Mount Makiling Forest Reserve, around a hundred kilometres south of Manila in the Philippines is a 4,244 ha area of forest administered and managed by the University of the Philippines, Los Baños. It is an important resource due to its biological, watershed, recreational, geothermal, educational and other scientific values. It is also a major source of employment and economic benefit to its immediate and surrounding communities. More than 50 per cent of the reserve is forested and its watershed ecosystem supplies water to five water districts and several water cooperatives that provide water for domestic, institutional and commercial water users. Recreational areas in the reserve are maintained through user charges. In principle, these fees are expected to ration the use of resources, by reducing congestion and resource degradation[63].

While a growing number of local and national governments are turning to forested areas for their water supply, the reasons for doing so often remain in dispute. In Panama, reforestation in catchments has been promoted both to reduce sediment load into the canal and to increase overall water flow. Panama City and Colon's drinking water comes from the watershed of the Panama Canal[64]. It was estimated that if 1,000 ha/year of deforested land in the watershed was reforested, it would not be necessary to construct an additional dam proposed for the Rio Ciri[65] and on the basis of these predictions new laws were passed (with USAID support) to promote forestation of the Panama catchments as a means of enhancing flows and improving the functioning of the canal[66]. However, the science was challenged by consultants from the World Bank, who questioned whether the evidence justified using public funds to reforest pasture areas and concluded that forest cover would not necessarily improve dry season stream flow[67]. Meanwhile the role of the trees in reducing sedimentation continues to be debated and for example the Director of Watersheds and the Environment of Panama's Canal Ministry was reported as saying that his department would support massive reforestation efforts to protect the Canal's water supply[68].

Forests therefore offer a range of options for water quality, depending on their type, location, age and on what water users need. A growing number of towns and cities around the world are recognising this and working with landowners and users in catchments to maximise water benefits, although often struggling with inadequate data on likely impacts. Some of the more general management implications are examined in the following section.

Management options for watersheds

Once the potential benefits of forested watersheds are recognised, a number of different management options exist, including protection, sustainable management and, where necessary, restoration. First, decisions need to be made about the potential benefits from forests

Managers are faced with a number of critical questions: about whether forested watersheds offer real benefits; how much forest is required to gain benefits for water; and how it can best be managed. In most cases choices will not relate just to supply of water, but this priority will have to jostle for space with other demands on the land, so that management for water will have to be balanced and traded off with management for other uses. The table below outlines some questions that need to be addressed before any decisions are made about management of forests.

<table>
<tr><th>Issue</th><th>Details</th></tr>
<tr><td>What kind of water supply is required?</td><td>A number of questions relating to the type of water supply are important
▪ Are the pressures on water supply primarily driven by the need to get enough water, or a constant supply of water, or is the priority more to do with water quality?
▪ What quality issues are most important? (For example amount of sediment will be most important for hydropower uses whereas pollutants like agrochemicals will also be of key concern for drinking water)</td></tr>
<tr><td>How is vegetation in the catchment likely to affect water quality and flow?</td><td>This question needs specialist analysis; although some generalisations can probably be made (cloud forests are likely to increase water, some old natural forests may also increase flow, young forests and plantations are likely to decrease flow) individual cases need to be assessed in turn, depending both on conditions (soil, climate, forest types and age, management regime) and on need</td></tr>
<tr><td>What is land use?</td><td>Current status is important, but so are recent changes and likely future trends</td></tr>
<tr><td colspan="2">Answering these three questions will help to determine what natural vegetation (and perhaps also other land uses) in the catchment offers in terms of water supply and whether future changes are likely to create problems or conversely whether planned changes could improve net benefits. With this information, more strategic analysis can help plan optimum management interventions.</td></tr>
<tr><td>What other demands are there on land in the catchment?</td><td>Some questions to determine both other pressures on the land and also how much land might be available for water management
▪ Are other pressures on land likely to improve or degrade water?
▪ How much land is available, partially or completely, for water management?
▪ Can current land uses be improved from the perspective of the water from the catchment?
▪ What impacts would watershed management have for local people and what are their needs and wishes?</td></tr>
<tr><td>What are realistic management options?</td><td>An analysis of present and future management and options including:
▪ Protected areas
▪ Other forms of protective forest
▪ Managed forests
▪ Areas requiring forest restoration
▪ Other forms of land use</td></tr>
<tr><td colspan="2">The analysis should tell whether the presence of forests can help the supply of water required from the catchment and provide the information needed to make informed choices about a landscape mosaic that will fulfil both water needs and other needs from the watershed.</td></tr>
</table>

Different water supply options will also have impacts on freshwater and estuarine habitats, and on local people. The World Commission on Dams (2000) proposed guidelines to minimise impacts from both existing and proposed dams, such as measures to maintain fish populations in dammed rivers. For new dams the Commission recommended a 'needs assessment', and if there was not a better alternative to a dam, an 'options assessment' to identify the best way to maximise benefits and minimise impacts[69]. WWF (2003) has produced a simple guide to investing in dams[70].

Different approaches to management

Following on from an assessment of needs and options, those interested in management for water then have a portfolio of different management options to choose from, ranging from various forms of protection through different types of management to restoration in cases where forest has already degraded or disappeared. While our principle interest here is on the link between watersheds and protected areas, significant links with management and restoration are also apparent in the land uses within many catchments serving towns and cities and so these are considered briefly as well

Protection

Forests can be protected in a variety of ways: as official "protected areas" as recognised by IUCN's World Commission on Protected Areas or as various other kinds of protective forest. A recent survey by the United Nations Economic Commission for Europe and the Ministerial Conference on the Protection of Forests in Europe found over 500 designations of protection for forests in Europe alone[71]. Some wetlands supplying water to urban areas and their forest watersheds have also been designated as protected areas under the Ramsar Convention on Wetlands.

- **The IUCN Protected Area Management Categories**

IUCN – The World Conservation Union has developed a definition and a series of categories of protected areas: as outlined below[72]. The overall definition and categories are as follows:

Definition: *An area of land and/or sea especially dedicated to the protection and maintenance of biological diversity, and of natural and associated cultural resources, and managed through legal or other effective means*.

Category Ia: ***Strict nature reserve/wilderness protection area managed mainly for science or wilderness protection*** – an area of land and/or sea possessing some outstanding or representative ecosystems, geological or physiological features and/or species, available primarily for scientific research and/or environmental monitoring.

Category Ib: ***Wilderness area: protected area managed mainly for wilderness protection*** – large area of unmodified or slightly modified land and/or sea, retaining its natural characteristics and influence, without permanent or significant habitation, which is protected and managed to preserve its natural condition.

Category II: ***National park: protected area managed mainly for ecosystem protection and recreation*** – natural area of land and/or sea designated to (a) protect the ecological integrity of one or more ecosystems for present and future generations, (b) exclude exploitation or occupation inimical to the purposes of designation of the area and (c) provide a foundation for spiritual, scientific, educational, recreational and visitor opportunities, all of which must be environmentally and culturally compatible.

Category III: ***Natural monument: protected area managed mainly for conservation of specific natural features*** – area containing specific natural or natural/cultural feature(s) of outstanding or unique value because of their inherent rarity, representativeness or aesthetic qualities or cultural significance.

Category IV: ***Habitat/Species Management Area: protected area managed mainly for conservation through management intervention*** – area of land and/or sea subject to active intervention for management purposes so as to ensure the maintenance of habitats to meet the requirements of specific species.

Category V: ***Protected Landscape/Seascape: protected area managed mainly for landscape/seascape conservation or recreation*** – area of land, with coast or sea as appropriate, where the interaction of people and nature over time has produced an area of distinct character with significant aesthetic, ecological and/or cultural value, and often with high biological diversity. Safeguarding the integrity of this traditional interaction is vital to the area's protection, maintenance and evolution.

Category VI: ***Managed Resource Protected Area: protected area managed mainly for the sustainable use of natural resources*** – area containing predominantly unmodified natural systems, managed to ensure long-term protection and maintenance of biological diversity, while also providing a sustainable flow of natural products and services to meet community needs

Such protected areas are generally but not invariably owned by the state and have often been designated for reasons other than their environmental services: frequently because of their wildlife or biodiversity values or because they have particular scenic or cultural importance. Nevertheless, because many protected areas have been established in mountainous and forested areas, many also have watershed values and a few – such as Bukit Timah reserve in Singapore – were established specifically because of their value for water or with this being a major contributory factor. Other protected areas, such as the famous Yosemite in California, were designated because of their scenic beauty but also have important watershed values which have increasingly been recognised.

- **Protective forests**

In addition to officially protected areas, which may or may not have a function in watershed management, many governments, local authorities and even private landowners protect a proportion of their forests specifically to maintain water supplies. (Forests are also protected for other purposes, including for example avalanche control.) In some countries such "protective forests" have been long recognised and are subject to special laws regarding their protection while in other cases designation is more local and ad hoc. Forests protected for watershed values fall into a number of main categories:

- Major parts of watersheds – as described in several case studies in the current report

- Forests on steep slopes or other places where erosion is likely – the Grain for Green programme in China is aimed specifically at preventing sedimentation and soil loss from steep slopes

- Forests and woodland along stream and river banks to maintain water quality and temperature – for example as outlined in the British Columbia Forest Practices Code[73]

Management

There is evidence that in some situations careful management interventions do little harm to forests' hydrological functions and may even enhance these[74]. Forests outside formally protected areas are also often necessary for the maintenance of ecosystems services, both on individual sites and within the wider landscape. Forest management in these circumstances should therefore seek to maintain forest quality and not degrade either the timber resource or the range of associated goods and services. There have been many attempts to define what is often called "sustainable forest management", ranging from national criteria and indicators (e.g. the Montreal Process and the Ministerial Conference on the Protection of Forests in Europe) to site approaches such as independent certification of good management, for example through the Forest Stewardship Council.

Some management interventions may also be justified on occasion to maintain forests even when these are in a relatively natural state – for example the use of controlled burns to avoid a hotter and more destructive fire. More commonly, management intervention is not necessarily the best option from the perspective of water management but is the best possible compromise in crowded landscapes. In many countries demand for land is so great that total protection can and should only ever be applied to a small fraction of forests. The human population around Beijing for example is so dense that complete protection of forests is impossible, or would cause considerable human suffering, so that an integrated approach to management is taken instead. Management might include some form of timber removal or extraction of non-timber forest products such as berries, medicinal plants or fodder.

Management for water resources is included specifically within the remit of several of the National Forests in the USA. Concern to maintain the quality and quantity of water supplies has led to the establishment of management programmes for entire river basins, such as the Murray Darling Basin in Australia where reforestation is a key element in reducing the threat from salinity to Adelaide's water quality and the now classic Tennessee Valley Authority programme, started in 1933[75]. Until recently, most of the research effort has been concentrated on mitigation of problems resulting from forestry operations rather than looking at potential positive benefits from forest management and there is clearly a need for further research on this issue. In Stockholm, Sweden, the water management company has undergone Forest Stewardship Council certification of its forests to ensure that management is of the highest standards for water.

Restoration

From 1990 to 2000 the UN Food and Agriculture Organisation estimated that forests were lost at a net rate of 9.4 million ha/year, with actual deforestation reaching 16 million ha/year. In addition, the quality of much of the remaining forest is declining rapidly. The need for restoration is therefore of growing importance, including for ecosystem services. However, the role and process of restoration is not necessarily simple in these cases: poorly planned restoration or restoration using unsuitable species can result in a net loss of water flow for many years.

Forest Landscape Restoration is defined as: "*a planned process that aims to regain ecological integrity and enhance human wellbeing in deforested or degraded forest landscapes*". It focuses on re-establishing functions and key ecosystem processes across a whole landscape rather than at just planting or restoring individual sites. As such, Forest Landscape Restoration looks at a mosaic of land uses including agricultural lands and forest types ranging from plantations to natural forests. It might for example be used to help buffer a small and isolated protected area by re-establishing trees on surrounding land that, whilst having a range of social or commercial functions, could also help support native biodiversity. The key principles of Forest Landscape Restoration are that it:

- Is implemented at a landscape scale rather than a site
- Has both a socio-economic and ecological dimension
- Implies addressing the root causes of degradation and poor forest quality (such as perverse incentives and inequitable land tenure)
- Opts for a package of solutions, which may include practical techniques – such as agroforestry, enrichment planting and natural regenerations at a landscape scale – but also embraces policy analysis, training and research
- Involves a range of stakeholders in planning and decision-making to achieve a solution that is acceptable and therefore sustainable
- Involves identifying and negotiating trade-offs

Examples of virtually all these types of land use can already be seen around the world, specifically linked to maintaining water supplies. The table overleaf gives some examples.

Table 1: Management options in watersheds

Type of management		Category	Example relating to drinking water
Protection	Protected areas containing forests	I (a) – Strict nature reserve	**Ecuador**: About 80 per cent of Quito's 1.5 million population have drinking water from two protected areas; *Antisana* (120,000 ha) and *Cayambe-Coca Ecological Reserve* (403,103 ha). To control threats to the reserves, the government is working with a local NGO to design management plans, which will highlight actions to protect the watersheds including stricter enforcement of protection to the upper watersheds and measures to improve or protect hydrological functions, protect waterholes, prevent erosion and stabilise banks and slopes[76].
		I (b) – Wilderness area	**Dominican Republic**: The Madre de las Aguas Conservation Area, consists of five separate protected areas including two wilderness areas: *Juan B. Pérez Rancier (Valle Nuevo) National Park* (Category Ia, 40,900 ha), and *Ebano Verde Scientific Reserve* (Category Ia, 2,310 ha). The area shelters the headwaters of 17 rivers that provide energy, irrigation and drinking water for over 50 per cent of the population[77].
		II – National park	**Honduras**: The cloud forests *of La Tigra National Park* (23,871 ha) in Honduras provide more than 40 per cent of the annual water supply to the 850,000 people of the capital city, Tegucigalpa[78], and this was a major incentive for their protection.
		III – Natural monument	No example found
		IV – Habitat/species management area	**Singapore**: *Bukit Timah and the Central Catchment Area* (Category IV, 2,796 ha) in Singapore were originally protected specifically to maintain water supply and the central catchment was also restored[79]
		V – Protected landscape or seascape	**Japan**: *Nikko National Park* (Category V, 140,698 ha) and *Chichibu-Tama National Park (Titibu-Tama) National Park* (Category V, 121,600ha) are both situated north of Tokyo and help to protect the watersheds of the main water supply for the city[80] and also provide recreational and wildlife values.
		VI – Extractive reserve	**USA**: *Angeles National Forest* (Category VI, 265,354 ha) is one of 18 national forests in the Pacific Southwest Region created specifically to safeguard and preserve water supplies[81]. These forests also supply timber and other benefits

Type of management		Category	Example relating to drinking water
	Protected forests outside protected areas	Watershed management	**Australia**: 90 per cent of Melbourne's water comes from forested catchments. Almost half are protected and much of the rest manages for water collection[82]. Other examples include Freetown, Sierra Leone and Kingston[83]
		Avalanche control	**Switzerland**: Around 8 per cent of forest is set aside as protection against avalanches: these areas are noted as regulating water flow[84].
		Game for hunting	No examples found
		Strategic reserves	No examples found
		Sacred sites	**Honduras**: Celaque mountain is called 'Box of Water' in the Lencan language and has been worshipped for millennia as a God Mountain that supplies life-giving water. Celaque mountain generates 9 major rivers, which feed clean water to nearby cities and communities[85].
		Recreational areas	**Colombia**: The Medellin River basin is the main source of water for Medellin and its source is protected in the *Alto de San Miguel Recreational Park and Wildlife Refuge* (721 ha)[86]
		Security reasons	No examples found
Management	Community benefits	Extraction from natural forest	**Malaysia**: The Rungus community in Sabah is negotiating with the government to manage forest in the Gomantong Hill for their water resources, rather than establish *Acacia mangium*[87].
		Management of secondary forests	**Dominican Republic**: When farmers in the Nizao watershed thought that deforestation reduced the duration of seasonal stream flows, they voluntarily adopted more stringent limits on tree cutting[88].
	Industrial benefits	Extensive – selective removal	**USA**: New York – one of a suite of actions supported by the water company is low impact, selective logging in the catchment to reduce impacts on water quality[89].
Restoration	Restoration of native or near-native forests	Natural regeneration	**Costa Rica**: hydroelectric utilities have funded reforestation upstream of their plants to maintain regularity of water supply. Payments re made by a power company to villagers through an NGO, with additional funds coming from the government[90].
		Assisted regeneration	**Brazil**: The forests on the *Tijuca Massif National Park*, near Rio de Janeiro, were reforested with native species to restore water supplies[91].
		Replanting with native species	**Australia**: an association of irrigation farmers are paying the State Forests of New South Wales to carry out large-scale reforestation to reduce salinity in irrigation water[92]. WWF Australia has a similar project with partners in the Liverpool Plains of New South Wales
	Industrial plantations	Exotic species	**Panama**: is intending to reforest catchment areas with plantations to reduce sediment in the Canal[93].

In practice, many water companies or authorities look at employing a suite of different responses depending on money, political and social factors and their own understanding of the likely impacts. Some of the policy implications of these changes are outlined below.

Social implications of protecting and managing forests for water supply

> *Secure and equitable access to and control of resources—and fair distribution of the costs and associated benefits and opportunities derived from conservation and development— will be the foundation of food and water security*[94]

Water catchment management offers benefits to people living downstream including millions of city dwellers who rely on water from forested watersheds. But what of the people living in the catchments themselves? Setting aside an area of land for forest protection or restoration might be good for water, but could have severe implications for the lives of people who live there and who have their own ideas about what it should be used for. For example, Mount Elgon National Park in Uganda is an important source of drinking water and water services were a major incentive for protection. But this caused conflict with local people who had used the forests for generations and abruptly found themselves excluded, creating problems that required considerable efforts to address[95]. The Manupali catchment in the Philippines provides another example of potential conflict. The catchment is an upland area surrounding the Mount Kitanglad Natural Park (Category II, 29,617 ha) in Mindanao. Property rights are insecure. In the upper watershed there are overlapping claims between the Forest Department, the ancestral communities and the migrant farm communities. The boundaries of the municipalities surrounding the protected area also overlap with the public state forests. Thus, three types of management plans must be reconciled for the land conflicts to be resolved.[96]

The main focus of this report is to investigate the links between protected areas and drinking water, but we recognise that protected areas create a potential conflict with livelihood issues. We asked Sara Scherr of Forest Trends to write an essay on the social implications of watershed protection, which starts on page 70. The following analysis draws both on this and on other experience in the area.

Land is seldom if ever freely available, so that choices about land use must be either imposed from above for the common good or negotiated with local land or right owners (or some combination of the two). In general, natural resource management is tending to move away from a reliance on imposed solutions, which have generally resulted in problems, and towards negotiated agreements and collaborative management approaches[97].

Because urban interests are more politically powerful than rural interests, watershed protection has often ignored rural people's rights, with negative impacts for millions of people, including:

- Transferring ownership or use rights to land from local people
- Denying rights of access to public or community land, forest, or water
- Offering payments for watershed services that encourage more powerful actors to appropriate land or water resources
- Establishing forest plantations on common lands valuable for livestock, wild foods and fuel
- Forcibly resettling people
- Forcing farmers to make high-cost conservation investments
- Damaging or denying access to cultural or religious sites
- Reducing employment due to closing farming, forestry or processing activities
- Diverting water to urban users

At worst, watershed protection has been a thinly disguised excuse for resettlement or social control of politically and culturally marginal groups. This has caused resentment and many programmes that established strict forest reserves or attempted to reforest farm and grazing lands have failed to achieve watershed objectives.

This has led to new approaches that seek to work with local people as watershed stewards. These recognise rights and management capacity, encourage negotiation, and provide technical and financial support for communities to invest in land management. When designed explicitly for local co-benefits, improved watershed protection may:

- Enhance the supply and quality of local water
- Restore depleted fisheries
- Increase availability of non-timber forest products
- Increase income and employment from enterprises compatible with watershed management
- Protect forest resources from invasion by outside settlers
- Reduce local health problems from contaminated water
- Validate the role of rural people as watershed stewards
- Pay local people for their role in protecting, managing or restoring watersheds
- Provide investment resources

Involving people in watershed management: in some urban watersheds, protecting or expanding forest cover will be essential for water management. Here, every effort should be made to embed biodiversity conservation and livelihood benefits into forest protection. Multiple-use community forestry can provide local income and communities and landowners can be paid to conserve resources and monitor water quality. Planting or regeneration can focus on the most critical sites for watershed services. Local people can identify sites producing unusual levels of sediment or contamination, or areas of compacted soil or barriers to water flow, that may not show up through remote sensing. They can also identify areas where there are strong community motivations to increase forest, such as around local water sources or cultural sites.

Alternatives to strict forest protection: completely undisturbed forest is not necessarily essential for good watershed management. While natural forest can often provide these functions most effectively and at a low cost, well-designed mosaics of other land uses may also do much the same. Where the "opportunity cost" of protection is very high for local people, alternatives should be explored. Timber and non-timber forest products can be produced commercially, under standards of certification. Crops may be produced using good erosion control or in agroforestry or organic systems. Rules can require wide strips of natural vegetation be left at intervals on contours on steep slopes. Financial credit, technical assistance, and marketing support can help to facilitate these changes, financed from urban water budgets or consumer charges. Critical sites for hydrological function (or biodiversity conservation) can be zoned for non-productive use, or farmers and landowners compensated for easements. Landscape mosaics that intersperse natural forest with crops, pastures or production forest can protect critical watershed sites. Upstream riparian systems can be linked to urban wetlands and larger protected areas through corridors of natural vegetation.

Strong public demand for water security can drive responses that seriously harm vulnerable populations living in and near water resources and catchment areas. However, serious attention to addressing potential social costs and impacts can result in greater net social benefits and greater sustainability of watershed and ecosystem services.

Economic benefits of protecting forests for water

One major reason why it has proved so difficult to halt and reverse global forest loss is that those who manage forests typically receive little or no compensation for the services that these forests generate for others and hence have little incentive to conserve them. Recognition of this has encouraged the development of systems in which land users are paid for the environmental services that they generate through their management. The central principles of the “payment for environmental services” (PES) approach are that those who provide environmental services should be compensated for doing so and that those who receive the services should pay for their provision. From our perspective here, this means that if particular management systems are needed in watersheds to maintain the quantity or quality of water supply downstream, the users – like drinking water or hydropower companies –should pay for these.

These benefits are known to be enormous. A team of researchers from the United States, Argentina, and the Netherlands has put an average price tag of US$33 trillion a year on fundamental ecosystem services, which are largely taken for granted because they are free. That is nearly twice the value of the global gross national product (GNP) of US$18 trillion. Water regulation and supply was estimated to be worth US$ 2.3 trillion[98]. At the national level, the economic value of the water storage function of China’s forests is estimated as 7.5 trillion yuan, three times the actual value of the wood in those forests[99]. Similarly, recent studies calculated that the presence of Mount Kenya forest (Category II, 58,800ha and Biosphere Reserve, 71,759ha), alone, saved Kenya’s economy more than US$20 million through protecting the catchment for two of the country’s main river systems, the Tana and the Ewaso Ngiro[100]. The issue for policy makers is how to translate these values into money that can help to support particular types of land management in catchments and thus address some of the potential social issues outlined in the previous section.

PES has raised great hopes that protected areas can be supported through the environmental services that they provide, perhaps particularly water services. Although this is clearly possible, and there are some existing and successful examples of this in practice, it is also clearly no universal solution or panacea to the questions of support for protection. As this issue is at the heart of much of the thinking in this report, we commissioned an essay from World Bank Senior Environmental Economist Stefano Pagiola, which is reprinted starting on page 63: the following summary draw on his writing along with other relevant material.

Projects using water resources as a springboard for Payment for Environmental Services schemes have been most thoroughly developed in Latin America, but interest is quickening throughout the world. In Costa Rica, for example, the government has been involved in a scheme to help users such as hydropower companies to pay farmers to maintain forest cover in watersheds, while in Quito, Ecuador, water companies are helping to pay for the management of protected areas that are the source for much of the capital’s drinking water.

Payment schemes only have a chance of working when conditions are right. An ideal combination would be when a relatively small amount of money used to support a particular management regime results in major economic benefits to a small group of users – like a water company. In these cases it is relatively easy to identify reasonable payments and to negotiate amongst the buyers and sellers of the environmental service. However, there are many possible complications. As discussed elsewhere, there are still disagreements about the likely impacts of management regimes and in any case these are likely to change in different places, making it sometimes hard to predict the costs and benefits of particular management approaches. Users have different needs; for example a hydropower company will be interested in quantity and freedom from sediment while a water company will have much wider quality interests. It may be difficult to identify and hence negotiate with the people using the land upstream (or with dispersed user groups). There are risks of a few users paying for services enjoyed by many. Clumsy use of payment schemes can create perverse incentives for example by raising hopes of payment in other areas and hence blocking other ways of reforming management.

Nonetheless, such schemes are already working in several places and are receiving a high level of attention from governments and from donor agencies. For example, the World Bank is currently supporting the development or implementation of PES systems in Costa Rica, Guatemala, Venezuela, Mexico, Colombia, Nicaragua, Dominican Republic, Ecuador, El Salvador and South Africa. Many of these look specifically at the services provided by protected areas, for example project financed by the Global Environmental Facility is under preparation, focusing on Canaima National Park in Venezuela, with significant co-financing from the hydropower producer CVG-EDELCA.

Payment for environmental services is not a panacea or a universally-applicable solution to forest loss: rather it should be regarded as one of many tools in a toolbox. If used well, however, it can provide concrete support for both good forest management and forest protection.

Environmental benefits of protecting forests for water

As the following research will show, many of the world's cities rely on protected forests for some or all of their water. Some cities that are currently struggling with an uncertain water supply would be well served by protecting, managing and where necessary restoring forests in strategic places.

Such protection clearly can also have enormous benefits beyond water supply – for example for biodiversity. In places where forests are important both for biodiversity and water, the twin benefits may help develop and strengthen arguments for protection or for other beneficial management systems.

Protected areas are the cornerstones of all national and regional conservation strategies. They act as refuges for those species that cannot survive in managed landscapes and as areas where natural ecological processes can continue unhampered by human interference. They are a vital resource for continuation of natural evolution and, in many parts of the world, for future ecological restoration. Human beings benefit directly from the genetic potential contained in the world's plants and animal species, a significant proportion of which are currently at risk. Most people also believe that we have an ethical obligation to prevent extinctions caused as a result of our own actions[101].

As forests are the richest terrestrial habitats for biodiversity, forest protected areas are particularly important in many conservation strategies. While it has been comparatively easy to protect areas of remote forests, or forests with low timber value such as some boreal forests or high mountain forests, it has proven particularly difficult to agree adequate protection for rich lowland forests, particularly when these exist close to major cities. Watershed protection, by giving additional impetus to the creation of protected areas or other forms of protective forests, can play a key role in assisting biodiversity conservation strategies.

Already, some of the world's most famous protected areas – such as Yosemite in California – have an additional watershed function. In other places, forests that were initially protected mainly for water values have also proven to be of enormous value for biodiversity – particularly around cities where urban expansion often means that protected watersheds are virtually the only remaining natural vegetation – and that watershed protection is in effect buying time for biodiversity that would otherwise have disappeared. This is currently the situation in Singapore for instance. In other cities – for example Santiago in Chile, Istanbul in Turkey and Brisbane in Australia – the twin goals of pure water and biodiversity conservation are currently creating powerful cases for additional designation of protected areas. Sometimes, particularly when watershed protection is outside a formal protected area, the wider biodiversity benefits are scarcely recognised. Indeed, we have been surprised how little water companies or local authorities are reporting protection of watersheds, even in places where they take pride in their environmental record.

An example from China

Conservation organisations are starting to recognise and work with these links. The Qinling Mountains are the natural division between north and south China and are extremely biologically diverse, with important populations of giant panda, golden monkey, takin, crested ibis and clouded leopard. Qinling is also the catchment for the country's two most important rivers: the Yangtze and the Hwang He (Yellow) rivers, and is the chief water source for Xi'an, China's ancient capital, which has a population of over seven million people. A survey of the world's major watersheds carried out in 1998 highlighted serious deforestation and little protection in the watersheds of the Yangtze and Hwang He. The Yangtze watershed has lost 85 per cent of its forest and only two per cent of the watershed was protected while the Hwang He watershed had lost 78 per cent of its forests and only one per cent was protected. In 2003, the Shaanxi Provincial Government agreed to greatly expand the total protected area in Qinling. Initially a series of panda reserves and corridors will increase protected areas by 180,000 ha from the existing 330,000 ha, with an additional proposal for seven more areas, adding approximately 225,000 ha to the protected area network. It is hoped that the reserves will also have substantial benefits for the drinking water of Xi'an and the surrounding area. The efforts to increase protected area coverage in Shaanxi Provincial Government have been celebrated by WWF as 'A Gift to the Earth' - a public celebration of a conservation action[102].

Buying time for biodiversity

In some cases, forests protected for their watershed values have only later been recognised for their biodiversity importance. Rising populations may mean that these protected watersheds become relatively less important – and examples from Singapore and Brisbane are discussed in this report – so that in these cases watershed protection has played a role in protecting habitats until their biodiversity values have been recognised.

This is not to argue that all cities should be surrounded by protected watersheds – many get their water from other sources or from protected forests that have no particular biodiversity value and are not necessarily worthy of full protected area status. But clearly where there is a coincidence of interest in forests for both their water services and their wildlife riches, opportunities for formal or informal protection are dramatically increased.

Some preliminary conclusions

The background research identified some clear issues related to watersheds and protected areas, which are summarised briefly on this page.

Natural forests provide benefits to urban populations in terms of high quality drinking water:

- Natural forests almost always provide higher quality water, with less sediment and fewer pollutants, than water from other catchment

- Some natural forests (particularly tropical montane cloud forests and some older forests) also increase total water flow, although in other cases this is not true and under young forests and some exotic plantations net water flow decreases

- Impacts of forests on security of supply or mitigating flooding are less certain although forests can reduce floods at a local scale

- As a result of these various benefits, natural forests are being protected to maintain high quality water supplies to cities

- Protection within watersheds also provides benefits in terms of biodiversity conservation, recreational, social and economic values

Maintaining high quality water supply is an additional argument for protection:

- Many important national parks and reserves also have value in protecting watersheds that provide drinking water to tons and cities

- Sometimes this is recognised and watershed protection was a major reason for establishing the protected area – here watershed protection has sometimes bought critical tie for biodiversity, by protecting natural areas around cities that would otherwise have disappeared

- In other cases, the watershed values of protected areas have remained largely unrecognised and the downstream benefits are accidental

- Where forests or other natural vegetation have benefits for both biodiversity and water supply, arguments for protection are strengthened with a wider group of stakeholders

- In some cases, full protection may not be possible and here a range of other forest management options are also available including best practice management (for example through a forest management certification system) and restoration

The watershed benefits of forest protected areas could help to pay for protection:

- The economic value of watersheds is almost always under-estimated or unrecognised

- It is possible to collect user fees from people and companies benefiting from drinking water to help pay for protected area management – although only in certain circumstances

- Payment for water services can also be one important way of helping negotiations with people living in or using watersheds to develop land-use mosaics that are conducive to drinking water

Part 2: The world's biggest cities, drinking water and protected areas

The study

To gain an idea of the importance of protected areas to water supply, we assessed how many of the world's top cities drew some or all of their drinking water from protected areas.

The methodology

The research team looked at water supply to the world's top one hundred cities – in fact 105 cities, by population, divided as follows:

- Americas – top 25
- Africa – top 25
- Asia – top 25
- Europe – top 25
- Australia – top 5

This breakdown was chosen to ensure a good geographical spread of information and to include most of the world's largest cities. The study aims to be indicative rather than definitive and using this method, cities were included from virtually every part of the world.

In each case, we looked at the water supply system and at whether protection – through official protected areas or other forms of protective forest – played a significant role in water supply. The results are summarised on two tables and then in a listing that includes details of each city by region.

Much of this work remains preliminary. We have been surprised at the variation in information about water sources: in some cities the facts are clear and also clearly understood, while in others there still remains a deal of confusion, even within those charged with maintaining water supply, about the status of land in catchments. Because few if any cities rely entirely on one source, or water from one protected area, we have had to make some relatively arbitrary choices about when protected areas become "significant" to a city's water supply. Some of the protected catchments we describe, for example in South Africa, are not predominantly forested but protection of other forms of natural vegetation also helps to preserve water quality. In the accompanying list of cities we give sources of facts and opinions and explain uncertainties.

The results

The following preliminary results

- Around a third (33 out of 105) of the world's largest cities obtain a significant proportion of their drinking water directly from protected areas

- At least five other cities obtain water from sources that originate in distant watersheds that also include protected areas

- In addition, at least eight more obtain water from forests that are managed in a way that gives priority to their functions in providing water

- Several other cities are currently suffering problems in water supply because of problems in watersheds or draw water from forests that are being considered for protection because of their values to water supply

Over the next few pages, these results are summarised in table form.

Table 2: Some cities drawing some or all of their water from protected areas

City	Protected Area
1. Mumbai (Bombay) India	Sanjay Ghandi National Park (Category II, 8,696 ha)
2. Jakarta, Indonesia	Gunung Gede Pangrango (Category II, 15,000 ha) Gunung Halimun (Category II, 40,000ha)
3. Karachi, Pakistan	Kirthar National Park (Category II, 308,733 ha) Dureji Wildlife Sanctuary (Category IV, 178,259 ha) Surjan, Sumbak, Eri and Hothiano Game Reserve (40,632ha) Mahal Kohistan Wildlife Sanctuary (70,577ha) Hub Dam Wildlife Sanctuary (27,219ha) Haleji Lake Wildlife Sanctuary (Category IV, 1,704ha
4. Tokyo, Japan	Nikko National Park (Category V, 140,698 ha) Chichibu-Tama National Park (Titibu-Tama) National Park (Category V, 121,600ha)
5. Singapore	Bukit Timah (Bukit Timah and the Central Catchment Area, Category IV, 2,796 ha),
6. New York, USA	Catskill State Park (Category V, 99,788 ha)
7. Bogotá, Colombia	Chingaza National Park (Category II, 50,374 ha)
8. Rio de Janeiro, Brazil	Within Rio de Janeiro Metropolitan area: Tijuca National Park (Category II, 3,200 ha) Tingua Biological Reserve Pedra Branca State Park Gericinó-Mendanha APA Atlantic Rainforest Biosphere Reserve and fourteen protected areas (covering a total area of 320,180 ha) also provide protection for the sources of the catchment areas supplying the city.
9. Los Angeles, USA	Angeles National Forest (Category VI, 265,354 ha)
10. Cali, Colombia	Farallones de Cali National Park (Category II, 150,000 ha)
11. Brasília, Brazil	Brasilia National Park (Category II, 28,000 ha)
12. Santo Domingo, Dominican Republic	The Madre de las Aguas (Mother of the Waters) Conservation Area: Armando Bermúdez National Park (Category II, 76,600 ha) Juan B. Pérez Rancier (Valle Nuevo) National Park (Category Ia, 40,900 ha) José del Carmen Ramírez National Park (Category II, 73,784 ha) Nalga de Maco National Park Ebano Verde Scientific Reserve (Category Ia, 2,310 ha)

City	Protected Area
13. Medellín, Colombia	Alto de San Miguel Recreational Park and Wildlife Refuge (721 ha)
14. Caracas, Venezuela	Guatopo National Park (122,464 ha, Category II) Macarao National Park (15,000 ha, Category II) Avila National Park (85,192 ha, Category II)
15. Maracaibo, Venezuela	Perijá National Park (Category II, 295,288 ha)
16. São Paulo, Brazil	Cantareira State Park (Category II, 7,900 ha) Guarapiranga Ecological Park, Morro Grande State Reserve, Itapeti Ecological Station, Juquery and Alberto Loefgren State Parks
17. Salvador, Brazil	Lago de Pedra do Cavalo Environmental Protection Area (Category V) Joanes/Ipitinga Environmental Protection Area (Category V, 60,000 ha)
18. Belo Horizonte, Brazil	Mutuca, Fechos, Rola-Moça, Taboões, Catarina, Bálsamo, Barreiro, Cercadinho, Rio Manso and Serra Azul (17,000 ha)
19. Madrid, Spain	Natural Park of Peñalara (15,000 ha) Regional Park Cuenca Alta del Manzanares (Category V, 46,323 ha)
20. Vienna, Austria	Donau-Auen National Park (Category II, 10,000 ha)
21. Barcelona, Spain	Sierra del Cadí-Moixeró (Category V, 41,342 ha) Paraje Natural de Pedraforca (Category V 1,671 ha)
22. Sofija, Bulgaria	Rila National Park (Category II, 107,924 ha) Vitosha National Park (Category IV, 26,607ha) Bistrishko Branishte Biosphere Reserve (Category Ia, 1,062 ha)
23. Ibadan, Nigeria	Olokemeji Forest Reserve (7,100 ha) Gambari Forest Reserve
24. Abidjan, Cote d'Ivoire	Banco National Park (Category II, 3,000 ha)
25. Cape Town, South Africa	Cape Peninsula National Park (29,000 ha) Hottentots Holland Nature Reserve (Category IV, 24,569 ha)
26. Nairobi, Kenya	Aberdares National Park (Category II, 76,619 ha)
27. Dar es Salaam, Tanzania, United Republic of	Udzungwa Mountain National Park (Category II, 190,000 ha) Selous ecosystem: Selous Game Reserve (Category IV, 5,000,000 ha and World Heritage site) Mikumi National Park (Category II, 323,000 ha) Kilombero Game Controlled Area (Category VI, 650,000 ha).
28. Durban, South Africa	Ukhlahlamba-Drakensberg Park, (Category I [48 per cent] and II [52 per cent], 242,813 ha, World Heritage Site, Ramsar site)
29. Harare, Zimbabwe	Robert McIlwaine Recreational Park (Category V, 55,000 ha) Lake Robertson Recreational Park (Category V, 8,100 ha)
30. Johannesburg, South Africa	Maluti/Drakensberg Transfrontier Park Ukhlahlamba-Drakensberg Park, (Category I [48 per cent] and II [51.5 per cent], 242,813 ha, World Heritage Site, Ramsar site)

City	Protected Area
31. Sydney, Australia	The Blue Mountains National Park (Category II, 247,021 ha) Kanangra-Boyd National Park (Category Ib, 65,280 ha) Dharawal Nature Reserve (Category Ia, 341 ha) Dharawal State Recreation Area (5,650 ha)
32. Melbourne, Australia	Kinglake National Park (Category II, 21,600 ha) Yarra Ranges National Park (Category II, 76,000 ha) Baw Baw National Park (Category II, 13,300 ha)
33. Perth, Australia	Yanchep National Park (Category Ia, 2,842 ha)

Table 3: Some cities where forest is managed for watershed protection

City	Forest managed for watershed protection
1. Seoul, Republic of Korea (South)	Nakdong watershed, has government established special protection zones including riparian buffer zones to restrict commercial activities around the river basins
2. Tokyo, Japan	Tokyo Metropolitan Government Bureau of Waterworks manages the forest at the source of drinking water in the upper reaches of the Tama River, to: increase capacity to recharge water resources; prevent sedimentation in the Ogochi reservoir; increase water purification capacity; and conserve the natural environment.
3. Beijing, China	Watersheds above the Miyun reservoir, the principal source of surface water for Beijing, are managed for water protection
4. Yangon (Rangoon), Myanmar	The forested watershed of the two dams, Gyobyu and Phugyi, which supply drinking water to Yangon, are managed by Forest Department of Myanmar who carry out forest conservation activities, i.e. restoration, in the watersheds.
5. Santiago, Chile	The Santiago Foothills have been classified as an 'Ecological Conservation Area', to be 'preserved in natural condition, in order to ensure and contribute to environmental balance and quality'. The forests are the source of potable water for Empresa Metropolitana de Obras Sanitarias which supplies potable water for part of the municipal district of La Reina – about 20 per cent of potable water in requirements for Santiago.
6. Stockholm, Sweden	Lake Mälaren and Lake Bornsjön, supply Stockholms water. Stockholm Vatten controls most of the 5,543 ha watershed of Lake Bornsjön, of which 2,323 ha, or about 40 per cent, is productive forestland certified by the Forest Stewardship Council. Management is focused on protecting water quality and areas are left for conservation and restoration.
7. Munich, Germany	Since the foundation of the Munich waterworks in circa 1900, forest management has been focussed on ensuring good water quality. Currently an area of 2,900 ha is managed primarily to maintain water quality and an additional area of 1,900 ha is under long-term contracts with local farmers, who commit to certified ecological/organic agriculture.
8. Minsk, Belarus	A green belt around the city of about 80 km and protective zone around the Minsk reservoir play an important role in ensuring water quality. The protective regime in these zones is quite strict, for example, logging is prohibited. Thanks to these restrictions, the forest around Minsk city has not destroyed.

City	Forest managed for watershed protection
9. Sydney, Australia	The Sydney Catchment Authority manages and protects Sydney's catchments. Around 25 per cent of the catchment is managed within 'Special Areas', which act as a buffer zone to stop nutrients and other substances that could affect the quality of water entering the water storage areas.
10. Melbourne, Australia	Ninety per cent of Melbourne's water supply comes from uninhabited forested mountainous catchments to the north and east of Melbourne. The government owned company Melbourne Water manages the water collection from these forests and has some legislative backing to protect water resources. Fifty one per cent of the water catchments are not within protected areas. Management priorities include to the protected forested catchments against the threat of bushfires.

The 105 cities by Rachel Asante Owusu, Sue Stolton and Nigel Dudley

In the chapter below we look at the world's top 105[103] cities, divided by continent, and provided an overview of how many relied on water from protected areas for some or all of their drinking water supply. Each entry gives a one line analysis of the role of protected areas or other kinds of deliberate watershed management and then a short paragraph describing water sources. Where applicable, details of protected areas are included, drawn from the *UN List of Protected Areas*[104] and from the UNEP-World Conservation Monitoring website.

- **Asia**

1. Mumbai (Bombay), India

Protected area important for city's water supply

Six lakes (Bhatsa, Upper Vaitarna, lower Vaitarna, Tansa, Vihar and Tulsi) supply Mumbai with about 663 million gallons of water a day[105]. The forested (southern tropical moist deciduous) Sanjay Ghandi National Park (Category II, 8,696 ha) is within the limits of Greater Mumbai and forms the catchments of the Powai and Vihar lakes[106].

2. Seoul, Republic of Korea (South)

Government established watershed protection zones

Lake Paldanghoho is the water source for the citizens of Seoul and its surrounding area. Seoul lies within the Nakdong watershed, one of the three watersheds (the others being the Han and Keum Rivers watersheds), which the government established special protection zones for in 1998. Protection includes the introduction of riparian buffer zones to restrict commercial activities around the river basins[107].

3. Jakarta, Indonesia

Protected areas are important for city's water supply

Jakarta's urban water supply comes mainly from the Ciliwung River and the Jatiluhur reservoir on Citarum River, located about 65 km southeast of Jakarta[108]. Two national parks Gunung Gede Pangrango (Category II, 15,000 ha) and Gunung Halimun (Category II, 40,000ha) protect watersheds which supply the city with water. Gunung Gede Pangrango National Park protects valuable examples of primary rain forest in West Java, with submontane and montane tropical rain forest covering the most extensive area[109]. The northern slopes of Gunung Gede are drained by many small streams, which flow into the Cipanas River, a tributary of the Citarum, which flows north-west to the Java sea. The north-western slopes of the park drain into the Cisarua and Cinagara, tributaries of the Ciliwung and Kali Angke Rivers which ultimately flow into Jakarta Bay and the Java Sea[110]. It has been estimated that the 60 or more rivers flowing from the park provide water worth US$1.5 billion for domestic and agricultural uses[111]. Gunung Gede forms the core of the Cibodas Biosphere Reserve. Gunung Halimun forms the principal watershed for West Java and is of considerable conservation importance as one of the most extensive areas of evergreen tropical rain forest remaining on the island. The Halimun region is one of wettest areas of Java, with a mean annual rainfall between 4000mm and 6000mm[112].

4. Delhi, India

Protected areas play no role in supplying the city with water

Most of the water comes from the Yamuna river

5. Manila, Philippines
Protected areas play no role in supplying the city with water
The Angat Dam in Norzagaray, Bulacan supplies 76 per cent of Manila Water's needs. Other sources of water are Ipo Dam (14 per cent), La Mesa Dam (7 per cent) and groundwater (3 per cent)[113].

6. Karachi, Pakistan
Protected areas are important for city's water supply
Pakistan's cities are expanding much faster than the overall population[114]. Karachi is Pakistan's largest city, is in far south of the country on the coast of the Arabian sea, between the mouths of the Indus and Hub rivers. In 1947, Karachi had a population of four million, today the population is over 14 million and is growing at an average of six per cent a year[115]. Karachi's water supply is the responsibility of Karachi Water & Sewerage Board (KWSB). At present, Karachi gets its water mainly from two sources: the Indus river and Hub reservoir[116]. The water supply from the Hub reservoir, however, has been intermittent in recent years as the dam's catchment area has remained dry in the monsoon season[117]. Forty per cent of the city's population lives in squatter settlements, and water supplies, in these and other areas is unreliable. Of the water supplied, 50 per cent is for domestic purposes, five per cent for industrial use, five per cent for commercial, and 40 per cent is lost in leakage[118]. By 1990 it was declared that nearly half the population of Pakistan enjoyed access to 'safe' water. However, researchers, noting that many diseases in Pakistan are caused by the consumption of polluted water, have questioned the classification of 'safe' used[119]. Even the 38 per cent of the overall population that receives its water through pipelines run the risk of consuming contaminated water, although the problem varies by area[120].

Kirthar National Park (Category II, 308,733 ha) and Dureji Wildlife Sanctuary (Category IV, 178,259 ha) in the province of Balochistan cover a significant part of the catchment area of River Hub and thus of the Hub reservior[121]. Kirthar lies 80km north of Karachi in the south-west of Sind Province. It covers the south-east extension of the Kirthar Range, to the west of the River Indus, and comprises a series of hill ranges, from 70m at Hub Dam to 1,004m on Karchat Mountain, separated by wide, undulating valleys. The park is part of a 447,161ha protected areas complex, being contiguous with Mahal Kohistan Wildlife Sanctuary (70,577ha) to the south, Hub Dam Wildlife Sanctuary (27,219ha) to the south-west and Surjan, Sumbak, Eri and Hothiano Game Reserve (40,632ha) to the east. Drainage from the Parks north and central sectors follows a south-westerly direction to the Indus River, whilst the west-central and south-west regions are drained by the Mahr and Hub rivers, respectively, which follow a southerly course to the sea. The parks flora is made up of communities of deciduous xerophytic trees and shrubs. Some 30 species of mammals have been recorded but larger species are either extremely rare, such as the wolf *Canis lupus* and striped hyaena *Hyaena hyaena*, or may have become locally extinct, such as leopard *Panthera pardus* and caracal *Felis caracal*. Despite their seasonality, few of the larger rivers ever dry up completely, allowing fish and other aquatic life to survive the dry season in deep pools of water. The park contains large populations of wild goat (*Capra hircus)* but is also heavily grazed by domestic stock. Full protection of core areas in the mountainous region, including cessation of grazing by domestic livestock, has enabled the habitat and its ungulate populations to recover. In 1989 the resident human population in the park was approximately 16,000, distributed among 118 permanent villages, and about 64,000ha of park land was under cultivation[122]. Are there any more recent figures on population and land ownership?

The Hub Dam Wildlife Sanctuary (Category IV, 27,219 ha) on the Hub River is 40km north of Karachi. The river rises in the Kirthar Range of eastern Baluchistan, and enters the Arabian Sea just west of Karachi. The dam is a large water storage reservoir constructed in 1981; as noted above the water level in the reservoir fluctuates widely according to rainfall in the water catchment area. The natural vegetation of the areas surrounding the dam is open forest dominated by *Olea ferruginea* and *Acacia senegal*. The area can provide a haven for water fowl and is an important staging and wintering area for grebes, pelicans, ducks, cranes and coots. Some 48,500 waterfowl were present in January 1987, and over 53,500 in January 1988[123]. Haleji Lake Wildlife Sanctuary (Category IV, 1,704ha of lake, surrounded by a buffer zone of 5km radius) is some 75km east of Karachi. Haleji is a perennial freshwater lake, with associated marshes and adjacent brackish seepage lagoons, in a stony desert of limestone and sandstone bedrock. The lake supports abundant aquatic vegetation and a wide variety of migrant waterfowl, particularly ducks and common coot *Fulica atra*, and is particularly rich in birds of prey. Originally a saline lagoon formed by seasonal rainwater collecting in a shallow depression, the lagoon was converted into a reservoir in the late 1930s to provide an additional water supply for Karachi. The salt water was drained, embankments were constructed around the lake, and the Jam Branch Canal carrying water from Kinjhar Lake diverted to it. This canal remains the principal source of water. The main purpose of the lake is to supply Karachi with freshwater for about 15 days in the year, usually in April when the canal from Kinjhar Lake is being cleaned out[124].

Although there are clear links between the protected areas around Karachi and drinking water supplies, protection has tended to concentrate on the protection of wildlife species and habitats. Given the problems facing Karachi to supply its citizens with constant sources of freshwater however, there is scope for management to also play a role in securing waters for the city. There is also clearly need to further research into the relationship between the protected areas and water supplies.

7. Shanghai, China

Protected areas play no role in supplying the city with water

Most of the water comes from the Huangpu River, which has serious pollution problems[125].

8. Dhaka, Bangladesh

Protected areas play no role in supplying the city with water

Ninety per cent of the municipal water supply for Dhaka is derived from groundwater storage[126].

9. Tokyo, Japan

Protected areas are important for city's water supply and additional areas are managed to protected water sources

Tokyo uses a daily volume of 6.23 million m^3 water. River water provides most of the water resources, with groundwater resources accounting for just 0.2 per cent of the water supply. The Tone and Ara River systems supply 78 per cent and the Tama River system provides 19 per cent of the water resources from rivers. Most of the headwaters upstream of dams are located in areas designated as national parks. Designation, however, was not intended for conserving sources of drinking water. Nikko National Park (Category V, 140,698 ha), north of Tokyo, is in the watershed for the Tone and Ara river system. The oriental deciduous forest supports conserable biodiversity including the Japanese macaque (*Macaca fuscata)*, Asiatic black bear (*Selenarctos thibetanis japonicus)* and Honshu sika (*Cervus nippon centralis)*[127].Chichibu-Tama National Park (Titibu-Tama) National Park (Category V, 121,600 ha) is situated 50km north-west of Tokyo. Four main river systems originate in the parks mountains: Fuefuki, Tanba/Tama, Kawamata and Nakatsu/Arakawa. The parks proximity to Tokyo is resulting in a number of threats, including visitor pressure, the damming of two major rivers within the park (at Chichibu and Okutama) to provide hydro-electricity for the Tokyo area and cement factories. The forests are exploited and the more remote areas are gradually being opened up with forest road construction[128]. The Bureau of Waterworks of the Tokyo Metropolitan Government manages the forest at the source of drinking water in the upper reaches of the Tama River, at elevations of 500 to 2100 m. The forest extends about 31 km from east to west and about 20 km from north to south. The area of the forest at the source of drinking water is about 216 km^2, occupying 44 per cent of the basin of the Tama River. The forests are managed to: increase capacity to recharge water resources; prevent sedimentation in the Ogochi reservoir; increase water purification capacity; and conserve the natural environment[129].

10. Tehran, Iran
Protected areas play no role in supplying the city with water
Roughly 60 per cent of the water comes from three large reservoirs and the rest from groundwater sources[130].

11. Beijing, China
Some forested areas are managed for water shed protection
Beijing is located in the northern part of the North China Plain. Supplying water to the capital has been a problem for centuries, with Guo Shoujing, a river conservancy expert in the 13th century, mapping out the first system of water resources for the area[131].Today, planners estimate that the city faces an annual water deficit of about 1 billion cubic metres. Watersheds above the Miyun reservoir are a principal source of surface water for Beijing. The areas are designated to be managed for water protection, but under the principle of multiple use. Of the 3,298ha watershed about 813 ha, on steeper hill slopes, is managed as conservation forest land and protected from harvesting[132].

12. Krung Thep (Bangkok), Thailand
Minimal protection of watershed a considerable distance from the city, but the need for more protection recognised
The headwaters of the Chao Phraya river originate in mountainous terrain in the northern part of the country and consist of four large tributaries, the Ping, Wang, Yom and Nan rivers. The main river system passes through or close to many of the major population centres of the country including Bangkok, which is situated at its downstream end. The Chao Phraya basin is the most important basin in Thailand[133]. Some 77 per cent of the original forest cover has been lost and only 12 per cent of the watershed is protected. Forest covers 36 per cent of the watershed and 46 per cent is cropland (92 per cent of which is irrigated)[134]. The majority of forest cover occurs in the northern sub-basins where the percentage of forest ranges from 50-75 per cent in Ping, Wang, Yom and Nan to 30 per cent in Pasak and only 7 per cent in Chao Phraya. In recent years there has been steady encroachment of people into forest areas for conversion to agricultural purposes while cultivated land near urban centres has been converted to residential or industrial use. The need to protect the upper catchment of the Chao Phraya basin from degradation and soil erosion has been identified as a priority by government[135].

13. Lahore, Pakistan
Protected areas play no role in supplying the city with water

14. Kolkata (Calcutta), India
Protected areas play no role in supplying the city with water
The majority of Calcutta's water comes from the River Hooghly along with some groundwater sources[136].

15. Baghdad, Iraq
Protected areas play no role in supplying the city with water
Most water is extracted from the Tigris and Euphrates rivers.

16. Chennai, India
Protected areas play no role in supplying the city with water
Surface reservoirs, i.e. Red Hills, Poondi and Tamarapakkam, supply drinking water to Madras[137]. However, current water supply only meets just over a quarter of the demand, leading to the city authorities going as far as 400 kms from the city to procure water [138].

17. Tianjin, China
Protected areas play no role in supplying the city with water
Tianjin is located on the downstream portion of the Haihe Basin in the northern apex of the Great North China Plain. Surface water is being contaminated by Beijing's upstream activities[139].

18. Pusan, Republic of Korea (South)
Protected areas play no role in supplying the city with water
T'aebaek Mountains form the backbone of the Korean peninsula, extending southward from Wonsan in North Korea almost to Pusan on South Korea's southeastern coast. The mountains form the countries main watershed[140].

19. Yangon (Rangoon), Myanmar
Some forested areas are managed for watershed protection
Two dams in Teikgyi Township, Gyobyu and Phugyi, are the main supply of drinking water to Yangon. Their watersheds are primarily forested (Gyobyu covers 3344 ha, of which 2,068 ha is forested and Phugyi 6176 ha, of which 5,042 ha is forested). The Gyobyu reservoir is protected as a recreation area. The Forest Department of Myanmar is responsible for forest conservation activities in the watersheds, and is currently restoring forest cover around the dams (to date, 304 ha have been planted around Gyobyu dam and 1,608 ha around Phugyi dam)[141].

20. Wuhan, China
Protected areas play no role in supplying the city with water
Wuhan is the capital of the Hubei Province, which lies in the middle Yangtze River valley. The Yangtze River and one of its largest tributaries, the Hanjiang River, are the main water sources for the city[142].The Yangtze watershed covers some 1.7 million km^2, with a population density of 224 people per km^2. 85 per cent of the original forest cover has been lost, and only 2 per cent of the watershed is protected. 11 per cent of the watershed is forested, 56 per cent is cropland and 22 per cent grassland[143].

21. Ahmadabad, India
Protected areas play no role in supplying the city with water
Most of the city's water comes from groundwater sources[144].

22. Hyderabad, India
Some protection of watershed a considerable distance from the city
About 850 million cubic metres of water are stored from the Majeera river for the domestic use in Hyderbad city. Manjeera river is a tributary of the Godavari river (Godavari basin), which has its source in the Western Ghats forests (which contain several protected areas such as: Eravikulam National Park, Category II, 9,700 ha; Silent Valley National Park, Category II, 8,952 ha). Currently about 500 million litres a day are supplied to the city[145].

23. Bangalore, India
Protected areas play no role in supplying the city with water
Water comes mainly from the Arkavathy River and the Cauvery River.

24. Singapore (see case study)
Protected areas are important for city's water supply
Half of Singapore's water comes from the Central Catchment Reservoirs. Bukit Timah (Bukit Timah and the Central Catchment Area – 2,796 ha), in the centre of the Island, are Category IV protected areas. The island state receives the other half of its approximate 300 million gallons of water per day usage from Johor in Malaysia.

25. Ar-Riyad (Riyadh), Saudi Arabia
Protected areas play no role in supplying the city with water
Most of the country's drinking water comes 33 desalination plants, which supply 3.5 billion gallons a day, equivalent to 70 per cent of drinking water needs. Other sources include groundwater reservoirs and almost 200 dams have been built to store rainwater[146].

The Americas

26. Buenos Aires, Argentina
Protected areas play no role in supplying the city with water
Buenos Aires sources its water from the Rio de la Plata, which is the final segment of the massive Paraná River System. The water is collected from the source, transported to large cleaning pools where it is then purified and distributed throughout the city. No protected areas contribute to the production and quality of the Rio de la Plata water. There are some protected areas and reserves along the lower course of the Paraná River, but they have been created with the main purpose of protecting selected components of the biodiversity[147]. The Paraná watershed covers over 2.5 million km^2 over 4 countries and contains 54 large cities (with populations over 750,000). Forest covers only 12 per cent of the land and over 70 per cent of the original forest has been lost. Only 3 per cent of the watershed is protected[148].

27. São Paulo, Brazil
Protected areas are important for city's water supply
São Paulo's 18 million inhabitants depend heavily on some key protected areas for their drinking water. Primary among these is the Cantareira State Park (Category II, 7,900 ha). The Cantareira catchment, located in the outstanding remnants of the highly endangered Atlantic forest, provides 50 per cent of the water supply to the Greater São Paulo Metropolitan area, and the State Park is of central importance for its protection. The 58,280 ha area known as Billings includes São Paulo's single largest water reservoir. From 1989 to 1999, 6 per cent of the area was deforested. Currently, 53 per cent of the area is still covered by native vegetation. Guarapiranga Ecological Park, Morro Grande State Reserve, Itapeti Ecological Station, Juquery and Alberto Loefgren State Parks are also all important for maintaining São Paulo water supply. Ensuring the management of the system is a daunting challenge. Urban encroachment on protected areas, degradation of soil and water catchment, water pollution, irrigation and water for energy are just a few examples of conflicting uses that need to be balanced.

28. Mexico City, Mexico
Protected areas play no role in supplying the city with water
Mexico City is in the southern part of the Basin of Mexico, an extensive, high mountain valley. Ground water is the main water source. The Sierra Chichinautzin is the most important natural recharge zone for the Mexico City Aquifer due to the high permeability of its basalt rock. By the 1930s, continued subsidence and the realisation that ground water supplies within the Basin of Mexico were being depleted prompted authorities to explore sources of water outside the basin. In 1982, an ambitious project was initiated that delivered surface water from the Cutzamala River Basin, a distance of 127 kilometres from the city[149].

29. New York, USA (see case study)
Protected areas and areas managed for watershed protection are important for city's water supply
The Catskill, Delaware and Croton watersheds deliver 1.3 billion gallons of water per day to New York City and the metropolitan area[150]. The Catskill/Delaware Watershed, northwest of New York City, provides 90 per cent of the City's drinking water. The Catskill State Park (Category V, 99,788 ha) protects the watersheds of the Catskill/Delaware system[151].

30. Lima, Peru
Protected areas play no role in supplying the city with water
Water supply is provided by a combination of groundwater and treated surface water taken from the Rimac River that flows from the Andes.

31. Bogotá, Colombia
Protected areas are important for city's water supply
Bogotá's water supply is derived from three main components. The main water source for the city (about 70 per cent) is the Chingaza system, located 50 km east from Bogotá. It collects water from the Guatiquía, Blanco, and Teusacá Rivers into two large reservoirs: the Chuza and San Rafael Dams. Both its integrity and functioning largely depend on the conservation of the watersheds involved within the Chingaza National Park (Category II, 50,374 ha). The second component is the Bogotá River system. It collects water from the upper watershed of this river and stores it in three reservoirs: the Sisga, Tominé and Neusa dams. The third component, the Tunjuelo System stores water from the Tunjuelo, San Francisco and San Cristobal Rivers in two dams: Chisacá and La Regadera[152].

32. Rio de Janeiro, Brazil (see case study)
Protected areas are important for city's water supply
Fourteen different protected areas and the Atlantic Rainforest Biosphere Reserve help to protect the sources of water for the main Guandu Water Treatment Facility, which provides over 80 per cent of Rio de Janeiro's water. Within the Rio de Janeiro Metropolitan area there are a further four protected areas protect areas, which were once the city's main sources for water, but which now only provide just under 10 per cent of the supply. The remaining 10 per cent of the city's water comes from the Lages reservoir, which has forest managed under the regulations established by the Forest Code.

33. Santiago, Chile
Areas in the metropolitan area have been slated for protection and there is also protection of the watershed a considerable distance from the city
Chile's national capital, Santiago, is dominated by a mountainous landscape estimated to cover some 85 per cent of the metropolitan region. The most important sources of water for Santiago are the Maipo River and the Laguna Negra (76 per cent) which run from Laguna Negra volcano in the Andes. The river basin covers some 15,000 km^2 and the main river runs for about 250 km. The water from this river comes from melted snow in the mountains. Other minor contributors are Mapocho River (4 per cent), Molina River, the Yerba Loca estuary, the San Francisco River and the Arrayan estuary. Surface water represents 80 per cent of the water used in the city and underground water contributes 20 per cent. There is considerable protection at the sources of the rivers, with a national park, national reserve and the nature sanctuaries located in the mountain range where little agriculture activity occurs (Cerro el Morado National Park (3,000 ha); Rio Clarillo Nacional Reserve (Category IV, 10,185 ha); Nature Sanctuaries (Predio Los Nogales, Predio Yerba Loca, Quinta Normal) (25,100 ha), total area of scientific interest (11,275 ha) and protected areas (820,947 ha)[153]. Chile's matorral ecosystem is the only example of Mediterranean scrub ecoregion found in all of South America and is only one of five such ecosystems in the world. Within Latin American and the Caribbean region, this ecosystem has been designated as a high-priority in terms of the need to conserve its biodiversity. The only representative sample of this important ecosystem is Chile's Rio Clarillo National Reserve, which represents only some two per cent of the ecosystem's total area.

In 1997, the National Commission for the Environment (Comisión Nacional de Medio Ambiente) conducted a survey that identified the Santiago Foothills, a primary example of the Chilean matorral ecosystem, as of 'singular relevance in terms of its biodiversity'. In 1998, the Ministry of Housing and Urban Development (MINVU) commissioned a survey of potential natural sites in the Santiago metropolitan area to be considered for conservation status. The results of the survey indicated that 19 out of the 24 sites surveyed were located in the Foothills and confirmed the importance of this ecosystem in the metropolitan region. The Metropolitan Santiago Master Plan (PRMS) administered by MINVU thus classified the Santiago Foothill ecosystem as an ‘Ecological Conservation Area’, to be “preserved in natural condition, in order to ensure and contribute to environmental balance and quality”. A proposed project area of 12,900 ha, bordered by hills to the west which limit the further expansion of Santiago’s urban development, the Mapocho and Maipo rivers to the north and south respectively, and a mountain range to the east, is being supported by the World Bank. In the past, the Foothills were used for extensive grazing, topsoil extraction and extraction of firewood and coal from existing sclerophyllous vegetation. Over time, these historical uses have contributed to a reduction in vegetative cover and soil degradation, which in turn are thought to have contributed to a change in the area’s hydrology and exacerbated downstream water quality conflicts. The major economic activities in the area are grazing, fruiticulture, and provision of potable water (*Empresa Metropolitana de Obras Sanitarias* which supplies potable water for part of the municipal district of La Reina) which represents about 20 per cent of potable water in Santiago[154].

34. Los Angeles, USA
Protected areas are important for city’s water supply
The Eastern Sierra watershed, comprised of the Owens Valley and Mono Basin watersheds, is an approximately 891,000 ha watershed which supplies the city of Los Angeles with water. The U.S. Forest Service, U.S. Bureau of Land Management and the Los Angeles Department of Water and Power (LADWP) own 98 percent of this land[155]. Many of California's national forests were created specifically to safeguard and preserve water supplies. The Angeles National Forest is one of 18 national forests in the Pacific Southwest Region of the US Department of Agriculture-Forest Service. The eighteen national forests in California cover only 20 per cent of the land in the State but produce almost half the State's runoff water[156]. The Angeles National Forest (Category VI, 265,354 ha), was established in 1892 and is administered by the US Forest Service. Part of an rugged range rising to over 3,000 m, its lower slopes are covered with chaparral; higher elevations have mixed conifer forest. Within the Angeles National Forest are wilderness areas totalling 32,500 ha and several strictly protected areas, including the 6,900-ha San Dimas Experimental Forest, a biosphere reserve managed for research and generally closed to the public; within it is the 555-ha Fern Canyon Research Natural Area, an oak woodland held as a control for studies on erosion, fire, and air quality[157].

35. Chicago, USA
Protected areas play no role in supplying the city with water
Chicago’s water comes from Lake Michigan (one of the Great Lakes) and is not protected[158, 159.]

36. Toronto, Canada
Protected areas play no role in supplying the city with water
Toronto’s water comes from Lake Ontario, which is not a protected area in any formal way[160].

37. Salvador, Brazil
Protected areas are important for city’s water supply
Two recently created protected areas provide drinking water to the metropolitan region of Salvador. The Lago de Pedra do Cavalo Environmental Protection Area (Category V) was created in 1997, and helps protect caatinga and riverine forests that are vital for the protection of the artificial lake that has been built to ensure the water supply to Salvador and other cities in its vicinity. The Joanes/Ipitinga Environmental Protection Area (Category V, 60,000 ha) protects mangroves, Atlantic forest relicts, and a network of rivers that ensure the provision of nearly 40 per cent of potable water to the metropolitan region of Salvador. Typical problems related to the conservation of these areas are: water contamination by uncontrolled domestic and industrial sewage, unplanned and illegal land occupation, deforestation and forest fires.

38. Havana, Cuba
Protected areas play no role in supplying the city with water
The water supply for the city of Havana comes from underground water aquifers developed in karstic areas that are about 20-30km from the city. Upper parts of the aquifers are protected from pollution by regulation to control activities that would limit their capacity to absorb water filtering from the soils. These regulations are strictly controlled and applied by the Ministry of Water Resources. However these "aquifer protective zones", as they are known in Cuba, are not classified as protected areas as they do not relate to areas of biodiversity value[161].

39. Belo Horizonte, Brazil
Protected areas are important for city's water supply
A network of 10 forest reserves ensures the provision of drinking water to the over 3 million inhabitants in the metropolitan area of Belo Horizonte. Together, the reserves of Mutuca, Fechos, Rola-Moça, Taboões, Catarina, Bálsamo, Barreiro, Cercadinho, Rio Manso and Serra Azul cover 17,000 ha of protected forests, under different IUCN categories and protective forest regimes.

40. Fortaleza, Brazil
Protected areas play no role in supplying the city with water
The water scarce region of Fortaleza relies on a complex system of dams, channels and wells for its drinking water supply. COGERH is the institution responsible for the provision of water to Fortaleza's more than two million inhabitants. Although currently there are no clear links between protected areas and the provision of drinking water, there is a need to ensure that key areas of some river basins, such as the Cocó and Pacoti Rivers, are strategically protected for water provision in the future.

41. Cali, Colombia
Protected areas are important for city's water supply
Cali sources its drinking water from several sources including Farallones de Cali National Park (Category II, 150,000 ha), one of the oldest parks in the country[162]. Cali is surrounded by seven rivers (Aguacatal, Cali, Cañaveralejo, Cauca, Lili, Melendez and Pance). However, most of them are under threat from pollution. The Cauca River watershed is the main source of water, and where most of the city's waste is disposed off. Serious water level reductions in the watershed, have recently led to the water companies to ask for more rational use of the resource (July 21, 2003). There are proposed projects for a total US$200,000 million to recuperate the Cauca River basin[163].

42. Guayaquil, Ecuador
Protection of watershed a considerable distance from the city
The major source of freshwater is the Guayas River, which forms 60 km upstream at the confluence of the Daule and Babahoyo rivers[164]. Although drinking water for the city does not come directly from protected areas, water sources in the lowlands receive water from the Western slopes of the Andes. Here there are several protected areas and other forms of protected forests, so that protected watersheds play some role in the overall water supply. Drinking water problems relate more to increased levels of salt, which one theory proposes is occurring because of rising sea levels and consequent forcing of saline water further into river systems. The mangroves that might provide a natural barrier to this water flow have been heavily degraded in the Guayaquil Gulf area, suggesting that restoration of mangroves might help overall drinking water quality[165].

43. Brasília, Brazil
Protected areas are important for city's water supply
Brasília National Park (Category II, 28,000 ha) was created to protect one of the most important sources of water for Brasília. Planned for 400,000 inhabitants, the Brazilian capital now has a population of over two million. About 40 per cent of the drinking water in the city itself is supplied

directly from the National Park[166], which comprises of upland tree savannah or cerrado and campo cerrado with gallery forests around the springs and watercourses. The area is also a much appreciated recreational site for the city dwellers

44. Santo Domingo, Dominican Republic
Protected areas are important for city's water supply
It is estimated that 52 per cent of the population of the Dominican Republic do not have access to potable water. The main sources of water for Santo Domingo are located in the Caribbean watershed, the source of the rivers Yuna and Nizao, Yaque del Sur, San Juan and Mijo. Many of the rivers are being polluted by sewage, agriculture and industry. The Madre de las Aguas (Mother of the Waters) Conservation Area, consists of five separate protected sections covering more than 323,760 ha: Armando Bermúdez National Park (Category II, 76,600 ha), Juan B. Pérez Rancier (Valle Nuevo) National Park (Category Ia, 40,900 ha), José del Carmen Ramírez National Park (Category II, 73,784 ha), Nalga de Maco National Park and Ebano Verde Scientific Reserve (Category Ia, 2,310 ha). The Madre de las Aguas shelters the headwaters of 17 rivers that provide energy, irrigation and drinkable water for more than 50 per cent of the country's population. The area ranges in elevation from 1,000 to 3,087 meters, making for a high degree of habitat diversity and endemic species. About 90 per cent of the conservation area's amphibian and reptile species, 43 per cent of the butterfly species, 10 per cent of the bird species and 94 per cent of the bat species are unique to the area. About 40 per cent of plant species in the conservation area are endemic. Hispaniolan pine forest covers much of the region, as well as manacla forest, named for an endemic palm tree that is critical in maintaining amphibian, reptile and bird populations. Cloud forests are the origin of fresh water for much of the country's river systems while montane broadleaf forests provide protection to waterways at lower elevations. At the beginning of the 1900's, forest covered around 85 per cent of total area of the country but by 1986 only just over 10 per cent remained forested. Since the 1960's, the government has prohibited deforestation in an effort to protect forest resources, but even protected areas remain under threat. Unsustainable logging, uncontrolled fires, slash and burn agriculture, expansion of sun-grown coffee fields and hillside farming are causing soil erosion and significant species loss in the conservation area[167].

45. Houston, USA
Protected areas play no role in supplying the city with water
Two-thirds of the drinking water provided to Houston residents comes from the Trinity River via Lake Livingston and the San Jacinto River via Lake Houston and Lake Conroe. The EPA's Index of Watershed Indicators has determined that a major Houston-area watershed, the Buffalo-San Jacinto Watershed, has serious contamination problems[168].

46. Medellín, Colombia
Protected areas are important for city's water supply
The Medellín River basin is the main source of water for the city. The origin of the basin is located in the Central Andes Mountain Range, where the Alto de San Miguel Recreational Park and Wildlife Refuge (721 ha), protects the source of the River. Traditionally the park area has been influenced by poor agricultural practices and more recently, logging activity in the neighbouring area. In addition, the water supply for Medellín and neighbouring settlements has three large subsystems known as La Ayurá, Manantiales and Piedras Blancas, with four processing plants and three dams. All of these components are interconnected to some extent. All of these areas have some degree of protection even though none of them is included in a National Park[169].

47. Caracas, Venezuela (see case study)
Protected areas are important for city's water supply
The city receives water form three main sources. These sources correspond to three national parks, the Guatopo (122,464 ha, Category II), the Macarao (15,000 ha, Category II) and the Avila National Park

(85,192 ha, Category II). All three parks are recognised as areas of hydrological importance that contribute to providing water for the city[170].

48. Guadalajara, Mexico
Protected areas play no role in supplying the city with water
Guadalajara is Mexico's second largest city, with over 3.5 million inhabitants. The city faces serious water shortages, as it prime water source, Chapala Lake – the largest natural lake in Mexico, is drying up. The lakes water level has been dropping for years, mainly due to poor water management, reaching a low point of only some 23 per cent of it capacity in 2001. Furthermore, about 40 per cent of the water that runs through the water distribution system in the city is wasted because of leaks. An alternative project to use a new source of water (Verde River) has not been approved by the authorities. There is also a project to build a new aqueduct for the city but it will require the relocation of local residents. Chapala Lake is fed by the Lerma-Santiago river basin, which has also suffered great decreases in flow due to water withdrawals upstream. The water that runs through this basin is one of the most polluted in the country. More positively, new educational campaigns are being started to recuperate the lake and a proposal exists to declare the lake a RAMSAR site. Presently it has been included as part of the network of Living Lakes[171].

49. Maracaibo, Venezuela
Protected areas are important for city's water supply
Up until 1938 the city took its water from the Lake Maracaibo. Currently the city receives water from the Mara and Paez basin, however the supply is becoming insufficient due to deforestation in the highlands of the basin and the growth of the city. Further supplies come from the Catatumbo basin which originates in Colombia. Authorities estimate that water from rivers in the southern part of the state could be used to fulfil the city needs, also rise in Colombia and are subject to significant pollution. Part of the mountain range where the Mara and Paez rivers originate is protected by the Perijá National Park (Category II, 295,288 ha), in the Perijá Mountain Range. The Perijá National Park has serious management problems due to the presence of Colombian armed groups, illegal crops, conflicts among Creole cattle people and the native communities, coal mining, and the advancement of the agricultural frontier (the last three issues occurring mainly in land adjacent to the park). Recent reports mention that heroin trafficking groups have deforested up to 2,000 ha to plant poppy fields, threatening the park's rare howler and capuchin monkeys, spectacled bears, wood storks and giant anteaters. The Perijá National Park is contigous with the Catatumbo-Barí National Park in Colombia (Category II, 158,125 ha)[172].

50. Ecatepec, Mexico
Protected areas play no role in supplying the city with water
The Monctezuma River basin and the sub-basin of the lakes Texcoco and Xaltocan are the main sources of water for the city. Although the area close to the city has a limited capacity of underground water, it is not used because 80 per cent is diverted to Mexico City[173].

Europe

51. Istanbul, Turkey (see case study)
Official protected areas currently play no role in supplying the city with water
There are several water reservoirs in the forests on both peninsulas of Istanbul which have been providing water for the city for several centuries The role of these reservoirs in providing potable water to the city is 'very significant'. However these forests are not classified as protected areas, although WWF-Turkey is currently lobbying the authorities to declare them as protected.

52. Moscow, Russia
Low levels of protection around areas supplying the city with water
Drinking water for Moscow comes from the Moscow and Volga rivers through a system of channels and reservoirs, which have protected buffer zones (although they are not formally included in the system of protected areas). Forests on the river banks, around lakes and reservoirs that are used for drinking water supply, help ensure water quality and quantity. These protective zones correspond to IUCN category VI. In the Moscow region, protective zones for drinking water represent more than 10 per cent of the forested area of the region (while the average figure for Russia is 0.15 per cent).

53. London, United Kingdom
Protected areas play no role in supplying the city with water
London's sources its water supply by abstraction from the River Thames and River Lee and pumping into fully impounded reservoirs in south west and north London respectively[174].

54. St Petersburg, Russia
Protected areas play no role in supplying the city with water
Water comes mainly from the River Neva.

55. Berlin, Germany
Water sources are protected through special protection zones
Nine waterworks supply Berlin with drinking water drawn entirely from groundwater sources, all of which are surrounded by protection zones. The boundaries of the conservation areas are set by isochrones, i.e. lines marking similar flow times to the well. In these protection zones, which are in three different degrees of protection and generally have a radius of a few hundred metres, activities likely to endanger eater supplies are prohibited[175].

56. Madrid, Spain
Protected areas are important for city's water supply
Madrid's water supply comes from 15 dams, all of them located in the northern area of the province (Sierra Guadarrama). Five out of these 15 dams, belonging to the Lozoya River Basin, which provides two-thirds of the total freshwater supplies (El Atazar, El Villar, Puentes Viejas, Riosequillo and Pinilla dams) none of these dams are in protected areas although the Lozoya's River watershed includes some important ecological areas. The upper part of this basin has recently been protected (Natural Park of Peñalara). The new 15,000 ha Natural Park was announced in 2003, and provides protection to Madrid's only glacier lake. The site will provide protection to the area's wildlife, regulate building and sanitise effluents into the river Lozoya[176]. One dam (Santillana) takes water from the Manzanares River Basin, which is included in the Regional Park Cuenca Alta del Manzanares (Category V, 46,323 ha)[177].

57. Rome, Italy
There are a number of protected areas in the watershed
The water system which supplies Rome and 60 other councils in Lazio is comprised of seven aqueducts, adding up to more then three hundred kilometres. Rome is one of the few cities in the world whose water supply is naturally potable, since the sources are particularly pure. 97 per cent of potable water comes from natural sources while the remaining 3 per cent comes from wells[178]. There are several protected areas in the watershed.

58. Kyyiv (Kiev), Ukraine
Protected areas play no role in supplying the city with water
Kiev does not source any of its potable water from protected areas. In Ukraine, in general most surface and underground water resources originate from the Dnipro (Dnieper) River, which supplies water to

two-thirds of the Ukrainian population and 60 per cent of Ukraine's farms. The watershed of the Prypyat River, a tributary of the Dniper River, is a wetland area which is likely (after Chernobyl) to be established as a National Park (currently being proposed as part of a GEF grant)[179]. Very little of the watershed (only some three per cent) is forested, and in 1998 only two per cent was protected[180].

59. Paris, France

Protected areas play no role in supplying the city with water

Paris's water comes from rivers (including the Seine)[181].

60. Bucharest, Romania

Protected areas play no role in supplying the city with water

Water comes from the River Dambobitza and from groundwater sources.

61. Budapest, Hungary

Protected areas are present in the watershed

Seventy per cent of Budapest's drinking water comes from Szentendre island, north of the city. All the wells (100 wells) are drilled in the bank zone and they filter Danube water. The island is designated as a hydrogeological protection zone where land use is restricted. Duna-Ipoly National Park covers about twenty per cent of the island due to its natural values (regardless of the position of the wells)[182].

62. Minsk, Belarus

Protected areas play no role in supplying the city with water, however forest areas are managed to protected water sources

There are two sources of drinking water supply for Minsk: underground source and waters from the Vileya River which are transported through a system of channels and reservoirs. There is no obvious link between existing protected areas and drinking water supply, however, the green belt around Minsk (radius is about 80 km) and protective zone around the Minsk reservoir play a very important role in ensuring water quality. The protective regime in these zones is quite strict. For example, logging is prohibited. Thanks to these restrictions, the forest around Minsk city has not destroyed[183].

63. Hamburg, Germany

There are protected areas within the catchment

The drinking water supply in Hamburg is based upon ground water taken from 18 different waterworks, 14 of them located within the city borders and 4 in the outer region. The water catchment areas of two in the outer region have some protection status[184].

64. Warsaw, Poland

Protected areas play no role in supplying the city with water

Forty per cent of Polish forests have a water protection function. Warsaw takes it water from the Vistula, the watershed of which covers 70 per cent of Polands area. In total 10 per cent of the Vistula watershed (180,247 km^2) is protected[185].

65. Vienna, Austria

Protected areas are important for city's water supply

The Donau-Auen National Park (Category II, 10,000 ha) is a significant source of Vienna's drinking water (up to 20 per cent). The remainder is piped from mountain areas, where there are some protected forests but not official IUCN category protected areas[186].

66. Barcelona, Spain

Protected areas are important for city's water supply

Until 1950, almost all the water supplied to Barcelona came from wells in the Besòs and Llobregat deltas. With increased demand and spreading underground contamination, the city of Barcelona decided to import water from two rivers: the Ter (some 100 km north of Barcelona) and Llobregat, next to the city. Currently, 90 per cent of the water consumed in Barcelona city comes from surface water of these two rivers. In 1997, the public service, AGBAR, supplied 153 hm^3 of water, 41 per cent of which came from the Ter River, and the rest from the Llobregat River.

Water quantity is highly dependant on dams. Above the *Estació de tractament d'aigua potable* (water purification plant), the Ter River has three dams (Sau, Susqueda and Pasteral) with a capacity of 400 hm^3 per year. Above the purification plant, the Llobregat River has three dams (Baells, Sant Pons and Llosa del Cavall) with a combined capacity of 224 hm^3 per year. Water quality from these two rivers is not good. Water from the Ter River is treated at the water purification plant of Cardedeu, it then connects with the water of the Llobregat River, as well as the collecting wells of the Llobregat delta, and it is treated at the water purification plant of Sant Joan Despí, in the lower valley, only 15 km from the sea.Taste of tap water in Barcelona is generally poor. For this reason, Barcelona has a very high rate of bottled water consumption. Over 90 per cent of the bottled water comes from springs located in several Catalan protected areas, such as the Montseny Nature Park.

A large portion of both watersheds are forested and there are several protected areas, although the level of protection varies. In the Llobregat basin, over Sant Joan Despí, where water is taken (although some water is taken a little above, from Abrera), the protected areas are:

- Parc Natural Serra del Cadí-El Moixeró (part) (Category V, 41,342 ha),
- Paratge Natural d'Interès Nacional del Pedraforca (Category V 1,671 ha)
- EIN Serra de Catllaràs
- EIN Serra de Picancel
- EIN Serra d'Encija-Els Rasos de Peguera
- EIN Serres de Busa-Els Bastets
- EIN Serra de Queralt
- EIN Els Tres Hereus
- EIN Serra de Navel
- EIN Muntanya de Sal de Cardona
- Parc Natural de Sant Llorenç del Munt i Serra de l'Obac
- Parc Natural de Montserrat
- EIN Roques Blanques
- EIN Serra de Collserola (part)
- EIN Muntanyes de l'Ordal

Natural protected areas in the Ter basin, over El Pasteral (where water is taken, after three dams: Sau, Susqueda and El Pasteral), are:

- EIN Capçaleres del Ter-Freser
- EIN Serra de Montgrony
- EIN Obagues de la Vall de l'Isard
- EIN Serra Caballera
- EIN Serres de Milany, Serres de Santa Magdalena i Puigsacalm-Bellmunt (partially)
- EIN Collsacabra (part)
- EIN Savassona
- EIN Les Guilleries
- EIN Riera de Sorreigs
- EIN Turons de la Plana Aussetana

EIN= *Espai d'Interès Natural* (created in 1992 by the *Pla d'Espais d'Interès Natural,* passed by the Government of Catalonia). Protection level equivalent to IUCN Category V protected landscapes.

Most of protected areas in these two basins are forested until 2200-2300m, above this altitude alpine meadows dominate. Except for those protected areas that have higher levels of protection, such as *Parc Natural* or *Paratge Natural d'Interès Nacional*, there not a significant difference in forest management whether the area is inside or outside an EIN. The main problems of water quality and quantity are related to multiple urban, industrial and agricultural uses and impacts above the points were water is taken in both rivers. For instance, the middle Ter basin, just above the dam of Sau, has the highest concentration of cattle of Spain, which causes widespread contamination of ground and underground waters. On the other hand, the lower Llobregat valley is one of the most important industrial areas of Catalonia. Global-climate experts agree that in this Mediterranean region annual precipitation will decrease by around 20 per cent by the year 2050. From now to then, they think there will be an increase of the frequency of intense precipitation events; flood hazard, and risk of water shortage, especially during summers[187].

67. Kharkov (Kharkiv), Ukraine
Protected areas play no role in supplying the city with water
Water comes from several surface sources including the rivers Ouda and Seversky Donets.

68. Nizhnij Novgorod, Russia
Protected areas play no role in supplying the city with water

69. Milan, Italy
Protected areas play no role in supplying the city with water
An aquifer system, which is the source of drinking water for the city of Milan, and extends over an area of about 400 km^2[188].

70. Ekaterinburg, Russia
Protected areas play no role in supplying the city with water
Most of the water comes from surface waters and groundwater sources are very limited.

71. Stockholm, Sweden
Protected areas play no role in supplying the city with water, but the watershed is managed for water quality, and some forest activities are FSC certified
Stockholm, the capital of Sweden in northern Europe, has a population of over 1.8 million (1999), just over 20 per cent of the countries population, in an area of about 6,500 km^2. The area is experiencing slow, but sustained, population growth. In 1999, the population increased by 1.1 per cent[189], and the region expects to house 4-600,000 more inhabitants within the next 30 years[190]. Water supply and sewage disposal in Sweden are by law a municipal responsibility[191]. In Stockholm, the local authority-owned company Stockholm Vatten delivers fresh water to Stockholm residents and ten neighbouring municipalities. The company owns and manages two fresh-water plants, three sewage purification plants, sewers for fresh water and sewage water and pumping stations in the Stockholm area[192]. In 2002, water production totalled 133.1 million m^3 and is reported as being of 'consistently high' quality[193].

Lake Mälaren is the water source for the Norsborg and Lovö waterworks, the cities main water providers. Lake Bornsjön, which was bought by the city in 1904, is the backup water source in the event of any temporary problem in Lake Mälaren[194]. Stockholm Vatten controls most of the 5,543 ha watershed of Lake Bornsjön, of which 2,323 ha, or about 40 per cent, is productive forestland[195].

Although forestry is conducted in the Lake Bornsjön watershed, Stockholm Vatten's management is focused on protecting water quality. This objective has a major effect on forestry practices, with management concentrating on measures to reduce soil erosion into the lake. Thus many trees are left standing to protect water courses and lakes and no scarification is carried out to avoid ground damage by heavy machinery. The main species grown and harvested are spruce (*Picea abies*), pine (*Pinus silvestris*) and birch (*Betula* sp.). Forest management is also to a large extent adapted for recreation purposes, and the forest has many areas of cultural significance which are also taken into consideration by forest management[196]. In September 1998, Stockholm Vatten was certified under the Swedish Forest Stewardship Council (FSC) standard[197].

As the role of the state declines in many countries, the importance of conservation initiatives by the private sector will increase. One important aspect of this is the role that commercial companies could play in protected areas. Companies can provide support to national protected area networks in a number of ways, ranging from providing financial, logistic or technical support for existing protected areas, to sympathetic management of buffer zones or even putting aside some of their own land into protection[198]. Forests cover around 60 per cent of Sweden's land area, but only 4,4 per cent of Sweden's total productive forest land is protected and in most regions of southern and middle Sweden is the figure below 1 percent[199]. Although the need for more protection of biologically-important forest areas is now generally recognised, the Swedish authorities have tended to put an emphasis on voluntary policies which work with forest owners in increasing protected area networks rather than relying on new legislation. A survey of voluntary protected areas in 1996 showed that a fifth of all the private forest owners and all large companies had established voluntary reserves. According to the Swedish National Board of Forestry and the Environmental Protection Agency, such reserves were expected to protect about 2-4 per cent of forest below montane forests, however they noted that '*information on voluntary reserves is, in many ways, unreliable and preliminary. Therefore, it is important to study them more closely to find out about their extent and their environmental values*'[200].

The voluntary nature of company protection has been further refined through independent certification of forest management. The Swedish FSC standard was endorsed in 1997 – the first national FSC standards in the world. The standard addresses a broad range of issues relevant to forest management in Sweden. Some important environmental components include protection for so called key habitats and old-growth forests (including restoration incentives), protection of mountain forests from further fragmentation and modified management and restoration of deciduous forest types[201]. The Swedish standard says that FSC certified management units must include protection for a range of important forest habitat sites within commercial holdings. At least 5 per cent of certified land (excluding very small areas and areas already legally protected and compensated for by the state) must be exempt from forest management – thus standardising the earlier proposals for protected area targets[202]. According to the certification report for Stockholm Vatten's Lake Bornsjön watershed, areas left for conservation and restoration '*will considerable exceed 5 per cent of the productive land*'[203].

72. Praha (Prague), Czech Republic

Protected areas play no role in supplying the city with water

Water comes from the Zelivka and Vltava rivers and from groundwater sources.

73. Munich, Germany

Protected areas play no role in supplying the city with water, but forests in the watershed is managed for water quality

Since the foundation of the Munich waterworks in circa 1900, forest management and the issuing of forestry-licences has been focussed on ensuring good water quality. Today, an area of 2,900 ha is managed primarily to maintain water quality and an additional area of 1,900 ha is under long-term contracts with local farmers, who commit to certified ecological/organic agriculture[204].

74. Samara, Russia
Protected areas play no role in supplying the city with water

75. Sofija, Bulgaria
Protected areas are important for city's water supply
Sofia relies for much of its water supply on sources originating from two mountain protected areas: the Rila (Category II, 107,924 ha) and Vitosha (Category IV, 26,607ha) National Park. Within the Parks are a number of higher IUCN category protected areas. For example, much of the water for several residential areas of Sofia is drawn from the Bistrishko Branishte Biosphere Reserve (Category Ia 1,062 ha), a high mountain peat bog area within Vitosha National Park, which is a Strict Reserve, a Biosphere Reserve and a drinking water protection zone [205]. The reserve comprises of coniferous forests mostly with spruce (*Picea abies*) and deciduous forests of beech (*Fagus sylvatica*) on lower slopes, whereas the higher parts are covered by subalpine shrub (*Juniperus sibirica*) and grassland communities. The botanical diversity is rich – more than 400 species of algae, 360 lichens, 500 fungi and 450 vascular plants have been recorded. The reserve is also home to many rare and endangered animals such as the brown bear (*Ursus arctos*), *Spermophilus citellus*, marten (*Martes martes*), *M. foina*, *Mustela nivalis* and wolf (*Canis lupus*). The forest was subject to timber exploitation until the establishment of a nature reserve[206].

Africa

76. Lagos, Nigeria
Protected areas play no role in supplying the city with water
Water comes from both surface and groundwater sources.

77. al-Qahira (El Qahira), Cairo, Egypt
Protected areas play no role in supplying the city with water
All three of Egypt's biggest cities lie at the end of the Nile watershed. Over the centuries the watershed has lost 91 per cent of its original forest cover and now has only 2 per cent forest cover (crop land accounts for just 10 per cent, grassland 52 per cent and 30 per cent is barren). The watershed has 7 large dams on it, and 30 large cities within it. Only 5 per cent is protected[207]. Some protected areas such as Mount Elgon in Kenya (Category II, 16,923 ha), Rwenzori (Category II, 99,576 ha), Queen Elizabeth National Park (Category II, 197,752 ha), Kibale Forest Corridor (IV, 33,918 ha) and Semliki Controlled Hunting Area (Category VI, 50,400 ha) and Murchison Falls National Park (Category II, 383,907ha) in Uganda feed into the Nile[208], but clearly have little influence on the quantity or quality in countries thousands of miles away.

78. Kinshasa, Congo (Dem. Rep.)
Protected areas play no role in supplying the city with water
Kinshasa is situated on the banks of the Congo River (also known as the Zaire). The Congo is the fifth-longest river in the world; it stretches over 4,000 km and its watershed covers over three million km^2. Its hydrological system straddles several countries (Congo and the Democratic Republic of Congo for the most part, but also Angola, Cameroon, the Central African Republic, Zambia and Tanzania, stretching through Lake Tanganyika). Forests would once have covered virtually the whole area, but now only 44 per cent of the watershed is forest, and deforestation is continuing at a rate of about seven per cent a year. Only about 5 per cent of the watershed is protected[209].

79. al-Iskandriyah (El Iskandriyah) (Alexandria), Egypt
Protected areas play no role in supplying the city with water
Much of the water comes from the Nile.

80. ad-Dar-al-Bayda (Casablanca), Morocco
Protected areas play no role in supplying the city with water
Most of the water comes from surface sources and there are currently problems in supply and pollution.

81. Kano, Nigeria
Protected areas play no role in supplying the city with water
Kano lies within the massive Niger watershed which encompasses ten countries and covers an area of over 2.5 million km^2. 96 per cent of the original forest cover has been lost and there are now no significant areas of forest left in the watershed. Only 5 per cent of the whole watershed is protected[210].

82. Ibadan, Nigeria
Protected areas are important for city's water supply
Part of Ibadan gets its water supply from the moist semi-deciduous forest of the Olokemeji Forest Reserve (7,100 ha) and Gambari Forest Reserve[211].

83. Abidjan, Côte d'Ivoire
Protected areas are important for city's water supply
Banco National Park (Category II, 3,000 ha) close to Abidjan serves as watershed to the rivers and dams providing drinking water to the city of Abidjan[212]. The Park, an area of dense rainforest traversed by the River Banco on the North bank of the Ebrié lagoon, is about 10km west of Abidjan in southern Côte d'Ivoire[213].

84. Cape Town, South Africa
Protected areas are important for city's water supply
Cape Town extracts significant water from catchment areas including the Cape Peninsula National Park (newly proclaimed see details below) and the Provincial Reserves along the Hottentots Holland (Hottentots Holland Nature Reserve Category IV, 24,569 ha) mountain range, in the Western Cape, most of which are managed as Mountain Catchment areas by the nature conservation agencies[214]. Cape Peninsula National Park (CPNP), which is almost entirely surrounded by the city of Cape Town, was proclaimed in 1998. The planned core area of the park will cover some 29,000 ha. Since proclamation the park has grown to nearly 22,100 ha, or about 73 per cent of the entire Cape Peninsula Protected Natural Environment (CPPNE). Of this, about 15,700 ha is proclaimed and some 6,400 ha is public land managed by the CPNP but not yet proclaimed. The predominant vegetation is mountain fynbos (fine bush), with other areas supporting a range of habitats from the rare renosterveld to evergreen forest. The Peninsula has more than 2,285 species of plants, of which 90 are considered endemic[215]. The Hottentots Holland Nature Reserve is also important for the conservation of mountain fynbos and has approximately 1,300 plant species, including several rare and endemic plants. Approximately 110 bird species have been recorded on the reserve, amongst them several species of raptor[216].

85. Addis Ababa, Ethiopia
Protected areas play no role in supplying the city with water
Water comes mainly from the Kechene and Akaki rivers.

86. al-Jizah (Giza), Egypt
Protected areas play no role in supplying the city with water
Much of the city's water is extracted from the Nile.

87. Nairobi, Kenya

Protected areas are important for city's water supply

Nairobi, the capital of Kenya, has a population of 3 million residents, which according to the U.N. Habitat (the United Nations Human Settlement Programme) is increasing at 5 per cent per annum[217]. Nairobi draws its water from several different sources, including the Ruiru, Sasumua, Chania II and Ndakaini systems[218]. The Sasumua dam, the second largest in the country, supplies two-thirds of the water to the Kabete reservoir in Nairobi's western suburbs, where it is then distributed to the city[219]. As the population grows, government figures predict that the country's per capita water supply will fall from the current 700m^3 to around 500m^3 by 2010. This shortfall is not helped by the fact that half of the water Nairobi imports daily, from between 125 and 370 miles away, is lost through leaks in the old pipelines and illegal connections[220]. According to the Water Resources Minister, Martha Karua, the future for ensuring sustainable water supplies to Nairobi and throughout Kenya, lies in harvesting rainwater, building reserves from dams, and replanting trees. This is, however, a long-term vision, which, as she states "will not produce results in an instant, but we want to look back five years, 10 years, 15 years later and say our forest cover now is 40 per cent — and this can be achieved"[221]. The main rivers emanating from the Aberdares (including the Aberdares National Park, IUCN Category II, 76,619 ha), and the Mt Kenya water catchment area supply Nairobi with drinking water. Much of the area is currently being logged, which may make the water supplies to Nairobi even more unreliable. According to a spokesperson from UNEP'S Global Resource Information Database: indigenous trees are important for the maintenance of water in streams as they capture mist from the atmosphere, and this mist contributes about 20 per cent of the water that flows from a forested area into a river[222].

88. Dar es Salaam, Tanzania, United Republic of

Protected areas are important for city's water supply

Dar es Salaam gets its water supply partly from the (southern) Ruvu River which arises in the Udzungwas (where there are forest reserves and Udzungwa Mountain National Park, Category II, 190,000 ha) and partly from the Selous Game Reserve (Category IV, 5,000,000 ha and World Heritage site)[223]. The Selous Game Reserve is the second largest in Africa and is part of the Selous ecosystem (7,400,000ha) which includes Mikumi National Park (Category II, 323,000 ha) and Kilombero Game Controlled Area (Category VI, 650,000 ha). The reserve was accepted as a World Heritage site in December 1982. A large area of the reserve is drained by the Rufiji River and tributaries which include the Luwegu, Kilombero, Great Ruaha, Luhombero and Mbarangardu (the only permanently flowing streams). There are two main vegetation types in the reserve: the eastern sector (17 per cent) is mainly wooded grassland dominated by *Terminalia spinosa* and the western sector (about 75 per cent) is deciduous miombo woodland with *Brachystegia*, *Julbernardia globiflora*, *Pterocarpus angolensis*, and *Combretum*. There are also areas of dense thicket, riverine and ground water forest. More than 2,000 plant species have been recorded, but it is thought that many more may be found in the remote forests in the south[224].

89. Durban, South Africa

Protected areas are important for city's water supply

Durban's water comes from a variety of sources, including the Drakensberg catchment areas (Ukhlahlamba-Drakensberg Park, Category I (48 per cent) and II (52 per cent), 242,813 ha, World Heritage Site, RAMSAR site) as well as protected areas such as the Umgeni Vlei. The Drakensberg is regarded as the most important mountain catchment in South Africa because of the high water yield and good quality water which flows from it[225]. The harvesting of this major resource is through a series of large dams set in the upper catchments of the province's major rivers such as the Thugela, the Bushmans and the Umgeni. The Umgeni River has several dams which supply water to Durban (Midmar Dam, Inanda Dam, Albert Falls Dam), which are proclaimed nature reserves and are managed by KZN Wildlife[226]. The Drakensberg is an island mountain range in the KwaZulu-Natal Province, along the south-western border with Lesotho. The World Heritage site is composed of four different designations: State Forest (6 sites), Game Reserve (1), Nature Reserve (4 sites) and National Park (1 site). The various protected areas that collectively constitute the nomination site were separately established, between 1916 and 1967. The Drakensberg is one of the least drought-prone areas of southern Africa. The vegetation forms three main topographical features: the low altitude belt (1280-1830m) with *Podocarpus* forest, the mid altitude belt (1830-2865m) with *Themeda* grasslands and *Passerina-Phillipia-Widdringtonia* thickets and the high altitude belt (2865-3500m) or alpine tundra with *Erica-Helichrysum* heath[227].

90. Dakar, Senegal
Protected areas play no role in supplying the city with water
A substantial proportion of Dakar's water is sourced 200 km from the city from Lac de Guiers in the Lower Senegal River Basin, as local sources of groundwater have been over exploited and polluted and aquifers over-pumped, resulting in increased salinity[228]. Ecological changes, particularly physical and chemical changes in the water environment, have resulted from the construction of dams (Diama and Manantali) in the river basin. Overall, the basin ecosystems and production systems are now threatened by decreasing productivity due to inadequate resource management, including deforestation, soil erosion, overgrazing and desertification. Species diversity has been reduced, along with elimination of wetlands by diking and expansion of irrigated areas. The watershed of the Senegal River covers over 400,000 km^2 has been completely deforested. Six per cent of the watershed is protected[229].

91. Luanda, Angola
Protected areas play no role in supplying the city with water
The Dutch introduced a water supply and sanitation to the city in the mid-17th century by building a canal from the Kwanza River to the south of the city. In 1889, water from the northern Bengo River was added to the system via aqueduct. Though the two rivers still supply Luanda, the city's existing 600km distribution network has failed to match rapid population expansion[230].

92. Tarabulus (Tripoli), Libya
Protected areas play no role in supplying the city with water
Tripoli is increasingly reliant on groundwater from the central Sahara desert, through a massive pipeline project called the Great Man Made River. Groundwater sources are currently being tapped faster than they are renewed, causing political tensions.

93. Harare, Zimbabwe
Protected areas are important for city's water supply
Harare draws its water from two lakes: Lake Chivero – formerly Lake MacIlwaine (within the Robert McIlwaine Recreational Park, Category V, 55,000 ha including 30,000ha water) which is contiguous with Lake Darwendale (within the Lake Robertson Recreational Park (Category V, 8,100 ha), both of which are under the Parks and Wildlife Act[231]. The 14.5km long Lake Chivero was created by a dam across the Hunyani River, and forms the main supply of water to Harare. The vegetation in the Robert McIlwaine Recreational Park is typical Mashonaland highveld, which is retained in its natural state in certain parts of the park and does not occur in other conservation areas in Zimbabwe[232].

94. Al-Jazia'ir (Algiers), Algeria
Protected areas play no role in supplying the city with water

95. Johannesburg, South Africa
Protected areas are important for city's water supply
Johannesburg derives a good deal of its water from the Maluti/Drakensberg Transfrontier Park – created in 2001 (which is also a nominated World Heritage Site). Water is sourced either (i) via the Tugela / Vaal transbasin pumped storage scheme, the water coming from the Ukhahlamba-

Drakensberg Park (see Durban entry), including some parts of the mountains, such as the Mnweni area, which are not protected areas; or (ii) the recently established Lesotho Highland Water Scheme (the source is the highland wetlands) which are traditionally protected e.g. the Phofung area (Mont-aux Sources) and the Senqu sources. Some small areas of the catchment are being incorporated into protected areas (Ts'ehlanyane, Bokong Nature Reserves). Although the scheme is not situated in the core area of a conservation site, the water drains from the catchments of the Maluti/Drakensberg Transfrontier Park on the Lesotho side. South Africa is one of the first countries in the world to adopt a National Water Act that incorporates a Catchment Management Strategy for sound water resource management. Johannesburg is one of the first cities in the country to develop catchment management strategies at a local level for two rivers flowing through town. Johannesburg receives water from the Vaal River and the Lesotho Scheme. Following current demand projections Johannesburg's water resources will be exhausted by 2020. The city is thus placing great emphasis on water conservation and demand management[233].

96. Khartoum/Omdurman, Sudan
Protected areas play no role in supplying the city with water
The Khartoum area is a part of Khartoum basin that is situated at the northern periphery of the Blue Nile rift basin[234]. Khartoum gets its water from either the Nile at the confluence or upstream from the White Nile at the Jebel Aulia Dam - in the watershed of the White Nile[235]. In total, 45 per cent of water supplies for the Khartoum area come from direct pumping from the two Niles[236].

97. Ar-Ribat (Rabat), Morocco
Protected areas play no role in supplying the city with water
Most of the water comes from surface sources and there are currently problems in supply and pollution.

98. Conakry, Guinea
Protected areas play no role in supplying the city with water
Much of the water comes from surface sources collected in the Grande Chutes reservoir, although there are major problems with distribution and supply[237].

99. Accra, Ghana
Protected areas play no role in supplying the city with water
Accra's main water supplies are piped from a coastal stream, the Densu. Water shortages, leading to power shortages, are due to substantial increases in population, and drought conditions[238].

100. Kaduna, Nigeria
Protected areas play no role in supplying the city with water

Australia/Oceania

101. Sydney, Australia
Protected areas are important for city's water supply

The Sydney Catchment Authority was established in July 1999 to manage and protect Sydney's catchments and to provide a bulk raw water supply to its customers; including Sydney Water which delivers around 1,600 million litres of water a day to more than four million people in Sydney and the surrounding areas. The catchments cover almost 16,000km^2, extending from the upper Blue Mountains, south to the source of the Shoalhaven River near Cooma, and from Woronora in the east to the source of the Wollondilly River near Crookwell. Although this area represents only about two per cent of New South Wales, the catchments supply water to over 60 per cent of the states population.

Around 25 per cent of the water supply catchments are known as 'Special Areas'. Special Areas are mostly of prinstine bushland close to the reservoirs or dams. Most Special Areas represent only a part of the entire catchment, acting as a buffer zone to stop nutrients and other substances that could affect the quality of water entering the water storage areas. The Sydney Catchment Authority and the National Parks and Wildlife Service jointly manage the Special Areas, in accordance with the Special Areas Strategic Plan of Management. The Blue Mountains National Park (Category II, 247,021 ha) is important as a major water catchment area for Sydney. Most of the southern section of the park, together with parts of the adjoining Kanangra-Boyd National Park (Category Ib, 65,280 ha), is included in the Warragamba Special Area and has an important function in contributing water to Lake Burragorang, Sydney's major potable water source. The park's vegetation is comprised of about 40 distinct communities, many of which are restricted in occurrence or unique to the Blue Mountains area. Most are dry forests (45 per cent of the park) and woodlands (38 per cent) dominated by eucalypts, with the remainder being 'rocky complex' heaths (10 per cent), 'plateau complex' heaths and low woodlands (3 per cent) and moist forests and rainforests (2 per cent). Blue Mountains National Park, together with Kanangra-Boyd, Wollemi, Gardens of Stone, Nattai, Thirlmere Lakes and Yengo National Parks and Jenolan Karst Conservation Reserve, is inscribed on the World Heritage List as the Greater Blue Mountains World Heritage Area. Other reserves within the catchment include the Dharawal Nature Reserve (Category Ia, 341 ha) and Dharawal State Recreation Area (5,650 ha)[239].

102. Melbourne, Australia (see case study)
Protected areas are important for city's water supply
Ninety per cent of Melbourne's water supply comes from uninhabited mountainous catchments to the north and east of the city. Mountain Ash (*Eucalyptus regnans*) produces approximately 80 per cent of Melbourne's water, and nearly 50 per cent of the catchments are in protected areas. Melbourne Water manages some catchments just for water collection, and works closely with the Department of Sustainability and Environment and Parks Victoria in managing catchments in state forests and the Kinglake (Category II, 21,600 ha), Yarra Ranges (Category II, 76,000 ha) and Baw Baw (Category II, 13,300 ha) National Parks[240]. Melbourne has been recognised as having the highest quality drinking water of any Australian city.

103. Brisbane, Australia
Protected areas play a minor role in the city's water supply
The water supply for Brisbane originally came from the protected forested catchment of Enogerra Creek. The Enoggera Reservoir was constructed in 1866 and provided the first reticulated water supply for Brisbane. The Gold Creek Reservoir was constructed in 1886 and served as a stand-by supply for Enoggera Reservoir. These two reservoirs were connected by an underground tunnel constructed in 1928. The third reservoir in Brisbane Forest Park is Lake Manchester. It was built in 1916 to provide emergency supply for the Mount Crosby treatment plant (which is on the Brisbane River) in times of high consumer demand or low river levels. Today, these three reservoirs are all managed for water catchment protection and cultural heritage values. D'Aguilar National Park (2,050 ha, Category II) covers five per cent of the Forest Park, and is managed Environmental Protection Agency, Queensland Parks and Wildlife Service. D'Aguilar National Park is managed over six areas, which include Maiala, Manorina, Boombana, Jolly's Lookout, Cabbage Tree Range and Kipper Creek. The vegetation types represented in these areas include wet and dry sclerophyll forests and rainforest[241]. They form part of the multipurpose Brisbane Forest park which covers 28,500 ha and stretches over 70km along the Taylor and D'Aguilar Ranges

The Brisbane Forest Park Authority was established in 1977, creating Queensland's first coordinated conservation area ('coordinated' because so many state and local authorities had responsibilities within the area). Today, the Brisbane Forest Park is an administrative construct involving an amalgam of National Park and State Forest, however currently State Forests are being transferred to National Park status[242]. The Authority manages in co-operation with three different land managers. State Forests comprise the largest section of land area in the Park (70 per cent) and are managed by the Department of Natural Resources, Forest Resources. Brisbane City Council manages 25 per cent of the land area, including the three reservoirs in the Park, Gold Creek, Enoggera and Lake Manchester, as well as some of the recreational areas.

While catchment management is still an important priority within the Park, the bulk of the cities water now comes from rural watershed further away from the city that supply three water main storages – Wivenhoe Dam, Somerset Dam and North Pine Dam[243]. Lake Wivenhoe is situated on the Brisbane River approximately 150km from the river mouth and commands around 40 per cent of the total catchment of the river. The dam was completed in 1985 and provides water supply and flood mitigation. Somerset Dam is situated on the Stanley River, approximately 220 km upstream from the mouth of the Brisbane River. Water is released from Somerset Dam to supplement Wivenhoe Dam, which in turn supplements the natural flow of the Brisbane River and maintains an adequate supply of water to the Mt Crosby pumping station, 132 kms downstream from Somerset Dam. The Mt Crosby treatment plant purifies the river water which is then piped to the cities of Brisbane, Logan, Ipswich and Redcliffe[244]. Approximately one third of the catchment areas of these storages is still under natural vegetation but only a small percentage is formally reserved as National Parks or State Forests. The most common land use in the catchment is cattle grazing.

104: Perth, Australia
Protected areas are important for city's water supply
A continuing period of climate variability affecting the south west of Western Australia has seen a 12 per cent decrease in rainfall reduce streamflow to Perth's water supply reservoirs by 50 per cent during the last 27 years[245]. About 70 per cent of Perth's mains water comes from reservoirs, the rest is pumped from underground. The Darling Ranges, large areas of which are covered with eucalypt forests, form the catchment for Perth's water supply, and contain 11 dams and reservoirs. The Yanchep National Park (Category Ia, 2,842 ha) lies towards the edge of the Gnangara Mound, an extensive unconfined ground water aquifer that provides approximately 20 percent of the public water supply for Perth. The Mound is recharged by the direct infiltration of rainfall, mostly between April and October. There are conflicts over the water resources within the Park with the Water Authority considering that the environmental impact on the Park of ground water abstraction is low, whilst the Environmental Protection Authority consider the impact on two of the parks main lakes, Loch McNess and Yonderup Lake, unacceptable[246].

105: Adelaide, Australia
Protected areas play no direct role in supplying the city with water, some of the watershed is protected
Adelaide's drinking water comes from two main sources; the Murray River and the catchments that form the Mount Lofty Ranges. Unlike the water supply catchments of most other Australian capital cities the catchments of the Mt Lofty Ranges are used for many different purposes including harvesting of drinking water, agriculture, intensive horticulture, recreation, rural living, tourism, environmental conservation and urban environments. Over time, these multiple uses have led to fundamental landuse conflicts that have placed pressure on the water resource and have resulted in a number of water quality issues, such as blooms of toxic algae in dams and reservoirs, stock deaths due to drinking water contaminated by toxic algae, pesticides causing contamination of some rivers and streams, water-bourne parasites, *Cryptosporidium* and *Giardia*, detected in rivers and streams, sediment from erosion of degraded river banks, overgrazing and intensive horticultural practices deposited in streams and localised heavy metal contamination. Large storage reservoirs have been constructed on some of the numerous rivers and streams of the Mt Lofty Ranges to harvest rainfall and supply Adelaide with drinking water. The Mt Lofty Ranges Watershed has a low 'water yield to catchment area' ratio due to the relatively low intensity rainfall and annual average rainfall, high number of farm dams and high

rates of evaporation, therefore there has been a need to supplement drinking water with water from the River Murray. Analysis of the volumes of water which have been supplied greater Adelaide mains water consumers, over a 21 year period to 2002, from natural intakes to reservoirs in the Watershed compared with volumes pumped from the River Murray to supplement water supply requirements, shows there has been a very wide variation in the proportions of natural runoff intake versus supplementary pumping from the River Murray from one year to the next. However, over the 21year period the natural runoff from the Watershed has supplied 64 per cent of Adelaide's water supply.

The Mt Lofty Ranges catchments cover 4,000 km^2. Within this area there are seven reservoirs, the largest of which is Mount Bold, capable of storing 45,900 megalitres of water. Annual Adelaide metro consumption of mains water is 300,000,000 m^3. There is less than 13 per cent of native vegetation remaining in the Mount Lofty Ranges and of this vegetation, less than 20 per cent is formally protected in the following forms:

- National Parks and Wildlife Act 1972 – Conservation Parks, National Parks and Recreational Reserves
- Crown Lands Act – Conservation Reserves
- Forestry Act – Native Forest Reserves
- Native Vegetation Act – Heritage Agreements (privately owned land)

The National Parks and Wildlife South Australia (NPWSA) reserves in the Mt Lofty Ranges Watershed protect less than 15,000 ha of native vegetation. Forestry South Australia (SA) also own and manage less than 5 per cent of native forest that would contribute to water quality. However all these government owned areas are small in comparison to the amount of privately owned native vegetation within the watershed. A further seven per cent of native vegetation is owned and managed by SA Water, however this is not 'formally' protected for the conservation of biodiversity (whilst SA Water land is managed primarily for water quality it is also managed with the understanding that water quality is ultimately linked to native vegetation, and because there is a no public access policy much of this land is in better condition than many of the NPWSA reserves in the region). The situation in the Mt Lofty Ranges is thus as follows:

- Most of the 'protected areas' (e.g. NPWSA reserves) are at the very edge of the Watershed boundary meaning the water exiting these land uses is lost as storm water via a metropolitan drainage system.
- Where protected areas occur within the Watershed, they are small and the water quality service they provide may be almost insignificant in relation to the area of native vegetation privately owned in the same area.
- The SA Water reservoir reserves generally contain a high level of native vegetation but only in the land immediately surrounding the reservoir. They also contain pine plantations (linked to raised dissolved oxygen levels in water), grazing land (*Cryptospyridium* and *Giardia*) and hay fields).

Over 12 years the former Engineering and Water Supply Department (now SA Water) conducted a major water quality monitoring programme which looked at the fundamental differences in water quality derived from different land uses in the Mt Lofty Ranges Watershed. The report prepared at the completion of this study identified major differences in the load of water pollutants derived from each of the dominant land uses. The pollutant loads derived from the native vegetation sub-catchment was lowest in all respects. This water quality monitoring programme clearly showed that native vegetation is by far the most preferred land use in the Mt Lofty Ranges Watershed from a water quality perspective, and that there are substantial differences in the water pollutant loads derived from a range of other land uses. Flow proportional composite water quality sampling conducted by the State Government during the 1994 to 2002 period showed similar fundamental differences in water pollutant loads derived from subcatchments dominated by different landuses in the watershed[247].

Part 3: A wider perspective on water and protection

Hydrology overview by Larry S Hamilton‡ and David Cassells§

Forests protecting the water spigots? Or thirsty trees using our water supplies?

Severe water shortages already occur in several parts of the world and this situation is worsening each year. Freshwater withdrawals increase with increasing population and increasing per capita needs and wants, and both ground water aquifers and low-season streamflows are experiencing depletion. This is being acerbated by the current alarming rate of mountain glacier retreat, for glaciers and winter snow accumulation in mountain areas nourish many of the world's rivers[248]. While this water use crisis will adversely affect water supplies for irrigation agriculture, farm animals, hydropower, navigation, in-stream fisheries and drinking supply for terrestrial and avian fauna, the most serious deficit crunch will be for potable water for humans in our cities, villages and rural areas. This derives from the need for water of sufficient *quality*, and at a reasonable price. Access to potable water is increasingly being recognized as a basic "human right", and this includes a reasonable price[249]. The minor revolution in Cochabamba, Bolivia in 2000, in which "water warriors" protested, struck and blockaded against the government over the management of the City's water utility by a private company is indicative of the increasing tension and conflict over water[250].

All plants intercept and re-evaporate precipitation, as well as transpire very large amounts of water from soil moisture. Trees and forests, with their deep root systems are particularly heavy users of water[251]. With this water however, they become photosynthetic "factories" churning out a host of useful and wonderful products and services. These range from conversion of carbon dioxide to oxygen, to construction material for shelter, to Brazil nuts, to tree frogs, tapirs, koalas and scarlet macaws. However, they do not do this "free of charge" and these various products and services are dependant on the forest's use of a significant share of the planet's water. However, forests, more than most other cover on the landscape, maintain the quality of the water they receive and that flows through them. Wetlands are probably equally good. Grasslands are usually grazed, and thus more prone to lose some water quality protection value.

Overview

Mountains receive the bulk of the earth's precipitation[252].Mountain forests, which are in the headwaters therefore of the land's water distribution channels, have a major influence on the quantity and quality of this precious freshwater resource. There are some special kinds of forests, montane "cloud" or "fog" forests, which have relatively low water use due to the frequency of a high humidity or wet envelope, and which actually rake moisture out of clouds or fog, and add it to the water supply of a catchment[253].This water extraction function is lost if cloud forests are removed, because it is an addition to vertical precipitation. Forests also are usually the very best cover for safeguarding water quality from the deleterious impacts of sediment and non-point source chemicals. Pollution from these substances can make water unfit for human (and other animal) use, or incur major costs for removal from the water supply. In addition, forest cover can reduce the problem of flooding from many small, frequent storm events in headwater watersheds close to the forest area in question[254]. In the remainder of this chapter, we will deal with each of these functions in more detail, to get a clearer picture of the role of forests in watersheds or catchments, and present some examples which help us to appreciate the value of forests with respect to water.

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Erosion and sediment

The undisturbed forest with its understory, leaf litter and organically enriched soil is the best watershed land cover for minimizing erosion by water[255]. Surface erosion (which includes sheet and rill erosion types) is minimal due to this understory and leaf litter, which protect the soil from raindrop impact particle dislodging, promotes maximum infiltration of water into the soil and slows downslope water movement by myriad barriers of leaves, twigs and debris. Any activity such as litter collection, fire, grazing or scraping in logging, that removes or significantly reduces this protection increases erosion. Even more serious, mass soil movements due to shallow landslips that are triggered in saturated soils in slip-prone locations, are also minimized by forests. In this case, it is the anchoring function of tree roots that provides an extra margin of shear strength to the soil mass[256]. Removal of the forest by land clearing, or even the temporary removal of most trees in logging increases the risk of landslips.

A dramatic example of landslip catastrophe occurred in southern Thailand in 1988 when thousands of landslips occurred in lands cleared for rubber plantations and farms[257]. This sent huge amounts of sediment into rivers already swollen by heavy rainfall of between 450 and 1000 mm in two days. The sediment-choked rivers and streams flooded massively. Loss of life exceeded 300; 4000 homes were lost and another 4000 partially destroyed along with 300 bridges and agricultural damage. Strangely, the catastrophe was blamed on logging, rather than forest clearing, and Thailand instituted a logging ban rather than tightening the conditions for forest conversion[258]. A similar kind of event occurred during Hurricane Bola in New Zealand in that same year. Thousands of shallow landslips developed over large landscapes in North Island in once-forested pasture lands, along with some major deep-seated slope failures[259]. Where forests older than 5 years occurred, the incidence of landslips was only one percent of the area, versus 30 percent for the cleared lands.

In minimizing surface erosion and mass movements, forests reduce the problem of sedimentation: the carrying or deposition of soil particles in water courses. Suspended soil in water supplies can render potable or irrigation water unfit for use, or greatly increase costs to make it useful. In addition sediment can reduce river channel capacity, kill or harm fish and other aquatic life, interfere with navigation, reduce reservoir capacity prematurely, and increase wear on hydroelectric turbines. Keeping soil in place on the land makes good ecological and economic sense, and forests do this better than most other kinds of land cover or land use (short of concreting it over).

Other contaminants

Most land uses that replace forests have a greater likelihood of impairing water quality through the addition of "pollutants" to the watershed. Excess fertilizer on agricultural or grazing lands, pesticides applied to horticultural or agricultural crops or to lawns find their way into ground water aquifers or surface streams and rivers. Animal manure is another source of possible over-enrichment or contamination. In areas of the world where salt accumulates in the subsoil, forest removal results in the groundwater levels rising closer to the surface (due to decreased evapo-transpiration) which may bring the salt into the root zone for plants. Surface salinization has rendered thousands of hectares of former forest in Australia, now cropland, unsuited to further cropping, except for very salt-tolerant plants[260]. Moreover, lateral movement of salts in groundwater recharge of streams, can render these surface watercourses unfit for irrigation or domestic water. In Western Australian, large-scale reforestation programs to lower groundwater levels, are attempting to repair the situation. Retaining protected forests in salinity-prone areas would be a better policy.

The search for water quality

When quality water is needed, forests are usually the safest cover or land use. As noted above undisturbed forest cover usually provides the best protection against erosion, sedimentation and the transport of other contaminants. These benefits do, however, depend very much on management - forest disturbance or even poorly planned or constructed roads and recreational infrastructure can significantly reduce the forest's protective function. In addition, deposition of most atmospheric pollutants to forests is higher because of the differences in aerodynamic resistance of forest canopies and shorter crops and, as a result, forest catchments may be more susceptible to long-term acidification of catchment soils and runoff in high pollution industrial climates[261]. This is especially true at high elevations and high latitudes due to the phenomenon of "cold condensation" of persistent organic pesticides.

The overall superiority of forests as a protective catchment cover has led to the establishment of protected watershed forests where a water supply source of potable water is needed. Good examples come from Melbourne in Australia and New York City (see case studies). Quito, Ecuador is undertaking a water supply charge which will be transferred to the two protected mountain watersheds of the Pita and Cinto Rivers in the Antisana and Coyambe Reserves[262].In the United States, 354 protected (roadless) areas of National Forest are source areas that provide water for drinking to communities, including the cities of Santa Fe, Portland and Seattle[263]. Much of the water in Harare, Zimbabwe and Freetown, Sierra Leone comes from forest protected areas[264]. Communities all around the world have sought water supplies that are free of suspended sediment and harmful chemical elements or compounds. They find these mostly in forest areas which do not have intensive use by machinery, humans or domestic animals, and especially find them in *forest protected areas*, where such uses are controlled or are minimal.

Floods and protected forests

There is still a fairly widespread but erroneous belief that forest-covered upper watersheds will *prevent* floods on the mainstem, downstream reaches of major rivers[265]. Forests are still visualized by many as behaving like a sponge, whose roots "suck up" water in times of excess (a storm event) and then release it gradually during the post-storm or post-monsoon season to augment dry-season flow. Unfortunately tree roots are more like a pump than a sponge[266]. Cutting the forest therefore usually increases the dry-season flow, but it also somewhat increases flood flows. The water storage on a piece of upland landscape is in the soil, and the amount that can be stored to reduce flooding from single storm events depends on the soil depth, its infiltration capacity (lack of compaction), texture, structure and degree of previous saturation with water. Forests influence some of these characteristics, -- antecedent soil moisture, infiltration capacity and structure, and are usually the hydrological best bet for reducing storm flow volumes, lowering peak flows and delaying peaks, in watercourses emanating from the watershed[267]. However, this flood reduction effect occurs only in the frequent, lower intensity, short-duration storm events, and becomes overridden in prolonged in prolonged, high intensity events or monsoons. Also, the effect may be significant in small watersheds, with deep soils, but diminishes as the watershed size increases to river catchments and river basins[268]. This happens because different land uses come into play, differences in geology and soil depth, direction of storm path across or along the basin, human constriction of channels and so forth. Catastrophic floods of the lower basin flood plains of major rivers cannot be blamed on lack of forest cover in the mountain headwaters, as has been so often claimed in the Ganges and Brahmaputra and others[269].

However, many people live in upland watersheds, and damage to their fields and homes, washout of roads and bridges, contamination of their water from flood runoff are major problems. Protected forested watersheds do have a beneficial effect to local communities or settlements close to the area in question. They are hydrologically the safest land cover and land use that exists, especially if any roads are well located, well designed and well maintained. If wood harvesting or non timber forest product harvesting is carefully done, adverse effects can be minimized. A truly protected, but "used" or "inhabited", forest would have such environmental safeguards (a Category V or VI in the IUCN system), and would therefore minimise the risk of close-to-source flooding events and severity.

The role of swamp forests in storing water and delaying its march to the lowlands and to the seas, also must not be ignored. The amazing flooded varzea forests of the Amazon are a remarkable example of the value of wet forests to river basin ecosystems[270]. But swamps in the uplands also have a water "balancing" function which often merits protected forest status (as well as the other biological values of wetlands).

Montane cloud forests

Cloud forest are the vegetation type where the interests of biodiversity conservation and watershed protection converge most clearly. Cloud forests not only provide the protective benefits previously discussed, but can also introduce additional water into the system above that received by vertical precipitation. These biologically rich mountain forests with their abundant mosses, lichens and other epiphytes capture water from horizontally moving cloud or fog on their myriad vegetative surfaces, especially where consistent winds drive these atmospheric moisture systems through the forest. Since water uptake from the soil by trees whose foliage is wetted is strongly reduced, overall water use by cloud forests is typically much lower than that of forests lower on the mountains. These two sources of gain in water yield means that stream-flow emanating from cloud forest areas tends to be larger for the same amount of rainfall, and is also more dependable during dry periods. The extra water is particularly marked, and particularly important in places with low rainfall but where a low cloud deck touches the mountains[271]. Here, water gains from cloud forest can be 100 percent or more greater than from ordinary rainfall. In humid areas, it may be only 15-20 percent greater, but even this addition can be significant to communities that are experiencing shortages of quality water.

These cloud forest belts or zones typically occur at elevations of 2000-3500 m on large continental interior mountains or mountain ranges, but on island mountains may occur as low as 400-500 m above sea level[272]. If they are totally removed, this water capture function of cloud "stripping" is lost. Very often the soils under these forests is not adaptable to other sustainable use, yet they are being cleared and converted to grazing or temperate crop production in the tropics, and being heavily harvested for fuelwood and charcoal. They are also being adversely impacted by global climate change (changes in occurrence of the cloud deck) and by cloud-borne air pollution.

While all water supply watershed forests merit protection status, montane cloud forests in the watersheds deserve special consideration as protected areas, to be minimally disturbed.

Protected streamside riparian zones

Also of high priority for tight protection within the watersheds are the forested (or other natural vegetated) strips of land along the streams in question. These riparian zones are probably the most critical of all needing protection in a water supply catchment[273]. This is especially true if there are non-forest land uses beyond the riparian zone which are a source of sediment, fertilizer, pesticides or other water contaminants. Intact forests along streams at least 20-30 m in width (wider if the land is steeply sloping) can filter and immobilize sediment and these compounds, reducing water pollution. They can only trap sheet and rill erosion from upslope, for channelised sediment, as in landslides, will break through most normal-width buffers. Riparian forests also reduce streambank erosion. They keep streams cooler. When these water-related values are added to their great value in providing terrestrial and avian fauna habitat and safe access to water, rich riparian plant habitat, and healthier stream habitat for fishes and other aquatic life, the critical nature of these zones becomes apparent[274][275]. Since they form the vital link between watershed lands and stream systems, they merit protected status as areas of great significance.

Protected mangrove forests along tidally influenced streams and rivers also perform many of these functions. In trapping and immobilizing sediment and toxins like heavy metals, in their muds they promote a healthy near-shore fishery and coral reef system[276]. They have too often been cleared as "wastelands" and converted to non-sustainable rice production or aquaculture ponds. They merit protected status in very many situations.

Dawning recognition of watersheds

At long last, urbanites and their politicians seem to be realizing that in most cases the water coming from the urban taps originates in rural or wild watersheds. Back in 1984, Director of National Parks in Venezuela, José Rafael García referred to Guatopo National Park (headwaters for water supply to Caracas) stating: "the most important thing is that the water from this park is of very high quality, and for this reason its treatment for human consumption is less expensive.[277]. Spectacular rainforests and high quality watershed only two hours from Caracas! Moreover, awareness is dawning that protection of the watershed supply area costs money, and water consumers will have to pay a reasonable amount for this. The water-payment scheme for Quito's protected watersheds has been briefly mentioned. In Honduras, an association of 16 municipalities near Lake Yojoa are engaging in an annual environmental service payment scheme through conservation easements on key watershed lands. "Payments for environmental services" involving forests and hydrologic benefits are also now in effect in Costa Rica, Mexico, El Salvador, Colombia, and Brazil[278]. This seems to be the wave of the future and a timely one as the water crunch spreads. However, in putting a price on watershed protection, we need to ensure that the rights of the poor to equitable and affordable access are not ignored[279]. Protected watershed forests have a major role to play in attending to this basic human need.

Economics overview by **Stefano Pagiola**[**]

Paying for watershed services

Tropical forests provide a wide variety of valuable services, ranging from the regulation of hydrological flows to biodiversity conservation and carbon sequestration. Nevertheless, an average of almost 15 million hectares of forest was lost every year during the 1990s, mostly in the tropics[280]. An important reason for this loss is that those who manage tropical forests typically receive no compensation for the services that forests generate for others. As a result, they have little incentive to conserve them.

Recognition of this problem and of the failure of past approaches to dealing with it has led to efforts to develop systems in which land users are paid for the environmental services they generate, thus aligning their incentives with those of society as a whole[281]. The central principles of the "payment for environmental services" (PES) approach are that those who provide environmental services should be compensated for doing so and that those who receive the services should pay for their provision. This approach has the further advantage of providing additional income sources for poor land users, helping to improve their livelihoods.

Although the approach is intuitively appealing, putting it into practice is far from simple. Making market-based mechanisms work for both forests and people is not easy. Designing and implementing the necessary rules and institutions is a daunting task under the best conditions. A large number of building blocks need to be in place, including a strong understanding of the underlying relationship between land use and service generation, an economic analysis of the benefits these services provide to users and of the cost to land users of providing them, and the creation or strengthening of the institutions required. Moreover, the precise details of the implementation of PES programmes can vary substantially from case to case, depending on the ecological, socio-economic, and institutional context.

Most PES programmes are still too new for a definitive assessment of their success and for detailed guidelines for their implementation to be developed. Nevertheless, considerable experience has been accumulated, and some initial lessons are discernible.

The logic of payment for environmental services

Land users often receive few benefits from forest conservation. In many cases, these benefits are less than the benefits they would receive from alternative land uses, such as conversion to pasture. But deforestation can impose costs on downstream populations, who no longer receive the benefits of ecological services such as water filtration. A payment by the downstream beneficiaries can help make conservation the more attractive option for land users. The payment must obviously be more than the additional benefit to land users of the alternative land use (or they would not change their behaviour) and less than the value of the benefit to downstream populations (or they would not be willing to pay for it)[282]. It is important to note that this logic remains in place year after year—payments must be made every year that service provision is desired, and not only on a one-time basis.

PES programmes promise to be more efficient than traditional command-and-control approaches. The costs of achieving any given environmental objective are rarely constant across all situations and

[**] This essay draws on on-going work on payments for environmental services at the World Bank. Portions of it have appeared previously, in sections of the book *Selling Environmental Services*, edited by Stefano Pagiola, Joshua Bishop and Natasha Landell-Mills (Earthscan, 2002) and in a paper presented to the spring 2003 meeting of the Society of Tropical Foresters, held at Yale University, which was co-written with Gunars Platais, also of the World Bank.

instruments such as PES can concentrate effort where costs are lower. Likewise, the benefits of conservation can differ substantially from case to case.

The value of environmental services to watersheds

Forests can provide a wide variety of services. The main services of interest are usually ***hydrological benefits***, including controlling the timing and volume of water flows and protecting water quality, reducing sedimentation, and preventing floods and landslides; ***biodiversity conservation***; ***carbon sequestration***; and, in some cases also ***scenic beauty***. These are for instance the four services named in Costa Rica's 1996 Forestry Law, which launched the country's PES programme. Here we concentrate on the first of these. For many developing countries, water services are of primary concern, as they have important national impacts.

For a PES programme to be developed, detailed information is needed on *which* services a given forest is providing, and to whom. Yet much less is known about the environmental services generated by different kinds of land uses than is often thought, particularly in terms of quantitative data.

Markets for watershed protection generally do not involve directly trading water quantity or quality. Rather, they usually involve 'selling' land uses that are thought to generate the desired water services. While forests are widely believed to provide a variety of hydrological services, the evidence is often far from clear (see accompanying essay by Hamilton and discussion in the main text). This is partly a reflection of the diversity of conditions encountered – variations in rainfall regime, soil type and topography all affect service provision. Deforestation can have multiple, sometimes contradictory impacts, making the net impact on water services hard to determine.

Water-related services provided by a given forest also depend on the number and nature of downstream users. Reducing sedimentation, for example, will be of limited value if there is little or no infrastructure vulnerable to sediment downstream of a forest. Likewise, reducing flood risk will be more valuable the greater the number of people and the value of assets at risk. The precise nature of services sought by downstream users also varies tremendously. Domestic water supply systems require a constant flow and high quality, but hydroelectric power producers with reservoirs usually prize total volume and care little about water quality except for the absence of sedimentation. Riparian communities are particularly concerned to avoid high peak flows that could flood their homes and fields. Depending on the mix, number, and relative importance of downstream uses, different types of water services will be particularly important in each case, with implications for the preferred upstream land uses. Where dry season water flows are of primary importance, land uses with high infiltration and low evapotranspiration would be preferred. Conversely, where minimizing the risk of flooding is the primary objective, land uses that maximize both infiltration and evapotranspiration would be preferred.

Unfortunately, most PES programmes developed to date have paid insufficient attention to the need to understand forest-hydrology linkages in detail. Costa Rica's PSA programme, for example, simply relies on the conventional wisdom that forest cover is beneficial for forest services[283]. More recent efforts in other countries have placed a greater emphasis on this topic, but are encountering significant constraints due to the lack of data.

Beyond the need to ascertain the linkage between forests and water flows, efforts to develop markets for water services face several particular challenges. First, water flows downhill, usually restricting access (and so, potential sales) to users within a watershed. The Río Nizao watershed in the Dominican Republic offers substantial potential for the use of PES, for example, as its four dams provide a substantial part of Santo Domingo's water supply, a major portion of the country's HEP generating capacity, and water to two major irrigation systems. By contrast, the adjacent Río Ocoa provides almost no water services, despite being almost identical ecologically and hydrologically, as there are no significant downstream users. Second, use of water flowing in a river, or in an underground aquifer, cannot easily be confined to those who paid to protect that flow. Hence non-payers ('free riders') may benefit from the expenditure of others, undermining the incentive to pay, particularly where there are many beneficiaries. There may also be problems of coordination among different types of users. Against these limitations, water markets have the advantage that services are well-defined and often of high value.

Financing compensation for environmental services

PES programmes involve three distinct financing needs. First the up-front costs of establishing the system itself, including the costs of clarifying technical factors (for example, understanding hydrological linkages), of establishing appropriate organisations, and of ensuring that a supportive legal framework is in place. Second, the need to make the payments under the system; this is clearly the largest single item. Third, the on-going running costs of the system must be paid, including the costs of administration and monitoring. (It should be noted that some of the transaction costs are pushed onto participants. Participants in Costa Rica's PSA programme, for example, need to develop management plans, at their own cost. Although these costs do not appear as a financial cost to the PES system, they are a social cost and need to be addressed.)

The up-front costs of creating a PES programme pose particular problems as they must be borne before it begins generating funds. Assistance from outside agencies is often invaluable, particularly when some of the costs involve research into environmental services, which is often beyond the capability of local agencies. (Once the PES scheme is in place, these costs can be repaid by a levy on payments.)

Financing the payments to service providers and the transaction costs of the system requires establishing secure, long-term sources of financing. As noted above, payments under a PES scheme usually have to be long term and open ended. The first step entails identifying not only the beneficiaries but also the specific services they receive, because the willingness of a given group of beneficiaries to pay depends on the specific service they receive, on the value of that service to them (compared with the cost of alternatives), and on the size of the group.

Water benefits are easiest to capture when users are already organised (as in the case of municipal water supply, irrigation systems, and HEP producers) and when payment mechanisms are already in place. Payments for the water service can then simply be added to existing channels – for instance domestic water users can be charged an additional fee for conservation – or more generally part of the revenue from water fees can be allocated to conservation. The town of Heredia, in Costa Rica, chose the former option, adding an 'environmentally-adjusted' water fee to its utility bills[284]. Conversely, Quito in Ecuador has adopted the latter approach[285]. In Costa Rica, hydropower producers have absorbed the cost of conservation payments into their costs of operation[286]. Where users are not already organised or lack a payment mechanism, the costs of capturing benefits are likely to be substantial.

Scale also has an effect. At small scales, cause-and-effect relationships are easier to establish, the number of actors is limited, and short distances ease the task of negotiating agreements: as the scale increases, all these factors become harder to determine and it can become exceedingly difficult to identify the impact of particular factors, such as land use change in a specific part of the watershed. A larger scale also brings more actors and often different actors. Not only will it be more difficult for downstream users to agree on common action to protect the upper watershed, but there may well be significant differences in needs. Finally, greater distance adds to the transaction costs of negotiating agreements and monitoring compliance. It is not surprising, therefore, that most successful efforts to date have been undertaken at a relatively small scale.

Actors

Commercial enterprises, various levels of government, local and international NGOs, donors, community groups, and individual land users all participate in markets for forest environmental services as buyers, sellers, intermediaries, brokers, and providers of support services. It is difficult to pigeonhole participants according to their main function, since most play different roles depending on the case, although some likely roles can be identified as outlined in the following paragraphs[287].

Commercial companies stand out as increasingly important buyers of environmental services, with for example private hydropower and water supply companies being frequent participants. In Costa Rica, several private HEP producers agreed to participate in the PSA programme long before the state-owned power producer CNFL came on board. Costa Rican HEP producers see watershed protection as essential to their commercial interests. In other cases, enterprise demand may depend on government regulations. The Clean Water Act in the USA, for instance, is the principal reason for growing payments for wetland conservation by real estate developers.

Governments also play an important role. In addition to developing policy and regulatory frameworks, governments may be significant buyers and sellers of services and they are frequently active intermediaries. For example municipal water suppliers and government-owned HEP producers are notable public sector buyers of watershed services. Brazil's ICMS-E system offers an interesting example of how state governments "buy" watershed protection from municipalities. ICMS-E allocation rules act as an implicit 'price list' for the environmental services the government wishes to buy and municipalities have responded by supplying them. Government agencies that manage forests often suffer chronic budget shortfalls and they increasingly view market mechanisms as a key component of long-term financing strategies, thus also becoming "sellers" of services. Ecuador's Ministry of Environment, for instance, has been a major driver behind Quito's emerging water fund, which it expects will fund the management of the Cayambe Coca and Antisana Ecological Reserves. Governments can also catalyse market mechanisms not only through regulatory action but by offering intermediary services that link buyers with sellers. Governments may also stimulate market payments through the provision of information, advice, and training.

Local NGOs and community groups often play a crucial role by working with smallholders to deliver service supplies, or by organising service buyers. In Quito, local environmental NGOs will implement watershed protection activities. On the demand side, community user groups are expected to help bring small-scale water consumers into the market for Quito's watershed services.

Donor organisations and international NGOs have likewise contributed in different ways to the development of markets for environmental services. Some have been important buyers of global environmental services and donor agencies and international NGOs have also facilitated the establishment and management of market mechanisms, helping to overcome start-up costs and technical constraints. The World Bank is playing an important role in this regard, by helping countries develop PES systems, studying PES efforts to derive best-practice guidelines, and undertaking capacity-building efforts in this area.

Developing effective compensation systems

PES programmes will only have the desired effect if they reach the land users in ways that influence their decisions on how to use the land; several general principles can be identified.

Make payments continuous and open-ended
In general, payments for environmental services should be on-going. In Costa Rica's PSA programme, for example, payments for forest conservation contracts are for 5 years, but they are renewable indefinitely by mutual agreement. Ending payments creates the risk that land users will revert to their previous land use practices. The only exception to this rule may come in situations where the desired land use practices would in fact be the most profitable for land users were it not for high initial costs.

Target payments
An undifferentiated payment system that pays everyone the same will be much more expensive than a targeted scheme. It will also make it difficult to tailor interventions to the particular requirements of given situations. Interventions should be targeted both geographically and according to the land use being implemented. Costa Rica's PSA programme was completely untargeted, with any land user eligible for participation, but has over time evolved towards increasing use of targeting. Providing a differentiated payment for different land uses is also important, as there are often several land uses that might contribute to providing the desired service, but not all to the same extent. A targeted payment scheme may, however, be more expensive to implement than a non-targeted one. A balance needs to be found between the efficiency advantages and the higher costs of better targeting.

Avoid perverse incentives
There is considerable danger that payments might provide perverse incentives, if they are not designed carefully. For instance perverse incentives can be created by limiting PES to "incremental" benefits, such as payment for reforestation (which would generate additional benefits) but not for existing forest cover (which is already generating benefits, and so would not be "incremental"). This risks continued deforestation in areas not covered by payments, thus negating benefits from reforestation, and also a broader risk that non-participants in surrounding areas would postpone adopting beneficial conservation practices because they are waiting for a project to come and compensate them for doing so[288]. One way of avoiding this is to allow for a payment to be made for pre-existing environmental services, albeit at a lower rate than incremental services.

Establishing the institutional framework

PES programmes require a supporting institutional infrastructure. Market participants must have access to information on the value and volume of the services being exchanged. Participants must have opportunities to negotiate payments. Property rights to service commodities need to be clearly defined, and ownership has to be assigned. Monitoring and enforcement mechanisms are required. A network of supporting regulatory and institutional arrangements may be necessary if markets are to function effectively. Establishing such market infrastructure is not easy and is rarely cheap.

Some caveats
Payment for Environmental Services cannot solve all conservation problems, but instead is applicable primarily in cases in which land uses provide substantial benefits to groups other than the land users. (Land use change is not always the cause of downstream problems: sedimentation, for example, sometimes arises from poorly constructed roads rather than from deforestation.) Even when PES may in principle be part of the solution, it may not always be possible to implement. The scientific understanding of forest-hydrology linkages may be too weak to convince downstream users that forest conservation would be a cost-effective means of obtaining the water services they desire. Or it might be too difficult to reach agreement among a large group of diverse downstream users. On the supply side, the transaction costs of contracting with many small, dispersed smallholders with insecure property rights may be so high as to make the approach prohibitive. In general, a wide range of instruments is likely to be needed with PES being seen as one of many tools in a toolbox.

In theory, PES can play an important role in poverty alleviation. The upper watersheds that are critical sources of water services are often inhabited by poor subsistence farmers, and payments for environmental services could be an important addition to their incomes[289]. This will not happen automatically, however and special efforts are needed to ensure that the poor have access to the new opportunities created by PES programmes.

PES programmes are most likely to be effective when downstream benefits are high (resulting in high willingness to pay) and upstream opportunity costs are low. It may be possible to implement such systems in situations when both downstream benefits and upstream opportunity costs are high, but it will be more difficult to do so because the margins will be small. When downstream benefits are low, in general there is little scope to use such mechanisms, even if upstream opportunity costs are also low.

Conditions that encourage use of payment for environmental services schemes

PES schemes are only likely to work with the right combination of information, user groups, economic values and legislation. The following elements need to be put in place

Hydrological information – a clear understanding of:

- Impacts of particular land management on the quantity, quality and reliability of water supply further down the catchment, including the relative importance of land management as compared with other factors

- User needs with respect to water supply: for example whether users are primarily interested in volume or also in quality and if so which elements of quality

To be worth pursuing PES, land management upstream should be capable of delivering desired and economically valuable benefits downstream

Actors in the market – both buyers and sellers:

- Identifiable user groups that are willing and able to pay for environmental services (ideally these should already be organised into definable groups to ease negotiation)

- Identifiable seller groups that would be willing to alter their land management policies in exchange for payments

PES schemes rely on a combination of people in the upper watershed able and willing to sell management services and people downstream capable and willing to buy these.

Economic benefits – enough relative value to make it worth implementing PES

- PES schemes work best when high downstream benefits are associated with low upstream costs.

Finance – in addition to regular payments from users to land managers, most schemes need a source of start-up money, usually from governments or donors but in some cases also from users.

- Such money helps finance initial research, organisations and negotiation

Organisation – a method of collecting payments is required and schemes also need to be monitored and for example charges altered depending on changing economic and hydrological conditions over time

Legislation – many successful schemes have also been bedded within a framework of supportive legislation

In addition, there are some important qualifiers to help make the PES system work; that the payments are:

- Long term
- Targeted
- Designed to avoid perverse incentives

Social overview by **Sara J. Scherr**[††]

Social implications of protecting and managing forests for water supply

Zoning and land use planning can have widely varying social impacts on different groups, and designation of lands and waterways for urban watershed protection is no different. Public or private development of new or enhanced watershed resources creates new assets. How those assets and the social benefits from them are allocated will be influenced by property rights and political factors. Because the livelihoods and welfare of low-income groups in developing countries are especially sensitive to access to water, forest and land, potential social impacts on such groups deserve special attention in developing watershed protection strategies.

Social impacts on the urban poor

Poor urban dwellers are clearly at serious risk to health and livelihood from the present and future threat of inadequate supply and quality of water for domestic use. However, the most straightforward way to ensure access for poor and vulnerable households is through the urban water distribution system. Domestic consumption accounts for only a modest share of total water consumed, and consumption by the poor is only a modest share of that total, so that major improvements in water availability for the poor could be ensured by extended piped water and sewage infrastructure, pricing water so that minimal levels of consumption are very inexpensive, and providing good maintenance for water-related infrastructure.

Maintaining extensive unbuilt green space in protected watersheds and along waterways within the city may provide positive aesthetic and recreational benefits to the poor. They may also provide nutritional, health and economic benefits from harvesting useful foods, medicines and raw materials from natural vegetation, and harvesting edible fish and amphibians from streams, rivers and wetlands.

For low-income peri-urban populations who collect their domestic water (and aquatic food) directly from urban rivers, streams and reservoirs, reduced water contamination resulting from good upstream watershed management may have dramatic impacts on human health. These benefits will not be realized, however, unless water quality in these sources is also protected by good management within the city, for example, protection for contamination by domestic livestock wastes, food and industrial wastes, and raw sewage. To the extent that low-income urban farmers, livestock owners, processing enterprises, etc. are responsible for such contamination, some negative livelihood impacts may result from improved management to reduce these urban pollutants (similar to those described below for the rural poor).

More indirectly, ensuring a secure supply of high-quality water may be an important factor in determining employment-generating urban investment, particularly for high-water-consuming industries and urban agriculture. Thus there may be strong indirect positive impacts on the unemployed and underemployed urban poor from improving water supply and quality. In China, for example, it is reported that reliability of water services is a major factor in competition between cities for foreign investment.

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Social impacts on the rural poor in urban watersheds

For the rural poor living in and around urban watersheds, decisions to protect, manage or restore forest cover for urban water supply will often have dramatic effects on livelihoods and welfare.

Potential social costs

Because urban interests are more politically powerful than rural interests, policy instruments used historically to protect urban watersheds have often ignored rural people's rights and needs for land, water and forests, with significant negative social impacts for millions of people.

Specific negative social impacts for local rural people living in urban watersheds may result from programmes that:

- Transfer ownership or use rights to land or forests from local people (for example, through land appropriation or rules restricting farming or forestry activity);
- Deny rights of access to public or community land, forest, or water resources on which local livelihoods depend (for example, water sources for domestic livestock, timber for local furniture enterprises);
- Offer payments for watershed services that encourage more powerful actors to seek such benefits by appropriating land, forest or water resources over which local people have weak property rights;
- Establish extensive forest plantations on common lands previously important to local people for livestock grazing, gathering of wild foods and fuel, or farm fallows;
- Forcibly resettle local people outside the catchment area;
- Force farmers to make high-cost conservation investments with little on-site benefit, or to convert land to much less profitable crops;
- Damage or deny access to important cultural or religious sites;
- Reduce employment due to closing of farming, forestry or processing activities; or
- Divert water from local users (domestic, irrigation, livestock, and processing uses), to urban users.

Tens of millions of rural people, particularly in upper watersheds feeding cities, reservoirs and irrigation systems in Asia and Latin America, have experienced these negative impacts. Indeed, watershed protection has sometimes has merely a thinly disguised excuse for massive resettlement or social control of politically and culturally marginal groups. In the face of large and growing rural populations in developing countries (which increased overall by 40 percent since the 1960s), it was difficult for public agencies to adequately police or manage these areas in the absence of local support. Thus, many public programmes in populated areas that established strict forest reserves or attempted to reforest previously cleared farm and grazing lands failed to achieve watershed objectives.

Potential social benefits

This mixed experience with watershed management has led to the development of a variety of new approaches that seek to work with local people as stewards of the watershed. These approaches recognize local rights and management capacity, encourage negotiation around design of watershed interventions, or provide technical and financial support for local communities to invest in improved land management. Local people living in and around critical water catchment areas can potentially benefit in many ways from better protecting or managing existing forests or from restoring forest cover. When designed explicitly for local co-benefits, improved watershed protection and management may, for example:

- Enhance the supply and quality of local water resources;
- Restore depleted local fisheries;
- Increase the availability of fuelwood, building materials, livestock fodder, fruits, medicines, wild foods and other raw materials for household consumption or local enterprises (from new or better-managed forest resources);

- Increase income and employment from local wood-based enterprises from timber and poles produced in sustainable systems compatible with watershed management;
- Protect locally-important forest resources from annexation or invasion by outside settlers, destructive infrastructure, or other threats to forest loss;
- Reduce local health problems caused by exposure to contaminated water and other materials in the local environment;
- Validate the important role that rural people play as stewards of the watershed;
- Pay local people directly for their role in protecting, managing or restoring watershed resources; or
- Provide investment resources for local farm and forest producers to improve productivity and sustainability.

Enhancing social benefits from urban watershed protection

Water policy for most cities around the world has been concerned too narrowly with allocating existing water supplies among competing parties, moving water to consumers, and processing water to remove contaminants. Clearly, careful management of critical natural sources of urban water – to enhance quality, supply and reliability – will be one of the most important governance challenges of this century. However, considerations of social impact should be a central factor in determining the most appropriate strategies to conserve and enhance watershed functions.

Increasing benefits from protected forests

In some urban watersheds, protecting or expanding forest cover will indeed be essential for water management. When that is the case, every effort should be made to embed both biodiversity conservation and local livelihood benefits into forest protection strategies. Multiple-use community forestry can provide supplemental local income from timber, non-timber forest products, hunting, recreation or tourism. Local communities and landowners can be paid explicitly to conserve the forest resource and monitor water quality controls.

Where afforestation is deemed important, planting or regeneration can focus first on the most critical sites from a watershed services perspective. Input from local people can be valuable for identifying sites producing unusual levels of sediment or contamination, or areas of compacted soil or barriers to water flow, that may not show up through remote sensing. Their input can identify areas where there are strong community motivations to increase forest cover, such as around local water sources or culturally important sites.

Alternatives to strict forest protection

It is important to remember that undisturbed forest cover is *not* necessarily essential for good watershed management. Most important is that the landscape performs essential watershed functions: slow the flow of runoff, minimize soil erosion and sedimentation of waterways, filter contaminants and maintain appropriate water chemistry, reduce or increase annual water flow, and ensure groundwater recharge. To also protect terrestrial plant and animal species, land uses must provide adequate food sources, adequate water, nesting areas, protective cover from predators, migratory pathways, and presence of pollinators and other interdependent species; to protect aquatic productivity and biodiversity requires providing appropriate shade and types of debris along stream banks. While undisturbed natural forest and associated under-story native vegetation can often provide these functions most effectively and at a low management cost, well-designed mosaics of other land uses may also provide many of these functions. Where the "opportunity cost" to local people is very high for keeping the land under forest, such alternatives should be actively explored.

Timber and non-timber forest products can be produced commercially, under standards of certification. Crops may be produced using good soil erosion control measures or in agroforestry systems with tree species that benefit associated crops or livestock, or grow products for sale. Organic production methods can be introduced to replace chemical-intensive farming systems, or vegetative filter strips can be established near streamways to minimize contaminated runoff. Grass cover can sometimes be as effective as tree cover for slowing runoff and enhancing water infiltration, and can be established for dual use as animal fodder. Rather than prohibit farming on steeper slopes, rules can require wide strips of natural vegetation be left at intervals on contours along the slope. Local people can be supported to establish rainwater harvesting systems, and to increase the water use efficiency and drainage of irrigation systems. Financial credit, technical assistance, and marketing support will often be needed to facilitate these changes, and can be financed from urban water budgets or consumer charges. Critical sites for hydrological function (or biodiversity conservation) can be zoned for non-productive use, or farmers and landowners can be compensated for permanent or temporary easements.

Landscape mosaics that intersperse patches of natural forest vegetation with patches of crops, pastures or production forest can strategically protect critical watershed sites and remove the most serious threats to water supply and quality. Upstream riparian systems can thus be strategically linked to urban wetlands and larger protected areas through corridors of natural vegetation, contributing to biodiversity conservation. Meanwhile, one of the most important sources of sedimentation, contamination, land compaction and water flow barriers in many watersheds is poorly designed rural infrastructure—roads, paths, electric lines, mines and human settlements. Thus landscape management for watershed protection will also require more systematic monitoring and regulation of construction sites and methods within rural areas.

Conclusion

Securing urban water supplies in the face of accelerating population and economic growth in both urban and peri-urban areas is a critical challenge for city and regional planning. Strong public demand for water security can drive responses that seriously harm vulnerable populations living in and near water resources and catchment areas. However, this demand could stimulate creative land use strategies that enhance livelihoods, while also enhancing biodiversity and the provision of other ecosystem services. Serious attention to addressing potential social costs and impacts can result in greater net social benefits and greater sustainability of watershed and other ecosystem services.

Part 4: Country case studies

The analysis of cities presented in part 3 is necessarily quite brief in a preliminary analysis of this kind. Below we have looked at some interesting examples in slightly more detail.

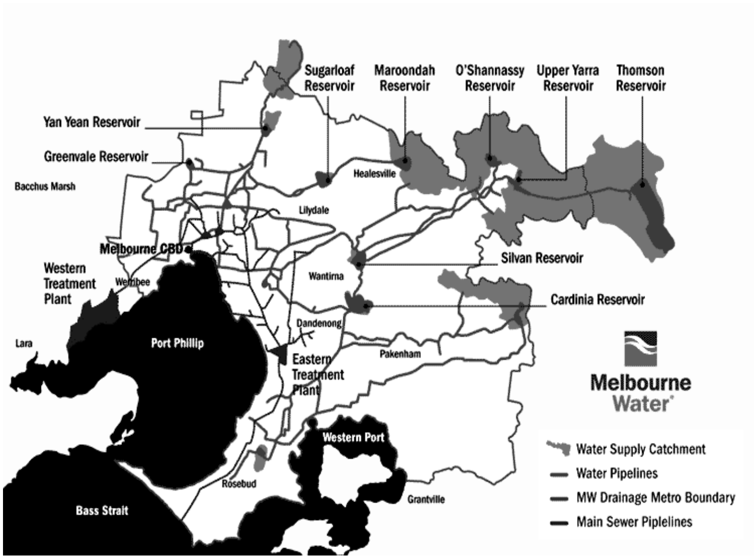
Melbourne, Australia

Introduction

Melbourne is the capital of the State of Victoria and is located in southeastern Australia. The city is centred on the banks of the Yarra River beside Port Phillip Bay. Melbourne has a population of over 3 million people and is the second most populous city in Australia after Sydney. Over the next 30 years, Melbourne's population is predicted to increase by more than 1 million people[290].

Melbourne's water system is highly centralised. Melbourne Water, which is owned by the State Government of Victoria, is responsible for the management of Melbourne's water supply catchments, removal and treatment of most the city's sewage and management of the waterways and major drainage systems – including 3,974 km of streams, creeks and lakes[291]. Three retail water companies (City West Water, South East Water and Yarra Valley Water) manage the reticulation systems, each for a nominated geographic area.

Melbourne Water supplies nearly 500,000 megalitres of water annually to consumers, and is widely regarded as supplying high quality drinking water, mainly due to the purity of the source[292]. Future requirements for water were forecast in the 2002 Water Resources Strategy; with demand by 2020 expected to increase at an average rate of 0.4 per cent per annum, with demand reduction measures, or 0.7 per cent per annum, without demand reduction measures. The ability to manage these increasing requirements will also clearly be affected by the general rainfall pattern in Australia. A seven year drought (1996 to 2002) has reduced the average annual streamflow from the four major catchments by 29 per cent when compared with the long-term average over a 30-year period.



Water source

Ninety per cent of Melbourne's water supply comes from uninhabited mountainous catchments to the north and east of the city[293]. About forty nine per cent of the catchments fall within National Parks, with much of the remaining area being in State forests.

Major catchment areas are:

- Wallaby – 9,100 hectares (within the Kinglake National Park) 1.9 per cent inflow
- Maroondah - 16540 ha (within the Yarra Ranges National Park) 10.8 per cent inflow
- OShannassy - 11870 ha (within the Yarra Ranges National Park) 11.4 per cent inflow
- Upper Yarra - 33670 ha (within the Yarra Ranges National Park) 18.7 per cent inflow

- Yarra Tributaries - 13480 ha (State Forest) - 3.8 per cent inflow
- Thomson - 48700 ha (mainly State Forest and small section Baw Baw National Park) 35.3 per cent inflow
- Sugarloaf, which is not a protected catchment and from which water is pumped out of the Yarra River and fully treated before entering system - 10.7 per cent inflow

About 50 per cent of this 157,000 ha catchment area is covered with the eucalypt species Mountain Ash (*Eucalyptus regnans*)[294]. Melbourne Water manages some catchments just for water collection, and works closely with the Department of Sustainability and Environment and Parks Victoria in managing catchments in state forests and the Kinglake (Category II, 21,600 ha), Yarra Ranges (Category II, 76,000 ha) and Baw Baw (Category II, 13,300) National Parks[295]. Melbourne Water claims that the city is one of only about five cities in the world that has such well-protected catchments[296].

Melbourne's water supply system consists of nine large storage reservoirs, with a capacity of 1,773,000 million litres, which are situated in remote forested areas[297]. The collected water is stored in these reservoirs for one to five years, helping to purify the water through a natural settling process[298].

Protected areas in the catchment

The Yarra Ranges National Park is Victoria's ninth-largest park and is a major water supply source area for Melbourne. The Yarra Ranges National Park has a Natural Catchment Area which is fully contained within the closed Designated Water Supply Catchment Area and represents 84 per cent of the park. A further 2 per cent of the park is also part of a Special Water Supply Catchment Area[299]. The area is recognised for its botanically significant old growth forest and Cool Temperate Rainforest. The park has a relatively low number of annual visitors and is relatively clear of weed infestation and pest animals. The entire Yarra Ranges National Park was reserved in 1995 and a management plan was finalised in 1998.

Kinglake National Park, the largest national park near Melbourne, protects a significant sample of the mostly dry eucalypt forests typical of the foothills and southern slopes of the Great Dividing Range, within the Yarra and Goulburn River catchments. Important features include a high diversity of native plants and animals, including almost 600 native plant species, over 40 native mammal and 90 native bird species. Areas within the Park were first protected in 1928 (5,585 ha) with additional land areas being added in subsequent years including, in 1995, a substantial part of the Wallaby Creek catchment area (9,965 ha). The protected area's management aims, as defined in the Management Plan, include the requirement to: "protect water catchments and streams" [300].

Other catchment management issues

Management of Melbourne's water catchment has been guided by a programme of experimental and analytical research on the relationship between catchment disturbance and catchment water yield, established initially by the then Melbourne Metropolitan Board of Works (now Melbourne Water) and more recently by the University of Melbourne and the Cooperative Research Centre for Catchment Hydrology. Research has been particularly important in clarifying the links between water yield and forest disturbance.

Studies of rainfall and runoff data, collected from large forested catchments in the Melbourne area that were completely or partially burnt by a large-scale wildfire in 1939, concluded that the amount of water yield from forested catchments is related to the forest age[301]. It was found that forest disturbance can reduce the mean annual runoff by up to 50 per cent compared to that of a mature forest, and can take as long as 150 years to fully recover. This is because evapotranspiration from older forests is lower per unit area than from younger forests. The implication is that forest disturbance, by fire or logging, reduces water yield in the short to medium term (except in the few years immediately after disturbance)[302].

One of Melbourne Waters major management activities in the catchment is to the protected forested catchments against the major threat of bushfires, which as well as destroying the tree cover within the catchment result in soot and ash, which can be washed into the reservoirs. Melbourne Water employs firefighters over the summer period to try to ensure that any fires that occur do not take hold.

Despite there being clear evidence that forest disturbance can have an effect on water yield timber harvesting is still carried out in some part of the catchment. The Thomson Reservoir catchment and the catchments of Armstrong, McMahons, Cement and Starvation Creeks are predominantly State forest and are available for timber harvesting and long-term contracts for timber are in place for these areas. Overall, an average of around 0.2 per cent of the total water supply catchment area is potentially used for timber harvesting each year[303].

Research on the impacts between timber harvesting and water yields is on-going. A research study undertaken in 1992, suggested that with no further timber harvesting combined with the maturing re-growth from the 1939 bushfires would lead to an increase in the Thomson catchment yield of around 17,000ML (or 3 per cent of Melbourne's current catchment yield) within about 20 years. This scenario assumes that the catchment is not affected by future bushfires or other disturbances. A recent hydrology study, however, showed that current catchment yields in forests can be maintained while allowing timber harvesting under the constraints imposed by the Code of Forest Practices for Timber Production and the Regional Forest Agreement[304].

The Department of Primary Industries manages the harvesting operations (in consultation with Melbourne Water) with the objective of ensuring that the timing, intensity and extent of operations are controlled appropriately to protect water yield and quality. Potential water yield is foregone in pursuit of the employment and economic benefits in metropolitan and regional Victoria provided by timber harvesting, sawmilling and paper production activities. All timber utilisation is supposed to be conducted in accordance with the *Victorian Code of Forest Practices for Timber Production*, which contains measures to protect water yield and water quality, including leaving buffer zones along streams, installing drainage on timber harvesting tracks and ensuring that access roads are well maintained. The Victorian Environment Protection Authority conducts audits to assess compliance[305].

WWF has reservations about the continued logging of Melbourne's catchments. WWF is concerned that forest areas of high conservation value in the catchments are not adequately protected, or that the logging practices currently conducted in accordance with the *Victorian Code of Forest Practices for Timber Production* adequately protect the environmental values of the production forests. For these reasons, WWF is unable to support the logging of the catchments, unless and until the forestry operations gain Forest Stewardship Council certification.

Given the likely future deleterious impacts of global warming on rainfall in Victoria, WWF believes the societal value of the water foregone may well be greater than the value of any timber harvested.[306]

Conclusions

Melbourne Water has made a conscious decision to rely largely on protected forest catchments to maintain its water supply, with the result that the city enjoys high quality water at a competitive price. Some of these catchments are in designated IUCN category protected areas so that there is also a clear link between maintaining water supply and maintaining other protected area values including biodiversity. However, the medium term value of these forests is dependent on them not burning and this may be difficult to achieve in forests that are naturally prone to fire. The recent debate in Australia regarding fires and protected areas suggests that the debate about protection is likely to intensify and may lead to further management controls to reduce fuel build-up in at least the less strictly protected parts of the catchments (e.g. by prescribed burning or selective removals). Here protection and management therefore are closely interlinked in both water management strategies.

Istanbul, Turkey by **Ahmet Birsel, Sedat Kalem and Yıldıray Lise**[‡‡]

Introduction

Benefiting from a strategically important geographic location and breathtaking natural beauty, Istanbul is situated on both shores of the narrow Bosphorus Straits which joins the Black Sea, to the North, with the Marmara Sea, to the South. Istanbul has been one of the world's largest cities for millennia. Straddling Europe and Asia, Istanbul is the point where east meets west, not only geographically but also culturally, as the city's western part lies in Europe and its eastern part in Asia. The city, founded in 660 B.C. as Byzantium was renamed Constantinopolis under the Byzantine Empire before being conquered by the Ottoman Empire in 1453. It remained the capital until 1923 when the newly emerging Republic of Turkey moved its capital to Ankara. Istanbul is still Turkey's largest city with a current population of over 12 million. One out of every six Turks lives in Istanbul and the city's population density is 1,700 people per km^2. It is estimated that by 2010, Istanbul's population will reach 17 million[307]. The provincial boundaries of Istanbul cover 5,110 km^2, yet supports a remarkably high diversity of plant species with approximately 2,000 species (more than the total floras of the Netherlands or United Kingdom[308].

Water consumption and source

The growing population has lead to an increasing demand for potable water, and in the last decade water consumption has tripled. Water sources in Istanbul are, however, abundant. There are seven ancient water reservoirs and a number of natural springs in the forests on both peninsulas of Istanbul which have been providing water for the city since the 15th and 16th centuries. Most of the major water resources (Terkos, Ömerli, Büyükçekmece, Küçükçekmece and Elmali) are no longer on the periphery of Istanbul as all, except Terkos, have been 'swallowed' by the expanding city limits. The Belgrad forest is located on the European side of the city and hosts several ancient water reservoirs from the Ottoman period. At one time all the drinking water in Istanbul came from Belgrad forest, and was piped to the city's central square, Taksim. The Ottoman Court architect Sinan's magnificent Maglova Aqueduct, built in 1560 to bring water from the edges of the Belgrad forest to the centre of the old city, the 51 km long Anastasius Wall near the Terkos Lake and the well-preserved aqueduct system of the Istranca Roman Water Supply Line dating back 1500 years to Byzantine times are other exceptional historical features

Water for human consumption is currently available from ten sources, typically providing 920 million cubic meters per annum; by 2010 the annual demand for water is predicted to rise to 1.7 billion cubic meters. In order to meet this increasing demand, six new dams have recently been built to bring water from the Istranca forest, an important site for conservation, near the Bulgarian border 200 km west of the city. The water is stored in Terkos Lake, which has caused the original water level to rise and has thus impacted the lakes natural habitats. There are also plans to bring water through pipelines from the Melen River 200 km east.

Problems of urbanisation and pollution

There is significant urbanisation pressure on the Belgrad forest and other forests surrounding the city. Although, forests are the most widespread habitat in the province, together with grasslands, heathlands, sand dunes and wetlands, their continued and rapid destruction is alarming. Nearly six thousand ha of forest have been destroyed over the last 10 years in 872 incidents, some of it caused by intentional fires. Without a concerted effort to protect these areas now, many are likely to be completely destroyed

[‡‡] All of WWF-Turkey

or altered beyond all recognition in the coming years. Not only will this represent an irreplaceable loss of features of international nature conservation importance but it will also result in the loss of already diminished outdoor recreational areas. The probability of such protection taking place is however hampered by the actions of both the national and local government.

The national government is currently promoting an agenda which will not only have an irreversible effect on forest areas nation-wide but will critically affect Istanbul. With the underlying aim of rewarding the political supporters that brought them to power and winning political support in the forthcoming elections, the government is currently proposing a new amnesty for settlers that have illegally occupied forest land. The new law, if passed by the Turkish Parliament, will not only reward those already illegally occupying forest lands but will most likely lead to further destruction of forested areas in the hope of future similar amnesty. For example, forest fires have increased by 35 per cent nation-wide on a year-to-year basis, probably as a result of people clearing land for development, and the population of the Istanbul suburb of Sultanbeyli, developed around the Ömerli Lake, has increased by 2000 per cent in the last 10 years. The government, however, has failed to make the link between the laws they propose and the resulting effect on forest land.

In Istanbul there is also conflict between various governmental organisations and municipalities on the possession, management and authority of water reservoirs and surrounding areas.
For instance, there is a conflict of authority between the Greater Municipality of Istanbul and the Ministry of Environment and Forestry, and ongoing conflicts of authority among the Greater and Local Municipalities especially on urban development, which is affecting even minimal efforts made to protect green spaces. The Ömerli Reservoir, on the Asian side of Istanbul and home to Bern Convention protected heathland habitat as well as critically endangered species, is under growing pressure by developers. The Chambers of Architects, the Chamber of City Planners and the Chamber of Construction Engineers have taken their case to court to stop and reverse the Istanbul Municipality Water Authority's new Drinking Water Catchment Area legislation that will allow construction around the water reservoir catchment area.
This development scheme is likely to increase pollution levels in the reservoir and destroy one of the last green areas around Istanbul.

Belgrad Forest

In Turkey, if a forest has an identified special function (providing water, purifying air, preserving soil, etc) it is usually set aside as a special forest which particular management, usually termed a 'Preservation Forest'.

Belgrad is broadleaved forest composed mainly of beech (*Fagus sylvativa*), hornbeam (*Carpinus betulus*), oak (*Quercus frainetto*, *Q. petraea*, *Q robur*), etc. It is jointly managed for research and recreation and because of its hydrological importance. It is not exploited for timber or other resources, but it receives some silvicultural treatment (e.g. thinning) mostly for scientific purposes or to ensure good forest cover. Although the Belgrad forest is called a preservation forest due to its hydrological purpose peripheral areas of forests are being replaced by illegal housing developments due to the rapid migration into the city.

Other threats to Istanbul's forests and water sources include the planned third bridge on the Bosphorus, which will further boost urban development and developments (industrial and residential) in the still well preserved northern green belt of the city, important for water reservoirs which are already confronted by increasing levels of pollution and disturbance. It has also been estimated that the construction of the Istranca water pipeline has destroyed 1,400 ha of forest, and is responsible for deteriorating water quality in Terkos Lake in the European side[309]. The Terkos Lake also suffers from water contamination as a result of intensive agricultural activities around the lake.

The campaign for protection

The forests around Istanbul have been selected by WWF as one of the ‘forest hotspots’ in Turkey and WWF-Turkey is lobbying the authorities to declare the forests as an official protected area.

Much of the province of Istanbul is of importance to nature conservation, but the Turkish Society for the Conservation of Nature (DHKD, formerly the WWF Associate in Turkey) identified 10 areas as being exceptional due to their high biodiversity. Most of these spots are also important water reservoirs around the town: 1) The Terkos Lake and forests (also identified an Important Plant Area – IPA); 2) The Büyükçekmece Lake (also identified an Important Bird Area – IBA); 3) The Küçükçekmece Lake (an IBA); 4) The Ömerli Lake and forests (an IPA).

WWF-Turkey’s campaign started in 1999, with a project titled ‘Istanbul Greenspace’. The motto of the project was ‘Istanbul: Forever Green’[310]. The project seeks to achieve positive conservation through:

- fostering an appreciation and understanding of the value of Istanbul’s unique habitats and rare species through education and public awareness campaigns;
- lobbying for development, introduction and implementation of effective planning and other land management policies to protect valued wildlife throughout the province;
- providing the best scientific information available to town planners and other land managers to ensure that nature conservation interests are fully taken into account of during planning and other land management processes;
- working with other NGOs, authorities, and individuals to secure formal protection for the most valued areas;
- advising on the best management practices to maximize the nature conservation benefits within individual sites; and
- fighting to halt destructive developments.

This campaign was later included within the framework of WWF’s Gift to the Earth Campaign, which aims to create new protected areas in Turkey’s nine forest hot spots including the Forests of Istanbul. In 2002, WWF-Turkey, in collaboration with relevant stakeholders, started the process leading to the creation of a new protected area with Terkos Lake as the core. Stakeholder workshops have been organised and a justification report was prepared and submitted to the Ministry of Forestry for necessary procedures. The process has yet to be completed due to the unstable political conditions the country has been experiencing.

In 2000, WWF-Turkey also launched a platform called Istanbul Water Initiative (IWI), with the participation of key stakeholders, including experts, NGOs, relevant organisations and individuals in order to monitor the water issues of Istanbul.

Conclusion

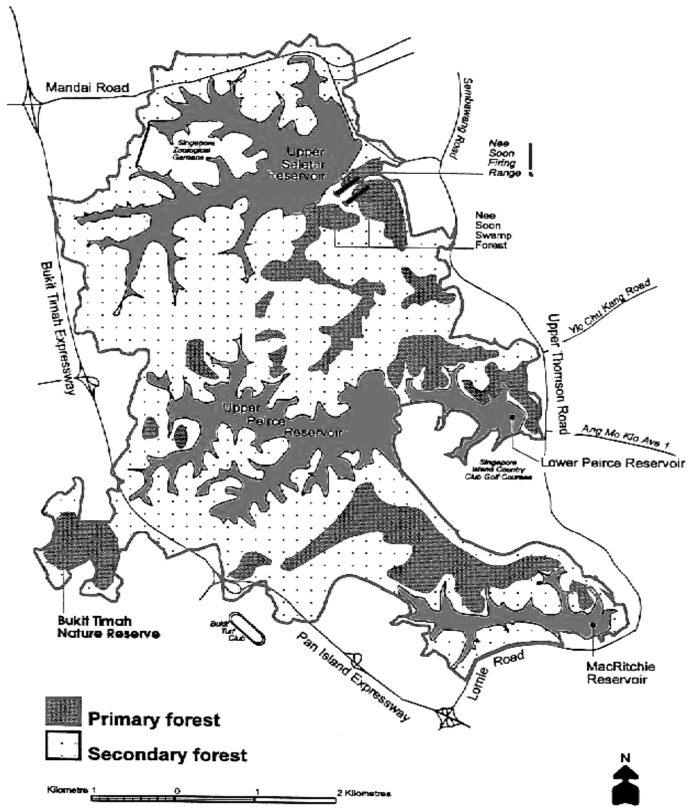
Despite their high value from a water perspective and for biodiversity and cultural reasons, only tiny areas of forest have been set aside for nature conservation and outdoor recreational activities in and around Istanbul. Within the city itself, the total urban greenspace formally set aside by the municipalities covers just under 900 ha. This equates to only an average of $1.13m^2$ per person and compares very poorly with the $40m^2$ set aside, on average, per person in Europe. In addition, a further $0.96m^2$ of natural parks and reserves is set aside per inhabitant. Outside this metropolitan area very few areas have been formally designated for protection: just a handful of nature reserves, game and wildlife reserves and natural heritage sites have been declared[311]. WWF-Turkey hopes that its campaigns will reverse the trend of forest loss, in terms of quantity and quality, in Istanbul, protecting forests for biodiversity and the cities supplies of drinking water.

Singapore by **Wang Luan Keng**§§

Introduction

Singapore (1°09'N, 103°36'E) is located off the southern tip of the Malay Peninsula, approximately 137 km north of the Equator. It has a total area of 648 km^2. The island has scarce natural resources, including water. The centre of the island consists of a series of low hills of granite and igneous rock, the highest, Bukit Timah, stands at 176 m. The coastline is mostly flat and muddy although 5,400 ha of this have now been reclaimed[312].

Before the arrival of the British, when Singapore was still a small fishing village, most of the island was covered with 82 per cent lowland everygreen dipterocarp rainforest, 13 per cent mangrove and 5 per cent freshwater swamp[313]. However, while more than 60 per cent of the island was still forested in 1848, by 1882 only seven per cent of that forest cover remained[314]. From 1819 onwards, the forests were being cleared for gambier plantations, which were abandoned after about 15 years due to depletion of nutrients from the soil. After 1900, rubber became the principal plantation crop. Although forest protection began in the 1840s and forest reserves were first established in 1882 to protect the water supply, prevent soil erosion and improve the climate[315], by 1936, all existing reserves except for Bukit Timah and parts of the Pandan and Kranji mangroves, were revoked and regazetted in 1939. Today, the only rainforest areas under protection are in the Bukit Timah Nature Reserve (164 ha) and the adjacent Central Catchment Nature Reserve (about 2000 ha) – IUCN Category IV protected areas. Together they comprise ~ 4 per cent of the original rainforest. These forests are managed by the Singapore National Parks Board.



Map of the Central Catchment Area showing the major vegetation types of the Nature Reserves. The major continuous areas of primary forest are at Bukit Timah Nature Reserve and around the Nee Soon Firing Range.

Population Growth

A century ago, Singapore had a total population of only 230,000.
Since 1901, the population has grown 16-fold to 4,017,700 by the year 2000.

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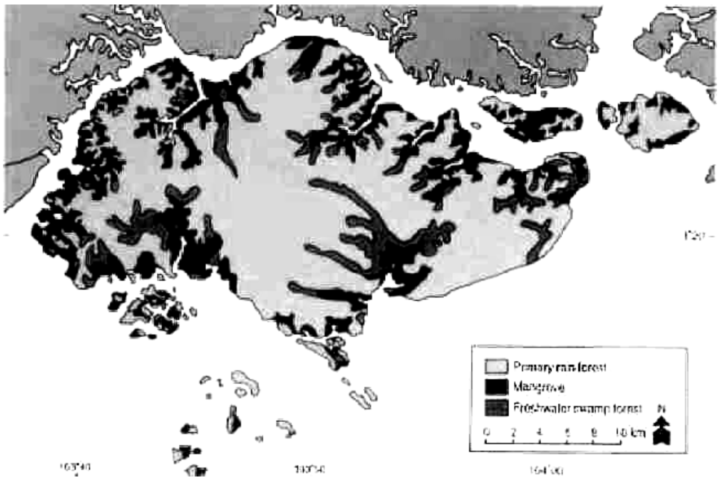
§§ The author acknowledges Ms Margaret Hall for providing reference material and personal notes about the central reservoirs, Ms Tan Beng Chiak for all the photographs and Dr Shawn Lum for kindly reviewing and commenting on the manuscript.

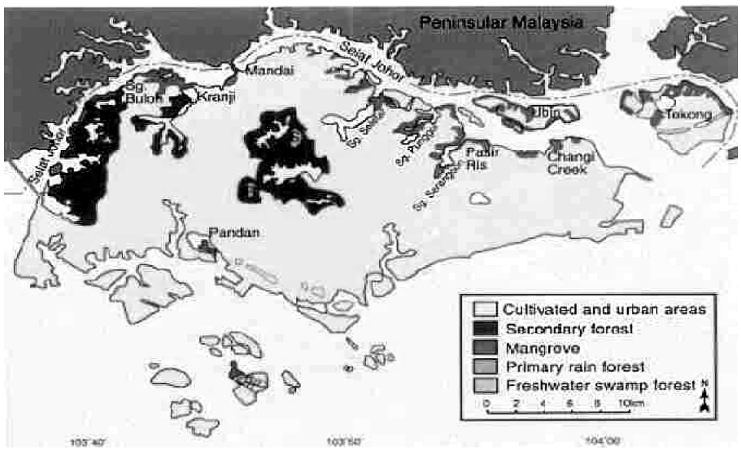
Population growth peaked at 4.4 per cent per annum during 1947–1957, largely due to the post-war baby boom. The growth rate subsequently declined to 1.5 per cent per annum during 1970-1980. Since then, the average annual growth rate for the population has been increasing, reaching a rate of 2.8 per cent for the period 1990–2000. Non-residents contributed significantly to the population growth, with a high growth rate of 7.6 per cent in 2001 (compared to that of resident at 1.7 per cent) and around 9 per cent per annum (compared to that of resident at 1.6 per cent) throughout the period 1970-2000[316]. The population is expected to grow and reach a peak of 5.5 million.

Water Source

When Singapore was founded in 1819 as a British trading port, freshwater on the island colony came from wells and rivers. However, these freshwater supplies became insufficient to meet the increasing demands by the growing population of immigrants, drawn to the small island by the opportunities for trade and money-making.

Plans to build the first impounding reservoir in an area known as Thomson Road were proposed as early as 1823 but the reservoir was only completed in 1863. The reservoir was created by damming the Whampoe River[317]. The pumps and distributing network were not completed until 1877. Two pumping stations were built at MacKenzie Road and Mount Emily. Singapore's first waterworks officially opened in 1878. In order to keep water as clean as possible, all human activities, including logging, planting, etc, around the perimeter of the Reservoir were banned. The surrounding area of mostly secondary forests was protected by Government gazette in 1868, five years after the completion of the reservoir[318].





Maps showing the major vegetation types of Singapore at 1819 (upper) and today (lower) [after Turner *et al.* 1994]

In 1891, the Impounding Reservoir, as it was then known, was further enlarged under the supervision of the Municipal Engineer James MacRitchie. MacRitchie Dam was enlarged between 1891 and 1894. The dam was further raised by 1.5m in the period 1903-1905 to increase its storage capacity. The cost of the extension was S$32,000 and it increased the capacity of the reservoir to over 1840 million cubic metres (468 million gallons). The enlarged reservoir was named the Thomson Road Reservoir in 1907 but in 1922, it was renamed MacRitchie Reservoir to recognise James MacRitchie's work.

By the beginning of the 20th century, the average daily supply of water was about 4 million gallons – not enough to meet the demands of 230,000 people. A combination of drought and increased demand led to water shortages and more plans to increase the water supply. One plan was to channel water from the upper section of the Kallang River into the Thomson Road Reservoir. Another was to build a service reservoir in Pearl's Hill. To take the water from the Upper Kallang, Thomson Reservoir was extended in 1905. The Kallang Tunnel Works were completed in 1907.

In 1902, the Municipal Engineer Robert Peirce had come up with a plan to create a second impounding reservoir across the lower reaches of the Kallang River. It would have created a storage capacity of 3.2 million cubic metres (845 million gallons). Known as the Kallang River Reservoir, this scheme was completed in 1900 and the surrounding forest protected in 1910[319]. This reservoir was expected to supply an extra 27-30 thousand cubic metres of water daily, boosting total supply to some 55 thousand cubic metres. This was considered adequate to meet demand until 1915.

Officially commissioned in 1912, the Kallang River Reservoir was renamed Peirce Reservoir in 1922 after the Municipal Engineer Robert Peirce who had been in charge of its construction. It became known as Lower Peirce Reservoir when work began on an even bigger impounding reservoir in 1975. The Upper Peirce Scheme was built a cost of S$55 million. It entailed the construction of a dam and ancillary works at the upper reaches of the old Peirce Reservoir. Water from the Upper Peirce Reservoir is treated at the Chestnut Avenue Waterworks.

Water demand surged after the First World War, and work on the latest of the Central Catchment reservoirs, the Seletar Reservoir began by damming the upper reaches of the Seletar River[320]. Singapore's third impounding reservoir was thus built in 1920.

In the early 1960s, work began to quadruple the capacity of Seletar Reservoir to 20 million cubic metres (5.3 billion gallons). The reservoir was enlarged by over 35 times. The natural run-off from the catchment upstream of the dam is augmented by water pumped from eight adjacent streams into the Seletar Reservoir. The water from the enlarged Seletar Reservoir is transferred to Lower Peirce and thence to Woodleigh Waterworks. Woodleigh Waterworks also had to be expanded to cope with the increased volume of water. The reservoir was Singapore's largest reservoir and was built at the cost of $27 million. It was renamed Upper Seletar Reservoir in 1992.

The four impounding reservoirs, located in the central part area of Singapore, were surrounded by 2059 ha of mostly secondary forests, which form the Central Water Catchment, ensuring a clean supply of water to the reservoirs. Bukit Timah Hill has a small amount of water, one side of it flows into the Rochor River.[321] Another side flows towards Upper Peirce Reservoir.

As demand for water continues to increase with the increasing population and industrial growth, the development of impounding reservoirs became impossible in land scarce Singapore. The establishment of more forested catchment areas would mean depriving other important needs such as housing. Other non-conventional ways of water collection were explored and major water supply schemes were completed. The Kranji/Pandan Scheme which comprised Kranji Reservoir was created in 1975 by damming the estuary of the Kranji River, and Pandan Reservoir, by building a dyke to enclose a mangrove swamp. As the water within these dammed estuaries was brackish, they initially had to be pumped out regularly to reduce the salt content.

Another major scheme, the Western Catchment Scheme started in 1977 and was completed in 1981 at a cost of S$67 million. Four estuaries – Murai, Poyan, Sarimbun and Tengeh were dammed and converted into reservoirs.

In 1986, the Sungei Seletar/Bedok Water Scheme was completed. The scheme involved the damming of Sungei Seletar to form a reservoir (Lower Seletar Reservoir), creation of Bedok Reservoir from a former sand quarry and construction of Bedok Waterworks. Its unique feature was the construction of nine stormwater collection stations to tap the storm runoffs of the surrounding urbanised catchments. Eight of these collection stations are ponds at Yishun, Tampines, Bedok and Yan Kit new towns.

Water management authorities

The Public Utilities Board was inaugurated on 1 May 1963 to take over the responsibility of providing electricity, water and piped gas from the former City Council. Under the Public Utilities Act, Chapter 261, the Board is to provide, construct and maintain such catchment areas, reservoirs and other works as may be required or necessary for the collection, supply and use of water for public and private purposes. Over the last three decades, several major water supply projects were undertaken by the Board to develop new water resources to support Singapore's rapid housing and industrialisation programmes.

Permission was granted by the government of the Malaysian state of Johor to seek a source of water from the state. Singapore has been receiving water from Johor as early as 1924, when the Gunong Pulai Scheme was started, where dams were built to form the Gunong Pulai and Pontian Reservoirs, a steel pipeline for pumping water from Pontian to Gunong Pulai, which also had a treatment plant. Treated water is pumped from Gunong Pulai to a service reservoir at Pearl's Hill in Singapore. By 1941, Gunong Pulai's treatment capacity was doubled. In the 1980s, water treatment capacities in Johor were extended. A pipeline was laid from the Johor River Waterworks to Singapore, across the Straits of Johor. The treated water goes to a covered service reservoir. If any raw water comes in at all, it goes into Upper Peirce Reservoir, which is then pumped to the Chestnut treatment works[322]. Water from Upper Seletar goes along that channel to Lower Peirce and then to Woodleigh. Water from MacRitchie goes to the Bukit Timah treatment beds. The island state now receives half of its approximate 300 million gallons per day usage from Johor. Another 150 million gallons needed daily come from the Central Catchment Reservoirs themselves.

In the past three decades, the water supply system has been extensively expanded to support Singapore's rapid economic developments and the attendant increase in water demand. Current total water supply comprises of nine water treatment works, 19 raw water reservoirs, 14 storage or service reservoirs and more than 5,000 kilometres of pipelines. These collect about 68, 000 cu m of rainwater daily, which is about 57 per cent of the daily consumption needs of about 1.2 million cu m[323]. The daily consumption of water in Singapore is expected to increase by 33 per cent in the next ten years[324].

To augment Singapore's water supply, the Public Utilities Board (PUB) has plans to further collect stormwater from residential new town developments as well as capture surface runoffs from highly urbanised catchments. More housing estates and built-up areas will soon channel stormwater into local reservoirs. Storm water collected in drains will also be channelled into reservoirs. Another reservoir will be created at the Marina basin in the south of the island. New reservoirs are being developed downstream of the present Lower Seletar Reservoir. The PUB is also looking into additional water supply from desalination of seawater. Desalination has become a feasible option due to rapid technological advancements in the last few years, resulting in lowering of costs. PUB will be purchasing desalinated water from the private sector through a Build-Own-Operate project. Desalinated water supply is targeted to be available in 2005.

Since May 2000, the PUB commissioned and has been operating an advanced water treatment plant using the latest membrane technology including reverse osmosis to purify treated wastewater (from sink and bathroom). The resulting high quality product water (called Newater) is suitable for supply to the industrial users that require copious amounts of pure water for wafer fabrication and other uses. From February 2003 onwards, the Singapore Government has given the go-ahead for two million

MacRitchie Reservoir

gallons of Newater to be blended with raw water supplies in Bedok, Kranji and Upper Seletar Reservoirs, after a panel of nine members endorsed the Newater safe and substainable[325]. This will help to diversify Singapore's water sources and also meet the anticipated rising demand for water in the future.

Future of watershed protection

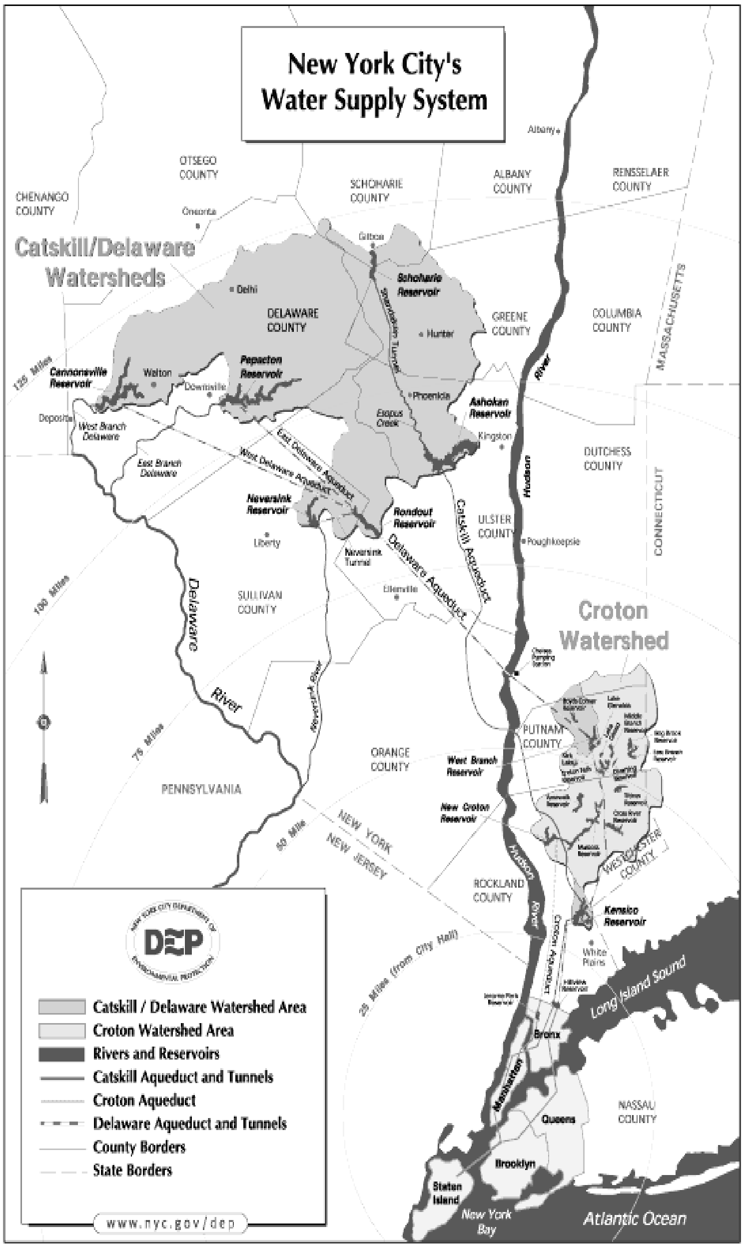
While protected catchment forests played a major role in ensuring an adequate supply of water during Singapore's formative years, enormous increases in the demand for water had led to the development of unconventional, non-traditional water supplies. Given that Singapore forests exist primarily for the sake of the island's water supply, it may lead one to wonder how secure these forests are should their role diminish further as contributors to Singapore's total water supply. Over the last 183 years, Singapore has suffered substantial rates of documented and inferred extinctions, especially for forest specialists, with the greatest proportion of extinct taxa (34 – 87 per cent) in butterflies, fish, birds and mammals. Although forest reserves today only cover 0.25 per cent of Singapore's area, they harbour over 50 per cent of the native biodiversity left on the island[326].

New York, United States of America

Introduction

New York is one of the many cities across the USA where watershed management and protection play an important role in providing water to its citizens. Management regimes are based on developing partnerships with landowners and users and a range of incentives.

New York is one of the most densely populated cities on the planet. The nine million residents of New York City and surrounding areas receive their drinking water supply predominantly from the rural Catskill and Delaware watersheds and the smaller and more industrialised Croton watershed[327]. Together, the three watersheds deliver 1.3 billion gallons of water per day to New York City and the metropolitan area. The watersheds of the three systems support reservoirs fed by the watershed that have a combined storage capacity of 580 billion gallons.



Water source

New York's watershed is actually divided into two separate systems – the Catskill/Delaware Watershed and the Croton Watershed. The Catskill/Delaware Watershed, located approximately 100 miles northwest of New York City, provides 90 percent of the City's drinking water. It covers over 1,600 square miles of land in five counties, and consists of six major reservoirs – the Ashokan and Schoharie Reservoirs of the Catskill System and the Rondout, Neversink, Pepacton and Cannonsville Reservoirs of the Delaware System[328]. The Croton is the city's oldest system dating back to 1842. It covers about 380 square miles and supplies about 10 per cent of the city's needs[329]. Forests constitute 75 per cent of the total land area in these watersheds[330]. Land ownership is diverse, with New York City owning less than 10 per cent of the watersheds that supply the city with water[331].

The Catskill State Park (Category V, 99,788 ha) overlaps significantly with the watersheds of the Catskill/Delaware system. The park contains 98 peaks of over 3,000 feet high and is a blend of public and private ownership (over 60 per cent is privately owned). The Catskill Forest Preserve is state land now contained within the Catskill Park[332] and protects approximately 25 per cent of the watershed from further development.

A watershed agreement

On January 21, 1997, New York State Governor George E. Pataki, and New York City Mayor Rudolph Giuiliani joined the United States Environmental Protection Agency, the Coalition of Watershed Towns and members of the environmental community in the signing of a landmark 'Memorandum of Agreement' for the long-term protection of water quality in the New York City Watershed[333].

The Watershed Agreement resulted from discussions as to how to manage issues of water quality in the Catskill/Delaware Watershed. There are approximately 400 dairy and livestock farms in New York City's watershed and agriculture poses a potentially significant source of pathogens, nutrients and other forms of pollution to surface waters[334]. The quality of the drinking water was first questioned in the late 1980s as concerns began to grow about possible microbial contamination. In 1989, the United States Environmental Protection Agency (EPA) instigated a requirement that all surface water supplies to cities should be filtered; however this requirement could be waived if existing treatment processes or natural conditions provided safe water.

Achieving clean water

New York City (NYC) has introduced a range of initiatives to achieve its aim of improved water quality. These include:

Financial aid:

- *Taxation*: NYC residents voted to allow the government to levy additional taxes on their water bills.
- *New York City Bonds*: NYC issued bonds for additional financing.
- *Trust Funds*: NYC financed the Catskill Fund for the Future, a US$60 million trust fund that provided loans and grants for environmentally sustainable projects in the Catskill watershed. Another Trust, the NYC Trust Fund, provided US$240 million for water quality and economic programmes in the Catskill watershed and US$70 million for programmes in the Delaware watershed.
- *Stormwater Controls:* NYC will pay all of the incremental costs of designing and implementing stormwater pollution prevention measures required by the regulations for certain residential projects and half of the costs for small businesses.
- *Good Neighbor Payments:* NYC has provided up to US$9.765 million for municipal capital projects to help establish a better working partnership with communities in the Watershed.

Compensation:

- *Cost-sharing /Subsidy Programme*: NYC provided US$40 million to dairy farmers and foresters who adopted best management practices. Of the approximately 350 Catskill/Delaware dairy farmers, 317 agreed to participate in the programme.
- *Logging permits for forest management improvements*: In return for improving forest management practices, such as the adoption of low impact logging, the timber industry gets additional logging permits in areas to which they had no prior access.

Conservation measures:

- *Land Acquisition*: NYC is acquiring land and conservation easements in hydrologically sensitive areas– such as that near reservoirs, wetlands, and watercourses. NYC has also created a farm easement program, with its partner the Watershed Agricultural Council, to protect farms from development and to establish best management practices. Such lands and easements are acquired at fair market value from willing sellers only; the City pays property taxes on all such lands acquired.
- *Stream Corridor Protection:* Design, construction and implementation of stream corridor protection projects such as streambank stabilisation and fish habitat improvements, in the Watershed.
- *Other Land Management Programs:* Under the federal Conservation Reserve Enhancement Program farmers and forest landowners can enter into 10 to 15 years contracts with the United States Department of Agriculture to remove environmentally sensitive lands from production. Forest landowners who own 50 acres (20 hectares) or more and are willing to commit to a ten-year forest management plan are also eligible for an 80 per cent reduction in local property tax.

In response, New York City committed to building a filtration plant for the Croton watershed but in the Catskill/Delaware watershed the authorities developed a programme of watershed management improvement. The Agreement signed in 1997 is a legally binding document which sets forth certain obligations by the parties involved on issues relating to the protection of the watershed. This is based in part upon improvements in farm and forestry practices that aim to reduce significantly microbial pathogens and phosphorous in water supplies (see box for a summary of the measures included in the initiative). The programmes aim is to improve water quality, thus making additional purification unnecessary. As a result of these actions the city received a temporary filtration waiver from the EPA; however there is no guarantee that the initiative will be successful in achieving the desired standards of water quality in the time allotted in the EPA waiver[335].

The City of New York paid the initial costs and lion's share of the watershed programme, with state, federal and local governments within the watershed area providing supplementary funding. The construction costs of an additional filtration plant were estimated at US$6-8 billion, plus an annual US$300-500 million operating costs. The alternative watershed programme will cost the city US$1 to US$1.5 billion over ten years. The programme was primarily financed by a 9 per cent increase in water taxes a five-year period; a tax rise that compares favourably with the alternative doubling of taxpayers' water bills that would have been needed to build a new filtration plant[336].

Protecting the watershed

Although all the initiatives developed as part of the 'Memorandum of Agreement' are based upon achieving the goal of the long-term protection of water quality, two programmes in particular are likely to particularly benefit conservation and forest protection in the watershed.

The Land Acquisition Program allows the New York City Department of Environmental Protection (NYCDEP) to purchase property in the Catskill/Delaware and Croton Watersheds. One of the main purposes of the program is to enable the City to develop a 'buffer' around reservoirs, their tributaries and other important land features to protect water quality. Under the terms of the Agreement, the City is required to approach the owners of 143,795 ha of eligible land in the Catskill/ Delaware Watershed (approximately 30 per cent of the watershed area) and must commit from US$250 to $300 million for acquisition. (It should be noted that the programme is voluntary and that this target is for contact only and does not mean that the City will acquire this much land). In order to maximise the effectiveness of the programme, the NYCDEP has developed criteria to evaluate the watershed and categorized priority areas eligible for acquisition. In most of the watershed, the City is only allowed to acquire vacant parcels of land, i.e. areas containing no structures other than uninhabitable dwellings. Once land has been acquired, management will focus on maintaining water quality, although recreational uses, such as fishing, hiking and hunting, may be allowed to continue on property in such cases where NYCDEP determines that it will not conflict with water quality and public safety[337].

The other tool, specifically aimed at conservation is the conservation easement – a covenant or restriction placed on a piece of property which limits development, management or use of the land in perpetuity. Property owners may sell conservation easements to the City to protect their land from inappropriate development, while retaining private ownership. In particular, conservation easement provides a mechanism for protection of property owned by people who are not necessarily interested in selling outright, but who wish to receive financial benefits for being good stewards of their land.

Protected areas in the watershed

The state-owned Catskill Forest Preserve was created in 1885, growing from an original 13,770 ha to almost 121,500 ha today. Since 1904, the Forest Preserve has been part of the larger Catskill State Park. The Park is reminiscent of the European model of national parks and is a mix of private and public ownership and habitats and usage. Most of the mountain peaks within the Park are protected, and thus provide drinking water for local people as well as millions of others in the lower Hudson Valley and New York City. The Ashokan, Rondout, and part of Neversink and Pepacton Reservoirs are found in the Park.

Coyotes, bears, bobcats and minks are found in the forest preserve and red squirrels and porcupines are common at higher elevations in balsam fir (*Abies balsamea*) and red spruce trees (*Picea rubens*) of the boreal forest. Old growth forests of hemlock (*Tsuga canadensis*) and others northern hardwoods survive on steep mountainsides and remote valleys, as they were inaccessible to the logging, tanbarking and charcoal industries that have taken place in the area over the last 300 years. Although many of the areas formerly logged have regenerated, forestry remains important on private lands, primarily as a source of lumber[338].

Conclusions

If all goes to plan, the land and forest resource protection strategy will result in substantial savings for New York City as compared with putting in a treatment plant. The strategies start-up costs being estimated at US$1 to US$1.5 billion over ten years, as opposed to US$6-8 billion, plus an annual US$300-500 million operating costs, that would be required for a treatment plant. The plans have general support from the citizens of New York. However, it remains uncertain as to whether the benefits will accrue in time to meet deadlines on purification imposed by state laws. Nor is it clear to what extent the protected forests will be classified as IUCN protected areas or not.

Caracas, Venezuela by José Courau

Introduction

Caracas was founded in 1567 as Santiago de León de Caracas and quickly became one of the most prosperous Spanish colonial communities in South America. The city became the capital of the Venezuelan Republic in 1829.

Caracas is located in the central section of the Coastal Mountain Range at 950 meters above sea level. The city has seen rapid, and unplanned, urban growth[339]. It is reported that during a period of just 50 years the population grew from 350,000 to over 1.5 million. In 1997 the estimated population was 1.8 million, and the city's population continued to grow at a rate of 2.3 per cent per annum[340]. The trend of migration from the rural areas to the city has been difficult to stop, and it is estimated migration will cause more radial growth around the city, bringing consequent problems for the provision of services and the social and health problems[341].

Water supply

Overall, the northern part of Venezuela, where Caracas is located and where most of the country's population lives, is the one with the least hydrological resources[342]. The city consumes an average of 17 thousand liters of water per second and it is estimated that the average resident uses 500 liters of water per day.

In 1600, Caracas, which consisted of 4 main streets and 2,000 inhabitants, had a water distribution system of pipes made out of clay covered with calcium carbonate. Over a short period of time the system became insufficient. In 1675, the Franciscan priests decided to build a private aqueduct for the exclusive use of the convents, monasteries and churches. These two water systems remained the main methods of water distribution for the next 200 years.

The first officially managed aqueduct in Caracas was opened in 1874. This system consisted of a 46 km canal connected to the Macarao River. Water was stored in a reservoir in the El Calvario hill and from there distributed to central Caracas.

The aqueduct provided 400 litres of water per second for Caracas, a record for the period. For 50 years the aqueduct solved the water needs of the city. As the population increased only two aspects of the distribution system were improved: the 46 km ground canal became a concrete canal and the reservoir at El Calvario was extended. The increasing demand for water led authorities in 1926 to declare Macarao as the first National Forest to protect the origins of the San Pedro, Macarao and Lagunetas rivers. The forest was declared a national park in 1973 (15,000 ha, Category II). The Guatopo National Park (122,464 ha, Category II) was declared in 1958 also with the purpose of protecting water sources (Lagartijo, Taguaza, Taguacita and Cuira Rivers) for the city[343].

The water used by the city is transported from sources located more than 150 km away in an area called Camatagua. From here the water is pumped 600 m: which requires a significant amount of electricity.

It has recently been reported that there are significant shortages of water in the city, due to reductions in the water table and the city's poor water management culture[344].

Water source

The city receives water form three main sources. These sources correspond to three national parks, the Guatopo, the Macarao and the Avila National Parks (85,192 ha, Category II). The Table 1 illustrates the different sectors of the city and the corresponding protected areas that provide them with water.

Water sources for the different population centres associated with Caracas

Population Centre	Population	Protected area
Caracas	1,822,465	Guatopo
		Macarao
		El Avila
Petare	338,417	El Avila
		Guatopo
Barua	182,941	Guatopo
Chacao	66,897	Guatopo
		El Avila
El cafetal	59,949	Guatopo
Los dos caminos	59,141	El Avila
Gran caracas	2,529,810	Guatopo
		El Avila
		Macarao

- **The Guatopo National Park** was declared in 1958. It is recognised as an area of hydrological importance that contributes to the water of the city of Caracas and is managed by the state agency INPARQUES. The water generated by the park is collected in the Lagartijo, La Pereza, Taguacita, Cuira and Taguaza dams[345].

  The park consists of deciduous and evergreen forests. The predominant tree species are the cedar (*Cedrela fissilis*), balso (*Ochroma lagopus*), bucare (*Erythrina poeppigiana*), sangre de drago (*Pterocarpus acapulcensis*), araguaney (*Tabebuia chrysantha*), indio desnudo (*Bursera simaruba*) and yagrumo (*Cecropia peltata*). Palms include seje (*Oenocarpus bataua*), macanilla (Bactris sp.) and the small endemic palm *Asterogyne spicata*. Epiphytes are mainly represented by the aracea, bromeliads, orchids and piperacea. Important fauna species found within the park include *Chironectes minimus*, three-toed sloth (*Bradypus variegatus*), anteater (*Tamandua tetradactyla*), and the endangered *Priodontes maximus*. Various carnivores have been reported, including the jaguar (*Panthera onca*), *Galictis vittata*, *Conepatus semistriatus*, and the kinkajou *Potos flavus*. There are also at least ten species of bird considered endemic or with limited distribution and more than 50 species of bats[346].

  Lack of park personnel is seen as the main threat to the park, along with the threat forest fires.

- **Macarao National Park** was declared in 1973. The park is located in the southeast of the city. It is part of the Coastal Mountain Range and includes the rivers Macarao, San Pedro and Jarillo. The altitude varies from 1000 meters to 2,098 at Alto de Ño León, the highest point of the basin[347].

The park contains semi-deciduous forests, evergreen forests and cloud coastal forests. The predominant tree species are represented by the genus Guarea, Gustavia, Inga, Ocotea and Tabebuia. There are at least 6 species of birds with restricted distribution. In addition, the park includes the blue-chested hummingbird (*Sternoclyta cyanopectus*); the puma (*Felis pardalis*), the howler monkey (*Alouatta seniculus*), the three-toed sloth (*Bradypus variegatus*), the deer (*Mazama americana*), the peccary (Tayassu sp.), paují (Pauxi sp.), guacharaca (*Ortalis ruficauda*) and querrequerre (*Cyanocorax yncas*)[348].

- **El Ávila National Park** was declared in 1958 (66,192 ha) and extended to 85,192 ha in 1974. It is located in the north-central part of Venezuela and inside the central part of the Coastal Mountain Range. It covers part of the Federal District (along the coast) and the State of Miranda (northwest region)[349]. The park includes several springs (Tocomé, Chacalito, Catuche, etc.) that carry water to the Tuy River[350].

  The main ecosystems protected in the park are evergreen forests, cloud forests and savannas. The main importance of the park is as a source of water and for the production of energy[351].

Water management

The management of hydrological resources in Venezuela is responsibility of the Ministry of Environment and Renewable Natural Resources (MARNR) through its Sector General Directorates (DGS). The provision of water and the waste management is decentralized to the municipalities. However, there have been some recent changes. The Hydrological Anonymous Venezuelan Company (HIDROVEN) is now responsible for dictating policy and providing technical assistance to the ten regional water companies, which are commonly referred to as ‘hidros’. These regional companies have a technical and supervisory role and are responsible for the production of potable water, the operation and management of water systems, building and rehabilitation of infrastructure, and the policies of charging and collection of fees. The companies also give financial support to the municipalities and promote municipal involvement in the water provision services and the creation of operating companies[352].

Due to the serious financial limitations faced by the protected areas in Venezuela, in 1999 INPARQUES started to consider charging the water companies for the direct services they obtain from the country’s protected areas, including water, antennas for telecommunications, admission fees and electricity generation. However, until now this initiative has not been further developed[353].

Rio de Janeiro, Brazil by Claudio Sericchio ***

Introduction

The city of Rio de Janeiro, capital of the state of Rio de Janeiro and formerly of Brazil, was founded in 1565. Located on the coast of the Atlantic Ocean (22º 54' 10" South and 43º 12' 27" West), Rio has a population of approximately 6 million, making it the third largest urban concentration in Latin America, after Mexico City and Sao Paulo. The larger Rio de Janeiro Metropolitan Area (RJMA) is composed of twenty municipalities, according to the state's administrative division, with a total population in 2000 of nearly nine million people. Estimates of population growth in the RJMA predict this population will rise to over ten million by 2010 and 12.5 million by 2030[354].

Water Supply

The water supply of the city of Rio de Janeiro and the Metropolitan Area is the responsibility of the State Water and Sewage Treatment Company – CEDAE, a public enterprise belonging to the state of Rio de Janeiro. The water comes from a variety of sources (see table).

RJMA Water Supply System (2002)

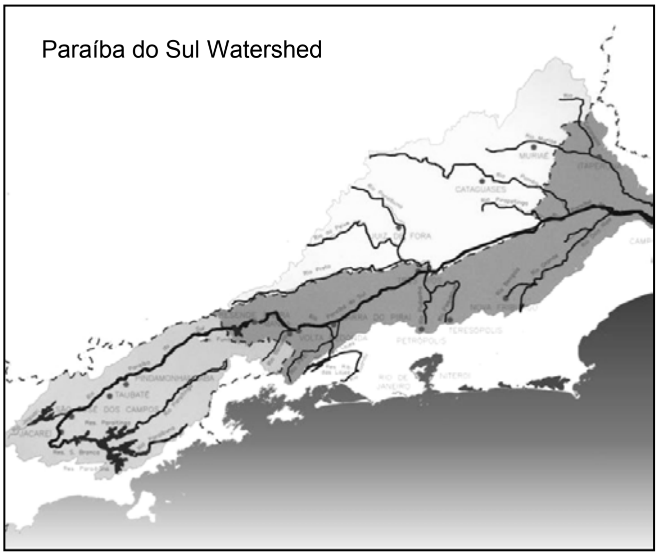
Supply Systems and Areas	Impoundment capacity (m^3/s)	Distributed yield (l/s)	Supply capacity (inhabitants)	%
1. *Guandu River (Guandu Water Treatment Facility):* Rio de Janeiro city and RJMA	47	40,000	9,600,000	81.2
2. *Lages Reservoir:* Rio de Janeiro city, Itaguai and Paracambi	5.5	5,000	1,200,000	10.1
3. *Other water sources*				
- *Within Rio De Janeiro:* Rio de Janeiro city, Tijuca, Santa Tereza, Gavea, Jacarepagua, Campo Grande and Guaratiba	-	600	144,000	1.2
- *Sao Pedro, Rio d'Ouro, Tingua, Xerem and Mantiquira rivers*: Baixada Fluminense municipalities	-	3,500	840,000	7.1
- *Mazomba and Itinguassu dams*: Itaguai municipality	-	167	48,096	0.4
Total	**-**	**49,267**	**11,832,096**	**100**

Source: CIDE (2002); Anuário Estatístico do Estado do Rio de Janeiro 2002. CD-Rom. Rio de Janeiro: Fundação Centro de Informações e Dados do Rio de Janeiro and Silva, Rosauro Mariano da (1998); colaboração de Joper Padrão do Espírito Santo. A luta pela água. Rio de Janeiro: CEDAE

1. Guandu River (Guandu Water Treatment Facility)

The Guandu River is the main source of water for Rio de Janeiro. Its flow volume averages of 136.2 cubic meters per second, of which 96.4 per cent is artificially created[355]. The Guandu River Catchment and its tributary, the Lages, have seen major engineering interventions since 1908, when the Lages reservoir was constructed to generate electricity. In 1913, the transport of water to the Guandu

*** Claudio Sericchio is an engineer specializing in environmental management. Coordinator of the Committee for the Integration of the Paraiba do Sul River Catchment – CEIVAP catchment began with the building of the Tocos reservoir, in the upper Pirai River – a tributary of the Paraiba do Sul River, and a gravity adduction tunnel for the Lages reservoir. In 1952, the trnsport of water from the Paraiba do Sul to the Guandu catchment was increased, through a system built and operated by the Light Electricity Company. Currently, the Guandu Water Treatment Facility, owned by CEDAE and inaugurated in 1955, is the main supplier of drinkable water for the city of Rio de Janeiro and the Metropolitan Area.



2. Lages Reservoir
The delivery of water directly from the Lages Reservoir was implemented in two stages (1940 and 1948) and added approximately 430 million litres per day to the water supply for Rio de Janeiro, thus solving a major supply deficit at the time. With a storage capacity of 601 million m^3, Lages reservoir is a strategic water reserve for the city. As the water from the reservoir is of high quality, due to forest protection along its watersheds, the water does not go through Guandu Water Treatment Facility and receives only chlorine and fluorine disinfectant treatment prior to distribution[356].

3. Other water sources of Rio de Janeiro and the Metropolitan Area
Several sources of water which supplied the city in former times, until the supply systems from the Guandu and Lages Rivers were developed, are still in use to today. The systems of Santa Tereza, Tijuca, Gavea, Jacarepagua, Campo Grande and Guaratiba, contribute on average nearly 60 million litres of water per day to the city – just less than 9 per cent of the total water supply. Formed by dozens of mountain springs, most have no type of yield regulations[357]. The water is usually impounded in the upper part of the rivers, in forested areas on the hillsides surrounding the city and is treated only with chlorine disinfectant.

Problems of water quality and quantity
The presence of large amounts of suspended sediments originating from hillside erosion causes large variations in the consumption of chemicals needed in the treatment of water from the Guandu Water Treatment Facility. During the annual period of intense rains (November to March), the lack of soil protection in the impoundment catchments increases turbidity and sediment in the water, making treatment difficult and costly. An increase in the chlorine consumption by 32 per cent from 1995 to 2000 is an indicator of the reduction in the water quality from the Guandu River. Overall, chemical products represents as much as 80 per cent of CEDAE's total expenditure[358]. The causes of poor water quality include: deforestation, irregular urban waste disposal, illegal sand extraction along river banks, population growth, open sewage disposal and open industrial waste disposal[359]. Compared with the limited water treatment required by the Lages Reservoir and the other older water supply systems detailed above, where forests around the watershed are protected, it would suggest that it would be cost effective if measures were taken to conserve soils around the watershed.

There are also problems with the quantity of water available, with, for example, the hydrological conditions in the Paraiba do Sul River catchment over the last seven years not providing the expected water yields.

The role of protected areas in maintaining Rio de Janeiro's water supply

The creation of protected natural areas in Rio de Janeiro and its Metropolitan Area began in the 19th Century. The first protected forests were on the Tijuca Massif's, just outside Rio de Janeiro. The forests here were cleared in the 18th century to make room for coffee plantations, as a result, the rivers and streams became silted and in the succeeding years the city suffered severe droughts. By 1861, the situation had become so serious that Emperor Pedro II ordered the expropriation of all Tijuca's farms and the complete reforestation of the area. Manuel Gomes Archer, who was given the task, was an amateur botanist and thus used native species for the reforestation. In 1961, to commemorate the 100th anniversary of Archer's reforestation, Tijuca was proclaimed a National Park[360].

Today, most of these areas are Conservation Units under the terms defined by Federal Law no. 9,982 of July 18, 2000, which instituted the National System for Protected Natural Areas – SNUC. However, the drainage catchments of Paraiba do Sul, Pirai, Lage and Guandu Rivers, which are now the main sources of water supply for the RJMA, do not have the same protection status as the older water sources, due to their vast extension and intense occupation. Instead, the Biosphere Reserve concept has been used to protect these watersheds and Atlantic Forest remnants. The Atlantic Rainforest biome, where all watersheds for RJMA are located, was declared a Biosphere Reserve by the UNESCO Man and Biosphere programme (MaB) in 1991. The territorial limits of the Atlantic Rainforest Biosphere Reserve in the state of Rio de Janeiro, located in physical-geographical region no. 8 (Neotropical Region), in bio-geographical province no.7 (Serra do Mar), and in biome group no.1 (Tropical Rainforest), were ratified on October 8, 1992. The mountainous areas of the Paraiba do Sul river catchment and practically all catchments of the Pirai River and Lages reservoir are within this reserve however few effective conservation measures have yet to result from this declaration. The Atlantic Rainforest is also considered a National Heritage according to Brazil's 1988 Federal Constitution (Chapter VI, Item 225, 4th Paragraph) and benefits from legal protection established by federal legislation (see table for details).

Federal Legislation Relevant to Forest Protection

Law	Protection defined
Forest Code: (Law # 4,771/65, modified by Law # 7,803/89, and complemented by the Temporary Measure # 2166-67, of 08/24 /2002, and by the Resolutions CONAMA # 302 and 303, of 03/20/2002.)	▪ Permanently areas of land between 30 and 500 meters along rivers, springs, lakes and reservoirs as well as hillsides, mountain tops, mountains, and hills (2nd Chapter) ▪ Determines that 20 per cent of the rural properties in the Atlantic Forest biome must remain forested as a Legal Reserve
National Environmental Policy: (Law # 6,938/81)	▪ Gives forests and permanently preserved vegetation defined by the 2nd Chapter of Law 4,771 the status of reserve or ecological station
Environmental Crime Law: (Law # 9,605/98)	▪ Considers it a crime and determines penalties for those who destroy forests or cause damages to Conservation Units and Permanently Preserved Areas
National Water Resource Policies: (Law # 9,933/97, supplemented by Law # 9,984/00)	▪ Determines the integration of water resource management and environmental management ▪ Foresees the creation of area subject to use restrictions aiming to protect water resources ▪ Foresees incentives, including monetary compensations, for the qualitative and quantitative conservation of water resources
National System for Protected Areas – SNUC: (Law # 9,985/00)	▪ Imposes the SNUC and establishes norms for the creation, implementation, and management of protected natural areas

Source: MMA - Ministério do Meio Ambiente. Legislação ambiental brasileira. www.mma.gov.br, in July 2003.

In the following section the status and protection levels of the RJMA watershed and the wider river catchments are examined separately.

- **Protected areas of the RJMA Watersheds**
  The watersheds of Rio de Janeiro and the Metropolitan Area are located in four areas protected as Conservation Units (see table). These units are concentrated in six of the twelve municipalities of the RJMA and cover nearly 16 per cent of the total land area. Although they are protected by law, the implementation and monitoring of these areas is precarious, and there is considerable pressure on remnant forested areas and watersheds associated with uncontrolled urban expansion.

RJMA Conservation Units/Protected Areas

Status the protected area	Area (ha)	Location (municipality)	Characteristics/Objectives
Tijuca National Park: Category II (Created by Federal Decree # 50,923 of 07/06/61 and # 60,183 of 02/08/67. Decree 577, of 12/11/1861, gave "temporary instructions for planting and conserving Tijuca and Paineiras forests"[361]	3,200	Rio de Janeiro	Integral protection unit which includes three areas within the city of Rio de Janeiro, at an altitude of 80 and 100 m. Probably the world's largest urban forest. Has been the site of preservation and restoration since the 19th Century, to protect the city's water sources.
Tingua Biological Reserve: Category I (Created by Federal Decree # 97,780/89 on land belonging to the Florestas Protetoras da União de Tingua, Xerem e Mantiqueira, as a result of demands by community associations. Declared a Protection Forest in 1833 to protect watersheds, the first legal environmental defense action in the country.)	26,000	Duque de Caxias, Nova Iguassu, Miguel Pereira, and Petropolis	Integral protection unit composed of dense tropical rainforest, aiming to protect the Atlantic Rainforest, its flora and fauna, and the water resources of Sao Pedro, Rio d'Ouro, Xerem, Tingua and Mantiquira and springs of the rivers on the Guandu catchment.
Pedra Branca State Park: Category II (Created by Decree # 1,634/63 and Law # 2,377/74, encompassing the area of Florestas Protetoras da União instituted by the federal government in the beginning of the 20th Century.)	12,500	Rio de Janeiro	Integral protection units located above 100 m associated to the protection of water sources supplying Jacarepagua and Guaratiba.
Gericinó-Mendanha APA: Category V (Created by State Law # 1,331/88 and Municipal Law # 1,958/93. Floresta Protetora da União created by Decree/Law # 3,889/41.	10,500	Rio de Janeiro, Nova Iguassu, and Nilopolis	Sustainable use unit located above 100m. Protection of threatened Atlantic Rainforest fauna and flora, alkaline rocks and watersheds in Campo Grande and water sources of the rivers of the Guandu catchment.
Total (ha)	**52,200**		

Source: SEMADS (2001); Atlas das unidades de conservação da natureza do estado do Rio de Janeiro. Secretaria de Estado de Meio Ambiente e Desenvolvimento Sustentável do Rio de Janeiro. São Paulo: Editora Metalivros

- **Protection of the Paraiba do Sul River, Pirai, Lage and Guandu Catchments**
  Three distinct areas determine the condition of waters supplying the Guandu water treatment facility:

1. *The Paraiba do Sul River catchment and the Santa Cecilia reservoir*. The area covers almost 16,300 km^2 in the states of Sao Paulo (13,900 km^2, 39 municipalities, and nearly 1,850,000 inhabitants) and Rio de Janeiro (2,400 km^2, 8 municipalities, and nearly 650,000 inhabitants). There are several protected areas (see table) within this area, which protect the headwaters of the Paraiba do Sul River.
2. *Pirai and Guandu River catchment*: The Pirai River catchment area covers some 1,100 km^2 and has 38,000 inhabitants. Since most of its area is considered part of the Atlantic Rainforest Biosphere Reserve, there are no specific conservation units in this catchment. There has been a slight reduction in forest cover in the past decades[362]. The Guandu River catchment covers an estimated 1,000 km^2 and has 300,000 inhabitants. The area is degraded, and has no legal protection, aside from a few small stretches of Conservation Units.
3. *Contribution catchment for the Lages reservoir:* This area, covering approximately 300 km^2, has no Conservation Units, and is only protected under the regulations established by the Forest Code. However, forest cover in the catchment is much higher than either the Paraiba do Sul or the Pirai River catchments (see table). Its superior water quality and forest cover can be attributed to:
    - A one-kilometre wide marginal area along the reservoir owned by Light Energy Company. When the reservoir was built in 1908, a malaria outbreak killed hundreds of people. The company purchased land around the reservoir to act a buffer and thus reduce the exposure of residents to the disease. Since then, forest cover of these areas has continually increased;
    - These areas are steep and of difficult access, thus discouraging occupation; and
    - There are no cities or industrial activities in the catchment.

Protected Areas of the Paraiba do Sul River Catchment upstream from Santa Cecilia

Status of the Protected Area	Area (ha)	Location (municipalities)	Characteristics/ Objectives
		Ecological Station: IUCN 1a	
1. Bananal Ecological Station (State Decree # 26,890, 03-12-87)	884	Bananal/SP	Located in the broadleaf altitudinal subtropical forest realm (Atlantic Forest).
		Parks (National, State): IUCN II	
2. Itatiaia National Park (Created by Federal Decree # 1,713/37, first in Brazil)	30,000	Itatiaia and Resende/RJ; Alagoa, Bocaina de Minas and Itamonte/MG	Located in the shade-tolerant dense ('ombrófila densa') Atlantic Forest realm, with a highest peak of 2782 m.
3. Serra da Bocaina National Park (Decree # 68,172, of 02-04-71)	120,000	Ubatuba, São José do Barreiro and Cunha	Located in the shade-tolerant dense ('ombrófila densa') Atlantic Forest realm. The park includes the headwaters of streams that form the Paraiba do Sul river.
4.Serra do Mar State Park (State Decree # 10,251, de 08-30-77)	309,938	São Paulo, São Bernardo do Campo, Santos, São Vicente, Cubatão, Praia Grande, Pedro de Toledo, Itanhaém, Mongaguá, Peruíbe, São Luis do Paraitinga, Cunha, Caraguatatuba, São	Located in the shade-tolerant dense ('ombrófila densa') Atlantic Forest realm. The park includes the headwaters of the Paraibuna, a tributary of Paraiba do Sul.

Status of the Protected Area	Area (ha)	Location (municipalities)	Characteristics/ Objectives
		Sebastião, Paraibuna, Biritiba-Mirim, Salesópolis, Mogi das Cruzes, Suzano, Embu-Guaçu, Juquitiba, Santo André, Rio Grande da Serra, Natividade da Serra and Ubatuba	
Area of Relevant Ecological Interest: IUCN III			
5. Cicuta Forest (Decree 90,792 of 01/09/85)	131	Barra Mansa and Volta Redonda	
6. Arie da Pedra Branca (Decree SMA n.º 26.720/87 e Lei n.º 5.864/87)	635	Tremembé/SP	The area protects natural forests, the local fauna and water catchments.
Area under Special Protection Regime: IUCN IV			
7. ASPE de Roseira Velha (Resolution SMA/87)	84	Roseira (SP)	Protects rare fauna and flora species, within the Roseira Velha Municipal APA, in Fazenda Boa Vista
Environmental Protection Area: IUCN V			
8. APA Federal da Bacia do rio Paraíba do Sul (Created by Federal Decree 87.561/82)	-	-	Protects headwaters, mountain tops, slopes and valleys of the Mantiqueira range. However, the protected area has not been implemented yet.
9. APA Federal da Mantiqueira (Created by Federal Decree n.º 91.304/85)	150,000	Cruzeiro, Guartinguetá, Lavrinhas, Lorena, Pindamonhangaba, Piquete, Santo Antônio do Pinhal, Queluz (SP) e Itatiaia, Resende (RJ)	Protected landscape and sustainable use protected area located in the shade-tolerant dense (‘ombrófila densa’) Atlantic Forest realm. It protects the upper reaches of the Mantiqueira range, which in the local indigenous language means "the place where water springs".
10. APA Silveiras (Law # 4,100, of 06-20-84 – State and Municipal)	42,700	Silveiras (SP)	Protected landscape and sustainable use protected area located in the shade-tolerant mixed high montane forests (‘ombrófila altomontana mista’ in the Atlantic Forest realm. The area protects the headwaters of the Paraitinga river.
11. APA Municiapl do Banhado de São José dos Campos (Law # 2,792, de 01-10-84 – Municipal)	-	São José dos Campos (SP)	

Status of the Protected Area	Area (ha)	Location (municipalities)	Characteristics/ Objectives
12. APA Municipal da Roseira Velha (Law # 424, 11-25-83 – Municipal)	-	Roseira (SP)	
13. APA Municipal de Bananal (Law # 033, de 09-15-97 – Municipal)	33,000	Bananal (SP)	
14. APA Municipal da Serrinha do Alambari	-	Resende/RJ	Buffer zone of the Itatiaia National Park, which protects the headwaters of a number of tributaries of the Paraiba do Sul river.
Total area	320,180		
Biosphere Reserve			
Reserva da Biosfera da Mata Atlântica (UNESCO, 10/10/92)	79,215	Barra Mansa, Barra do Piraí, Itatiaia, Resende, Volta Redonda	All remnants of the Atlantic Rainforest, especially the Serra do Mar forest corridor.

Source: SEMADS/RJ, 2001; ANA, 2002 and Rambaldi, 2002.

Vegetation Cover and Soil Use in the Paraiba Do Sul and Pirai River Catchments

Land cover	Paraiba do Sul to Santa Cecilia		Pirai		Paraiba do Sul to Santa Cecilia and Pirai	
Main Types	**ha**	**%**	**ha**	**%**	**ha**	**%**
1. Dense Tropical Forest	215,300	13.2	31,264	28.4	246,564	14.2
2. Seasonally Deciduous Tropical Forest	16,836	1.0	5,512	5.0	22,348	1.3
Total Forests(1+2)	232,136	14.2	36,766	33.4	268,912	15.4
3. Secondary Forest	205,292	12.6	15,108	13.7	220,400	12.7
Total forest cover(1+2+3)	437,428	26.8	51,874	47.1	489,312	28.1
4. Field/pasture	970,444	59.5	55,380	50.3	1,025,824	58.9
5. Farm areas	66,332	4.1	0	0	66,332	3.8
6. Reforestation	64,476	4.0	1,388	1.3	65,864	3.8
7. Urban Areas	43,728	2.7	548	0.5	44,276	2.5
8. Other	48,860	3.0	816	0.7	49,676	2.9
Total	1,631,276	100	110,016	100	1,741,292	100
% of total area of the Paraiba do Sul Catchment (5,547,448 ha)	-	29.4	-	2.0	-	31.4

Source: data table of the PGRH-RE-029-R0, LABHIDRO-COPPE report (in Agência Nacional de Águas (2002); Projeto Gestão dos Recursos Hídricos da Bacia Hidrográfica do Rio Paraíba do Sul: PGRH-RE-029-R0 - Plano de Proteção de Mananciais e Sustentabilidade no Uso do Solo. Rio de Janeiro: Laboratório de Hidrologia e Estudos do Meio Ambiente da COPPE/UFRJ) accomplished through a GEROE mapping (1995) based on Landsat TM/ 1993-95 images.

Variation in Forest Cover: The Paraiba Do Sul and Piraí River Catchments and Lages Reservoir (State of Rio de Janeiro)

Catchment	1956/75*	2001**			Variation 1975/ 2001
	Forest Cover (%)	Original Forest (%)	Secondary Forest (%)	Total Forest Cover (%)	
Mid upper Paraiba do Sul River (only RJ state)	15.44	5.84	15.23	21.07	+ 5.63 (+36.5%)
Pirai River	41.31	5.94	33.94	39.88	- 1.43 (-3.5%)
Lages Reservoir – estimated (data from the Rio Claro municipality)	43.52	10.06	37.64	47.70	+ 4.18 (+9.6)

Source: * IBGE, from aerial photos in black and white taken between 1956 and 1975; ** Soil Use Map from the CIDE Foundation from Landsat TM/2001 images

Note: When comparing information on forest cover along the Pirai catchment in the two tables above there is a clear discrepancy between the sources used, research to ascertain which source is correct is beyond the scope of this project.

Conclusions

Historically, Rio de Janeiro had a good record of protecting the watersheds that provided water to its population. However, as newer water facilities were developed the importance of forests in protecting, in particular, water quality seems to have been forgotten as chemical water treatments became available. This case study shows, however, that where forests have been protected water quality standards remained high and the water treatment is much reduced.

As the economics of providing safe water to Rio de Janeiro, along with questions of maintaining an adequate water supplies, come to the forefront the Committees for the Paraiba do Sul and Guandu River catchments, legal entities, water consumers, the public administration and civil organisations should be encouraged to develop integrated planning arrangements that recognise the needed for investment, waste reduction, rationing and environmental conservation to ensure the future water supply in for the city and surrounding area.

The declaration of the Atlantic Rainforest Biosphere Reserve in 1991 provides a vehicle for the protection of the forests and the city's water catchment areas, however, much more work is needed to ensure that the existing protected areas are implemented and managed effectively, and their borders consolidated against urban encroachment and land speculation.

Part 5: Conclusions and policy recommendations

Our research shows that many cities are reliant on protected forests for their drinking water. A clear understanding of the links between watersheds and water supply can encourage management decisions with benefits for biodiversity, for people in cities and, through compensation schemes, for people in the catchment. None of these links is simple. The hydrological processes are complex and the results of their interactions with precipitation inputs and land-use will vary from one place to another: management decisions based on incomplete understanding may do little good or actual harm. Careless protection can undermine the rights of the rural poor living in the catchment. Good catchment management will only benefit urban dwellers if treatment and distribution of water are also effective. The links between water, protected areas, livelihoods and biodiversity conservation will only be optimised if management is carefully planned and negotiated with all relevant stakeholders. Below we suggest some responses that might help to maximise the gains.

- **Awareness-raising**: we were surprised about how hard it was to find information for this report. Even in cities where water comes from protected areas, or other forms of active management, this seldom features in reports, publicity or websites. Many people have no idea where their tap-water comes from. Yet where there has been a debate and an information campaign – as in New York City – support for catchment management is high. Better information about links between forests, protected areas and water supply could help build a constituency for good watershed management.

- **Protection**: protected areas are not a panacea, but they are clearly an important option to help to secure urban water supplies. We found several instances where lack of protection has been already been identified as a problem and other cities where it seemed that better catchment management would help to address urgent problems in quality and in some cases also of supply. Increased use of protection, including protected areas, could help many cities to maintain their drinking water.

- **Landscape approach**: protection is also not the only or always the most appropriate action. In crowded areas, or where existing land use and tenure makes full protection inappropriate, other approaches exist including management and restoration, which can for instance result in a mosaic ranging from full protection to a number of carefully chosen management interventions.

- **Livelihoods**: care is needed to ensure that politically powerful urban populations do not gain high quality water at the expense of rural communities. Approaches that include negotiation, joint decision-making and compensation, including payments for environmental services, have proved to be the most successful in ensuring equity.

- **Economics**: experience shows that with the right set of circumstances, it pays to protect the watershed, instead of building expensive water purification systems. In the context of growing population and increasing urbanisation, strategic choices are needed now to set aside funds not only for protection but for effective management of forests and other vegetation.

- **Biodiversity**: protection of forests for their watershed values has important and usually beneficial implications for biodiversity. But we also found that in many cases these links had hardly been made and for example water companies were not really aware of the additional benefits that might be coming from their land management. Better understanding of biodiversity issues is required within water supply companies to make the best use of land set aside for water supply.

The World Bank-WWF Alliance is in an ideal position to encourage joint approaches by engineers, water companies, communities and conservation interests to ensure that well-managed natural vegetation plays a key role in ensuring access to a safe, secure source of drinking water.

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References and endnotes

[1] De Sherbinin, Alex and Victoria Dompka [editors] (1998); *Water and Population Dynamics: Case Studies and Implications*, American Association for the Advancement of Science, Washington DC

[2] World Water Council (2000); *World Water Vision*, Earthscan, London

[3] According to the GlobeScan Survey (January 2002) undertaken by Environics, a Canadian public opinion firm specialised in Sustainable Development, as reported in: World Bank (2002); *Water – Priority for Responsible Growth and Poverty Reduction: An Agenda for Investment and Policy Change*, World Bank, Washington, USA

[4] McNeill, J (2000); *Something new under the sun: an environmental history of the twentieth century*, Penguin, London

[5] United Nations Human Settlement Programme (2003); *Water and Sanitation in the World's Cities: Local Action for Global Goals*, Earthscan, London

[6] ibid

[7] Information from: waterportal@unesco.org – UNESCO, Water and Cities Fact Sheet

[8] McNeill, J (2000); *Something new under the sun: an environmental history of the twentieth century*, Penguin, London

[9] World Bank (2002); *Water – Priority for Responsible Growth and Poverty Reduction: An Agenda for Investment and Policy Change*, World Bank, Washington, USA

[10] Brandon, C and R Ramankutty (1993); *Toward an Environmental Strategy for Asia*, World Bank Discussion Paper No. 224, The World Bank, Washington, D.C., USA

[11] Anon (2003); At a Glance: The world's water crisis; *Our Planet*, UNEP, Nairobi, Kenya

[12] World Water Council (2000); *World Water Vision*, Earthscan, London

[13] Shiva, V (2002); *Water Wars: Privatization, pollution and profit*, Pluto Press, London

[14] Abramovitz, J N (1996); *Imperilled Waters, Impoverished Future: The decline of freshwater ecosystems*, Worldwatch Paper number 128, Worldwatch Institute, Washington DC

[15] United Nations Human Settlement Programme (2003); op cit

[16] See case study in this report

[17] World Bank (2002); *Water – Priority for Responsible Growth and Poverty Reduction: An Agenda for Investment and Policy Change*, World Bank, Washington, USA

[18] Narayan, R (2003); Getting there; *Our Planet*, UNEP, Nairobi, Kenya

[19] Reid, W V (2001); Capturing the value of ecosystem services to protect biodiversity. In *Managing human-dominated ecosystem*s, eds. G. Chichilenisky, G.C. Daily, P. Ehrlich, G. Heal, J.S. Miller. St. Louis: Missouri Botanical Garden Press

[20] Panos Institute (2002); High Stakes: The Future For Mountain Societies, Press Release, World Environment Day, 5 June

[21] European Environment Agency (1995); *Environment in the European Union 1995: Report for the Review of the Fifth Environmental Action Programme*, Office for Official Publications of the European Communities, Luxembourg

[22] World Commission on Dams (2000); *Dams and Development: A new framework for decision-making*, Earthscan, London

[23] ibid

[24] Gould, J (1999); *Rainwater Harvesting*, Contributing paper for the World Commission on Dams Thematic Review IV.3 Water Supply

[25] World Commission on Dams (2000); *Thematic Review IV.2 Irrigation Options*, Annex 6

[26] Seitzinger, S P and C Kroeze (1998); Global distribution of nitrous oxide production and N inputs in freshwater and coastal marine ecosystems, *Global Biochemical Cycles* **12**: 93-113

[27] Anon (2003); WWF Position Paper on Bottled Water, WWF, Gland, Switzerland

[28] Gujja, B and M Perrin (1999); *A Place for Dames in the 21st Century?* WWF International, Gland, Switzerland

[29] Anon (1996); *Facts about Euphrates-Tigris Basin*, Centre for Strategic Research, Ankara

[30] Hammond, A L [general editor] (1996); *World Resources 1996-1997*, World Resources Institute, Washington DC

[31] Carley, M and P Spapens (1998); *Sharing the World: Sustainable Living and Global Equity in the 21st Century*, Earthscan

[32] Press Release, Loss of forest cover threatens freshwater supplies, FAO, 6 March 2003, Rome, FAO.org

[33] Anon (1993); *Agenda 21*, Chapter 18: Protection of the quality and supply of freshwater resources: application of integrated approaches to the development, management and use of water resources (Objective 18.8), United Nations

[34] Kiersch, B (2000); *Land use impacts on water resources: A literature review,* FAO's Land-Water Linkages in Rural Watersheds Electronic Workshop, 18 September – 27 October 2000, FAO, Rome

[35] Aylward, B (2000); *Economic Analysis of Land-use Change in a Watershed Context* presented at a UNESCO Symposium/Workshop on Forest-Water-People in the Humid Tropics, Kuala Lumpur, Malaysia, July 31 –August 4, 2000

[36] US Environmental Protection Agency (1993); *Water quality effects and non-point source control practices for forestry: an annotated bibliography*, EPA 841-R-97-008, Washington DC

[37] See, for example, Eschner A R and J Larmoyeux (1963); Logging and trout: four experimental forest practices and their effect on water quality, *Progress in Fish Culture* **25**: 59-65; Moring J R and R L Lantz (1975); *The Alsea Watershed Study: Effects of logging on the aquatic resources of three headwater streams of the Alsea River, Oregon Part 2 – Changes in Environmental Conditions*, Fishery Research Report number 9, Oregon Department of Fish and Wildlife, Corvallis, Oregon; Dickerson B P

(1975); Stormflows and erosion after tree-length skidding on Coastal Plain soils, *Transactions of the American ociety of Agricultural Engineers* **18**(5): 867-868, 872

[38] Lynch, J A, W E Sopper, E S Corbett and D W Aurand (1975); Effects of management practices on water quality and quantity: the Penn State experimental watersheds, *Municipal Watershed Management Symposium Proceedings*, General Technical Report NE-13, Northeastern Forest Experimental Station, USDA Forest Service, Radnor: 32-46

[39] Binkley, D, H Burnham and H E Allen (1999); Water quality impacts of forest fertilization with nitrogen and phosphorus, *Forest Ecology and Management* **121**: 191-213

[40] Anon (1999); *Silviculture and water quality: A quarter century of Clean Water Act progress*, Special Report number 99-06, National Council for Air and Stream Improvement, Research Triangle Park NC

[41] Kiersch, B (2000); op cit

[42] Calder, I R (2000); Forests and hydrological services: reconciling public and science perceptions, *Land Use and Water Resources Research* **2**: 2.1-2.12

[43] Bosch, J M and J D Hewlett (1982); A review of catchment experiments to determine the effects of vegetation changes on water yield and evapotranspiration, *Journal of Hydrology* **55**: 3-23

[44] Shiva, V and J Bandyoppadhyay (1984); *Ecological Audit of Eucalyptus Plantations*, Dehra Dun, India

[45] Poore, M E D and C Fries (1985); *The Ecological Effects of Eucalyptus*, FAO Forestry Paper 59, FAO, Rome

[46] Calder, I R (2000*); Background paper: Land use impacts on water resources,* FAO's Land-Water Linkages in Rural Watersheds Electronic Workshop, 18 September – 27 October 2000, FAO, Rome

[47] Scott, D F and W Lesch (1997); Stream flow responses to afforestation with *Eucalyptus grandis* and

Pinus patula and to felling in the Mokobulaan experimental catchments, South Africa, *Journal of Hydrology,* **199**: 360-377

[48] Chomitz, K M and K Kumari (1996); *The domestic benefits of tropical forests: A critical review emphasizing hydrologic functions,* World Bank Policy Research Working Paper, Number 1601, Washington DC

[49] Gregersen, H M, K N Brooks, J A Dixon and L S Hamilton (1987); Guidelines for economic appraisal of watershed management projects, FAO *Conservation Guide* No. **16**, FAO, Rome

[50] Gilmour, D A, M Bonell and D S Cassells (1987); The Effects of Forestation on Soil Hydraulic Properties in the Middle Hills of Nepal: A Preliminary Assessment, *Mountain Resources Development* **7**: 239-49.

[51] Nair, U S, R M Welch, R O Lawton and R A Pielke (2000); *Influence of Surface Characteristics on the Development of Cumulus Cloud Fields*, Paper presented at the 15th Conference on Hydrology, American Meteorological Society 9-14 January, Long Beach, California

[52] Langford, K J (1976); Change in yield of water following a bushfire in a forest of Eucalyptus reglans, *Journal of Hydrology* **89**: 87-114

[53] Calder, I R (1998); Water-resource and land use issues. *SWIM Paper* **3**. Colombo: IIMI.

[54] Calder, I (2000*);* op cit

[55] Anon (1997); *A Summary of the Environmental Impact Statement for the Revised Land and Resource Management Plan: Caribbean National Forest, Luquillo Experimental Forest Puerto Rico*, United States Department of Agriculture and Forest Service Southern Division, Palmer Puerto Rico

[56] Johnson, N, A White and D Perrot-Maître (undated); Developing markets for water services from forests: Issues and lessons for innovators, Forest Trends, USA

[57] Natural Resources Defense Council (2003); *What's On Tap? Grading Drinking Water in U.S. Cities*, Natural Resources Defence Council, USA

[58] Natural Resources Defense Council (2003); op cit

[59] EPA (1999); *Protecting Sources of Drinking Water Selected Case Studies in Watershed Management*, United States Environmental Protection Agency, Office of Water, EPA 816-R-98-019, April 1999, http://www.epa.gov/safewater

[60] Natural Resources Defense Council (2003); op cit

[61] Collins, B R and E W B Russell [editors] (1988); *Protecting the New Jersey Pinelands: A New Direction in Land Use Management*, New Brunswick and London: Rutgers University Press

[62] European Observatory of Mountain Forest (2000); *White Book 2000 on Mountain Forests in Europe*, European Federation of Local Forest Communities, France

[63] University of the Philippines (1999); *Economic Instruments for the Sustainable Management of Natural Resources: A Case Study on the Philippines' Forestry Sector*; United Nations Environment Programme, UNEP/99/4, New York and Geneva

[64] Kaimowitz, D (undated); *Useful Myths and Intractable Truths: The Politics of the Link Between Forests and Water in Central America,* Center for International Forest Research (CIFOR), San Jose, Costa Rica

[65] CEASPA (1997); Panama: Evaluation of National Sustainability. *Panama Today,* **7**: 11

[66] Calder, I (2000*);* op cit

[67] Kaimowitz, D (undated); op cit

[68] Diaz, I (2000); "Arboles maderables para reforestar cuenca del Canal" [Timber trees to reforest the Canal watershed] *El Panama América*, June 11

[69] World Commission on Dams (2000); op cit

[70] World Wide Fund for Nature (2003); *Dam Right, An investors' guide to dams*, WWF, Gland

[71] MCPFE and UNECE/FAO (2003) ; *State of Europe's Forests 2003: The MCPFE Report on Sustainable Forest Management in Europe*, Vienna and Geneva

[72] IUCN Commission on National Parks and Protected Areas with the World Conservation Monitoring Centre (1995); *Guidelines for Protected Area Management Categories*, IUCN, Gland, Switzerland

[73] Anon (1993); *British Columbia Forest Practices Code: Discussion Paper,* British Columbia, Canada

[74] Kiersch, B (2000); op cit

[75] Huxley, Julian (1943); *TVA: Adventure in Planning*, Readers Union and the Architectural Press, London

[76] Pagiola, S, J Bishop and N Landell-Mills [editors] (2002); Selling Forest Environmental Services: Market-based mechanisms for conservation and development, Earthscan, London, UK

[77] Information from: The Nature Conservancy web site: nature.org/wherewework/caribbean/dominicanrepublic/work/art8531.html and UNEP-Caribbean Environment Programme (1999); *CEP Technical Report No. 36 1996: Status of Protected Area Systems in the Wider Caribbean Region: Dominican Republic*, UNEP-Caribbean Environment Programme, Kingston, Jamaica, www.cep.unep.org/pubs/techreports/tr36en/countries/domrep.html

[78] Bruijnzeel, L A and Hamilton, L S (2000); *Decision Time for Cloud Forests*, IHP Humid Tropics Programme Series no. 13, IHP-UNESCO, Paris

[79] See case study in this report

[80] Information from the UNEP-World Conservation Monitoring Centre database – for further details see the table of 100 cities in this report

[81] Information from: US EPA Surf Your Watershed website http://www.epa.gov/surf/, Angeles information from: http://www.r5.fs.fed.us/angeles

[82] See case study in this report

[83] Michaelsen, T (1994); Management for soil and water conservation, *Readings in Sustainable Forest Management*, FAO Forestry Paper number 122, FAO, Rome

[84] Küchli, C, M Bollinger and W Rüsch (1998); *The Swiss Forest – Taking Stock: Interpretation of the Second National Forest Inventory in terms of forest policy*, Swiss Agency for the Environment, Forests and Landscape, Bern; and Anon (1995); *Swiss Forests in Balance*, Swiss Agency for the Environment, Forests and Landscape, Bern

[85] Bruijnzeel, L A and Hamilton, L S (2000); op cit

[86] Information from M L Higgins in the WWF Colombia programme office

[87] Ferrari, M F (2002); Community Conserved Areas in South-East Asia: Final report, http://www.iucn.org/themes/ceesp/Publications/TILCEPA/CCA-MFerrari-part2.pdf

[88] Uphoff, N and J Langholz (1998); Incentives for avoiding the Tragedy of the Commons, *Environmental Conservation* **25** (3):251-261.

[89] See case study in this report

[90] Johnson, N, A White and D Perrot-Maitre (2000); *Developing Markets for Water Services from Forests: Issues and Lessons for Innovators*, Forest Trends, World Resources Institute and the Katoomba Group, Washington DC

[91] P Da Cunha, E Menzes and L O Teixeira Mendes (2001); The mission of protected areas in Brazil, *Parks*, **11**:3, IUCN, Gland

[92] State Forests of New South Wales (1999); Salt trade to fund salinity trial in Macquarie catchment, press release, 27 October, quoted in Johnson *et al*, op cit

[93] Diaz, I (2000); op cit

[94] Cosgrove W J and F R Rijsberman (2000); *The World Water Vision*, Earthscan Publications Ltd, London, UK

[95] Scott, P (1998); *From Conflict to Collaboration: People and Forests at Mount Elgon, Uganda*, IUCN The World Conservation Union, Nairobi

[96] Swallow, B M, D P Garrity and M van Noordwijk (2001); *The effects of scales, flows and filters on property rights and collective action in watershed management*, CAPRi working paper number 16, CGIAR System-wide Programme on Collective Action and Property Rights, International Food Policy Research Institute, USA

[97] Gibson, C C, M A McKean and E Ostrom [editors] (2000); *People and Forests: Communities institutions and governance*, The MIT Press, Cambridge and London

[98] Costanza R, *et al*. (1997); The Value of the World's Ecosystem Services and Natural Capital, *Nature*, Vol. 387

[99] Athanas, A; F Vorhies, F Ghersi; P Shadie and J Shultis (2001); *Guidelines for Financing Protected Areas in East Asia*, IUCN, Gland, Switzerland

[100] Emerton, L (2001); Why Forest Values are Important to East Africa, *Innovations*, Vol. 8, No. 2, July 2001, African Centre for Technology Studies, Nairobi, Kenya

[101] Carey, C, N Dudley and S Stolton (2000); Squandering Paradise: The importance and vulnerability of the world's protected areas, WWF, Gland

[102] Information from the WWF China Programme Office

[103] The designations used here do not imply the expression of any opinion whatsoever concerning the legal status of any country, territory, city or area or its authorities, or concerning the delimitation of its frontiers or boundaries. The list has been drawn from the World Gazetteer web site © Stefan Helders www.world-gazetteer.com, with additional population data from the Population

Reference Bureau (Washington, DC); Population Division of the Department of Economic and Social Affairs of the United Nations and the United Nations Statistics Division.

[104] Anon (1997); *1997 United Nations List of Protected Areas*, IUCN and World Conservation Monitoring Centre, Cambridge UK

[105] Information from: theory.tifr.res.in/bombay/amenities/water

[106] Information from: www.unep-wcmc.org/protected_areas/data/sample/0206v.htm

[107] *Korean Environmental Newsletter*, January 2001, produced by the Environment team at the Canadian Embassy in Seoul and Seoul municipal authority website

[108] Marpaung, M E (1997); *Improving the efficiency of water supply management. A Case Study of The Jakarta Public Water Supply Enterprise, Indonesia,* Centre for Developing Cities, Australia, cities.canberra.edu.au/CPublications.htm

[109] Information from: www.unep-wcmc.org/protected_areas/data

[110] UNDP/FAO (1978); *Proposed Gunung Gede-Pangrango National Park management plan 1979-1983*, UNDP/FAO Nature Conservation and Wildlife Management Project FO/INS/73/013. Field Report No. 11, Bogor, Indonesia

[111] Wells, M, S Guggenheim, A Khan, W Wardojo and P Jepson (1999); *Investing in Biodiversity: A review of Indonesia's Integrated Conservation and Development Projects*, The World Bank East Asia Region

[112] Information from: www.unep-wcmc.org/protected_areas/data

[113] Information from: www.manilawater.com

[114] Blood, P (1994); *Pakistan: a country study*, Federal Research Division, Library of Congress

[115] Information from: www.arts.mcgill.ca/152-497b/h2o/water/gwater/supcase.htm and Malick, M F K, W Akhtar and S Jilani (1998); Drinking water quality in the city of Karachi, paper given at the 24th WEDC conference

[116] Malick, M F K, W Akhtar and S Jilani (1998); Drinking water quality in the city of Karachi, paper given at the 24th WEDC conference

[117] Sharif, A (2002); Water supply from Hub dam to stop in next 10 days, *The Dawn*, 22/8/2002, www.dawn.com/2002/08/22/local4.htm

[118] Information from: www.arts.mcgill.ca/152-497b/h2o/water/gwater/supcase.htm

[119] Malick, M F K, W Akhtar and S Jilani (1998); op cit

[120] Blood, P (1994); *Pakistan: a country study*, Federal Research Division, Library of Congress

[121] Information from: Ashiq Ahmad Khan, Chief Technical Advisor, WWF-Pakistan

[122] *Kirthar National Park.* www.unep-wcmc.org/protected_areas/data/sample/0782v.htm

[123] *Hab Dam Wildlife Sanctuary*: www.unep-wcmc.org/protected_areas/data/sample/1720v.htm

[124] *Haleji Lake Wildlife Sanctuary*: www.unep-wcmc.org/protected_areas/data/sample/0948v.htm

[125] Anon (2001); *Environmental protection in China's wealthiest city: Shanghai water quality*, US Embassy, Beijing

[126] Information from: www.clw.csiro.au/UGD/UGDabc.html

[127] Information from WCMC: www.unep-wcmc.org/protected_areas/data/sample/1306v.htm

[128] Information from WCMC: www.unep-wcmc.org/protected_areas/data/sample/1308v.htm

[129] Information from: Mr Koji Ikeuchi, River Environment Division, River Bureau, Ministry of Land, Infrastructure and Transport (of Japan), ikeuchi-k2hq@mlit.go.jp

[130] Mojjed, N and A H Hariri (1999); Tehran's growing water crisis, *Water and Environment* number 36

[131] Information from: 202.84.17.11/english/china_abc/beijing.htm

[132] Shuhuai, D, G Zhihui, H M Gregersen, K N Brooks and P F Ffolliott (2001); Protecting Beijing's Municipal Water Supply through Watershed Management: An economic assessment, *Journal of the American Water Resources Association*, **37**:3, American Water Resources Association, USA

[133] From UESCO World Water Assessment Programme Web site: Population and socio-economic situation in the Chao Phraya basin

[134] Revenga, C, S Murray, J Abramovitz and A Hammond (1998); *Watersheds of the world. Ecological value and vulnerability,* World Resources Institute and Worldwatch Institute, Washington DC, USA

[135] From UESCO World Water Assessment Programme Web site: Population and socio-economic situation in the Chao Phraya basin

[136] Information from: www.calmanac.org/cmcnew/cmc/water/02.htm?showmenu=no

[137] Information from: www.clw.csiro.au/UGD/UGDabc.html

[138] Raghupathi, U P (1996); *Financing options for water supply*, 22 WEDC Conference, Reaching the unreached: challenges for the 21 St Century, New Delhi, India

[139] Information from: www.clw.csiro.au/UGD/UGDabc.html

[140] Information from: Korean Sustainability Network, www.ksdn.or.kr/index_e.htm

[141] Information from: Thiri Tin, Director, Forest Department, Myanmar

[142] Information from: Weng Lida

[143] Revenga, C, S Murray, J Abramovitz and A Hammond (1998); op cit

[144] Ahmadabad city council website

[145] Information from: Biksham Gujja, bgujja@wwfint.org, WWF Living Waters Programme

[146] Article from the official Saudi Arabian government website: *Water in the Kingdon* by Syed Faisal Ali

[147] Information from: J Beltrán, Buenos Aires, jbeltran@netizen.com.ar

[148] Revenga, C, S Murray, J Abramovitz and A Hammond (1998); op cit

[149] Anon (1995); *Mexico City's Water Supply Improving the Outlook for Sustainability*, National Research Council, National Academy Press, Washington, D.C. 1995

[150] EPA (1999); *Protecting Sources of Drinking Water Selected Case Studies in Watershed Management*, United States Environmental Protection Agency, Office of Water, EPA 816-R-98-019, April 1999, http://www.epa.gov/safewater

[151] Information from: www.dec.state.ny.us/website/dlf/publands/cats/

[152] Information from: M L Higgins, mlhiggins@wwf.org.co, M Castro Schmitz, mcastro@wwf.org.co and L Germán Naranjo, all of WWF-Colombia

[153] Information from: Proyecto Regional Sistemas Integrados de Tratamiento y uso de Aguas Residuales en América Latina: realidad y potencial convenio: idrc – ops/hep/cepis 2000 – 2002 estudio general del caso Santiago, Chile, elaborado por: ing. María Pía Mena Patri Chile, Junio de 2001

[154] Information from: Chile "santiago foothills" a GEF Medium-sized project brief, www.gefweb.org/Documents/Medium-Sized_Project_Proposals/MSP_Proposals/Chile_-_Santiago_Foothills.PDF and Kathy Mackinnon of the World Bank

[155] EPA (1999); Protecting Sources of Drinking Water Selected Case Studies in Watershed Management, United States Environmental Protection Agency, Office of Water, EPA 816-R-98-019, April 1999, www.epa.gov/safewater

[156] Information from: US EPA Surf Your Watershed website, Angles info from: www.r5.fs.fed.us/angeles

[157] Trzyna, T (2001); California's urban protected areas: progress despite daunting pressures**,** *PARKS*, **11**:3, IUCN, Gland

[158] Information from: W Smith, Director World Wildlife Fund Southeastern Rivers and Streams Project, serivers@hotmail.com

[159] Natural Resources Defense Council (2003); op cit

[160] Information from: J Langer, jlanger@wwfcanada.org

[161] Information from: P Rosabal, Programme on Protected Areas, IUCN, Gland

[162] Information from: M L Higgins, mlhiggins@wwf.org.co

[163] Information from: www.elpais-cali.com/HOY/MTR/A209N1.html; cali.gov.co/ecocali.htm; elpais-cali.terra.com.co/historico/ene182003/MTR/B418N2.html; www.ideam.gov.co/rios/cuencas/cauca.asp; elpais-cali.terra.com.co/historico/feb042003/OPN/editorial.html

[164] Rivera-Monroy, V H, R R Twilley and B F Jonsson (undated); *Guayas River estuary, Guayas, Ecuador*, web paper for the Land-Ocean Interactions in the Coastal Zone (LOICZ) Project of the International Geosphere-Biosphere Programme, LOICZ International Project Office, Netherlands Institute for Sea Research (NIOZ)**,** data.ecology.su.se/MNODE/South%20America/guayaquil/GuayasR/GuayasRbud.htm,

[165] Information from: G Oviedo, Senior Social Policy Advisor, IUCN, Gland

[166] Information from: M Milano, miguelm@boticario.com.br

[167] Information from: The Nature Conservancy, nature.org/wherewework/caribbean/dominicanrepublic/work/art8531.html and UNEP-Caribbean Environment Programme (1999); *CEP Technical Report No. 36 1996: Status of Protected Area Systems in the Wider Caribbean Region: Dominican Republic*, UNEP-Caribbean Environment Programme, Kingston, Jamaica, www.cep.unep.org/pubs/techreports/tr36en/countries/domrep.html

[168] Natural Resources Defense Council (2003); op cit

[169] Information from: L Germán Naranjo, Coordinador Ecorregional Andes del Norte, WWF

[170] Information from: www.inparques.gov.ve

[171] von Bertrab (2002); *Reconciling the brown and the green agendas in an urban an regional water crisis; the case of Guadalajara, Mexico*, Development Planning Unit, University College London, London and information from: zedillo.presidencia.gob.mx/pages/disc/may97/22may97.html; www.unesco.org.uy/phi/libros/uso_eficiente/escamilla.html; www.amigosdelago.org/level-s.html and www.amigosdelago.org/characterisitics-s.html

[172] Information from: lanic.utexas.edu/la/region/news/arc/lasnet/1999/0300.html; www.elarmonista.com/politica/guerras_agua.html; www.logoscorp.com/clientes/oci/perija.htm;

www.earthisland.org/eijournal/fall97/departments/bioWatch.html

www.cecalc.ula.ve/frontino/conservation_cont.htm; www.iucn.org/themes/ssc/actionplans/bears/bearsAP_chapter9_Venezuela.pdf and (www.moles.org/ProjectUnderground/drillbits/980321/98032103.html

[173] Information from: www.edomexico.gob.mx/se/ecatediag.htm and odontologia.iztacala.unam.mx/clinicas/ecatepec/generalidades.html

[174] Information from: P Spillett, Thames Water Plc. Peter.Spillett@Thameswater.CO.UK

[175] Berliner Wasserbetriebe website http://www.bwb.de/englisch/index.html

[176] Press Release, 4/2/03: *El parque natural de Peñalara ocupará 15.000 hectáreas*, www.natuweb.com/paginasasp/Contenido.asp?ID=3888&Nombre=Noticias

[177] Information from: A Troya, ATROYA@CENTRAL.ifa.es

---

[178] Rome's Local Agenda 21, http://www.comune.roma.it/ambiente/agenda21/eng/local/water.htm

[179] Information from: O Stephanska, Olena.Stephanska@mail.doc.gov

[180] Revenga, C, S Murray, J Abramovitz and A Hammond (1998); op cit

[181] Information from: V Graffin, Président du Programme "Eau Douce Europe" – WWF International, vgraffin@wwf.fr

[182] Information from: E Lanyi, eszter.lanyi@wwf.hu

[183] Information from: A V Kozulin, Institute of Zoology, Belorussian Academy of Sciences, kozulin@biobel.bas-net.by

[184] Information from: H.-W. Krüger, Hamburger Wasserwerke GmbH, pr@hww-hamburg.de

[185] Information from: R Knysak, Forest Office, WWF Poland and Revenga, C, S Murray, J Abramovitz and A Hammond (1998); op cit

[186] Information from: R Brunner r.brunner@eunet.at and G Steindlegger, WWF Austria

[187] This text was written by J M. Mallarach i Carrera, Consultor ambiental, and draws on the following sources: Soler, M (2000); Captació i tractament de les aigües blanques, in J Acebillo and R Folch, directors *et al*, *Atles Ambiental de l'Àrea de Barcelona.* Balanç de recursos i problemas, Ariel Ciencia; Barracó, H, M Parés, A Prat and J Terradas (2000); *Barcelona 1985-1999 Ecologia d'una ciutat*. Ajuntament de Barcelona and Prat, Narcís (1999); Ecological status of rivers and water management in Catalonia. *Medi Ambient, 25: Aigua:gestionar l'escassesa*, Departament de Medi Ambient, Generalitat de Catalunya (texts in Catalan, Spanish & English)

[188] Information from: Prof. M Giudici, Universita' degli Studi di Milano, Dip. Scienze della Terra

[189] Information from: National Atlas of Sweden web site: www.sna.se/webatlas/county/stockholm.html

[190] Stockholm Vatten (2002); *Environmental and Annual Report*, Stockholm Vatten, Sweden

[191] Lannerstad, M (2002); Water Supply and Sanitation in Sweden: A Public Trust, *Stockholm Water Front*, 4, Stockholm International Water Institute, Sweden

[192] Soil Association (1998); Public Certification Summary for Stockhom Vatten AB, Sweden, Soil Association, UK

[193] Stockholm Vatten (2002); *Environmental and Annual Report*, Stockholm Vatten, Sweden

[194] ibid

[195] Soil Association (1998); op cit

[196] ibid

[197] The Swedish FSC standard can be found at: www.fsc-sverige.org

[198] McNeely, J A (1998); *Mobilizing Broader Support for Asia's Biodiversity: How civil society can contribute to protected area management*, Asian Development Bank, Philippines

[199] Stolton, S, N Dudley and K Beland Lindahl (2000):The role of large companies in forest protection in Sweden in Stolton, S and N Dudley [editors]; *Partnerships for Protection: New Strategies for Planning and Management for Protected Areas*, Earthscan, London, UK

[200] National Swedish Board of Forestry and Swedish Environmental Protection Agency (1997); *Nature Protection and Nature Conservation in Forests*, National Swedish Board of Forestry, Jönköping and Swedish Environmental Protection Agency, Stockholm, Sweden

[201] Stolton, S, N Dudley and K Beland Lindahl (2000):op cit

[202] Swedish FSC Working Group (1997); *Endorsed Swedish FSC Standard for Forest Certification*

[203] Soil Association (1998); op cit

[204] Information from: A Mackensen, WWF Germany

[205] Information from: R Hauser, WWF, Croatia

[206] Information on the B Branishte Biosphere Reserve from the MAB web site

[207] Revenga, C, S Murray, J Abramovitz and A Hammond (1998); op cit

[208] Information from: Edmund Barrow, EGB@iucnearo.org

[209] Information from: www.abc.lv/thinkquest/tq-entries/16645/the_land/congo_river.shtml and earthobservatory.nasa.gov/Newsroom/MediaAlerts/2002/200201117297.html and Revenga, C, S Murray, J Abramovitz and A Hammond (1998); op cit

[210] Revenga, C, S Murray, J Abramovitz and A Hammond (1998); op cit

[211] Information from A Adeleke, WWF Cameroon

[212] ibid

[213] Information from: Protected Areas Programme, UNEP World Conservation Monitoring Centre, Document URL: www.unep-wcmc.org/protected_areas/data/sample/0073p.htm

[214] Information from: T Sandwith, Coordinator: Cape Action Plan for the Environment (CAPE)

[215] Information from: http://www.cpnp.co.za/

[216] Information from: http://www.capenature.org.za/Nature_Reserves/html/hottentots.html

[217] Nguyen, K (2003); Dry Kenya taps water-saving measures, Rueters Environmental News Network, 25 April 2003

[218] Nakagawa, H, S Ikebuchi, S Kohsaki, K S Makhanu and K Wakabayashi (1994); *21st century water challenges in Kenya*, paper given at the 20th WEDC Conference, Affordable Water Supply and Sanitation, Colombo, Sri Lanka, 1994

[219] Anon (2003) Million residents of Kenya capital Nairobi still without water, May 15 2003, Agence France-Presse

[220] Nguyen, K (2003); Dry Kenya taps water-saving measures, Reuters Environmental News Network, 25 April 2003

[221] ibid

[222] Information from: *The East African,* Monday, March 26, 2001, www.nationaudio.com/News/EastAfrican/02042001/Regional/Regional15.html

[223] Information from: E Barrow, EGB@iucnearo.org

[224] Information from: UNEP-World Conservation Monitoring Centre database

[225] Information from the RAMSAR database: http://www.wetlands.org/RDB/Ramsar_Dir/SouthAfrica/ZA013D02.doc

[226] Information from: T Sandwith, Coordinator: Cape Action Plan for the Environment (CAPE), information on the Dams can be found at: http://www.kznwildlife.com/dams_dest.htm

[227] Information from: Protected Areas Programme, UNEP World Conservation Monitoring Centre, Document URL: *http://www.wcmc.org.uk /protected_areas/data/wh/draken.html*

[228] UN-HABITAT (2003); *Water and Sanitation in the World's Cities: Local Action for Global Goals*, United Nations Human Settlements Programme, Nairobi, Kenya

[229] Committee on Data for Science and Technology (CODATA) (2002); *Workshop on Scientific Data for Decision Making Toward Sustainable Development: Senegal River Basin Case Study: Abstracts*, Senegal National Committee for CODATA and U.S. National Committee for CODATA, National Research Council, Dakar, Senegal; Cogels, F X, S Fraboulet-Jussila and O. Varis (2001); Multipurpose use and water quality challenges in Lac de Guiers (Senegal), *Water Science & Technology* Vol 44 No 6 pp 35–46 and Revenga, C, S Murray, J Abramovitz and A Hammond (1998); op cit

[230] Information from: www.louisberger.com/berger/world/1999q4/africa.html

[231] Information from: J Chafota, jchafota@wwf.org.zw and www.unep-wcmc.org/protected_areas/data/sample/0140p.htm

[232] Information from: www.unep-wcmc.org/protected_areas/data/sample/0140p.htm

[233] Information from: T Sandwith, Coordinator: Cape Action Plan for the Environment (CAPE)

[234] Information from: www.clw.csiro.au/UGD/UGDabc.html

[235]Information from: E Barrow, EGB@iucnearo.org

[236] Information from: www.clw.csiro.au/UGD/UGDabc.html

[237] Ménard, Claude and George R G Clarke (2000); *A Transitory Regime: Water supply in Conakry, Guinea*, Policy Research Working Paper 2362, The World Bank, Washington DC

[238] Information from: www.clw.csiro.au/UGD/UGDabc.html

[239] Information from: Sydney Catchment Authority, www.sca.nsw.gov.au/ and Environment Australia, www.ea.gov.au/index.html and NSW National Parks and Wildlife Service

(2001); *Blue Mountains National Park, Plan of Management, w*ww.nationalparks.nsw.gov.au/PDFs/pom_final_bluemountains

[240] See case study for full references

[241] http://www.brisbaneforestpark.qld.gov.au/pdf/park_management.pdf

[242] Information from: Queensland Museum (1996); *Wild Places of Greater Brisbane*, Queensland Museum and Brisbane City Council, Brisbane, Australia and David Lamb, University of Queensland

[243] Information from: www.brisbane.qld.gov.au//residential_services/water_sewerage/water_quality.shtml

[244] Information from: http://www.esk.qld.gov.au/dams_&_rivers.htm

[245] Hughes, G J (2003); Meeting the challenge of climate variability in a major water supply system, *Water Supply* Vol 3 No 3 pp 201–207, IWA Publishing

[246] Department of Conservation and Land Management (1989); *Yanchep National Park Management Plan*, Department of Conservation and Land Management, Western Australia

[247] This text was written by: M Blason, Acting SA Water Land Management Officer, Email: monique.blason@sawater.com.au, Web Site: www.sawater.com.au

[248] Mountain Agenda (1997); The risks of climate change in *Mountains of the World: Challenges for the 21st Century,* University of Bern, Switzerland

[249] UNESCO-WWAP (2003); "Human rights to water". Box 5.6 in *Water for People, Water for Life*, Report of the World Water Assessment Programme (WWAP), UNESCO Publishing, Barcelona

[250] Blue Planet Project (2001); *The Cochabamba Declaration,* www.canadians.org/blueplanet/cochabamba-e.html

[251] Zang, L, W R Dawes and G R Walker (2001); Response of mean annual evapotranspiration to vegetation changes and catchment scale, *Water Resources Research* **37** (3): 701-708

[252] Bandyopadhyay, J, J C Rodda, R Kattelmann, Z W Kundzewicz and D Kraemer (1997); Highland waters – a resource of global significance in B Messerli and J Ives [editors] *Mountains of the World: A Global Priority*, Parthenon, New York and London

[253] Hamilton, L S, J O Juvik, and F N Scatena (1995); The Puerto Rico tropical cloud forest symposium: introduction and workshop synthesis, in *Tropical Montane Cloud Forests* [edited by] L S Hamilton, J O Juvik and F N Scatena, Springer-Verlag Ecological Studies 110, New York: 1-23

[254] Hamilton, L S with P N King (1983); Tropical Forested Watersheds: Hydrologic and Soils Response to Major Uses or Conversions, Westview Press, Boulder

[255] Wiersum, K F (1984); Surface erosion under various tropical agroforestry systems, in *Proceedings of Symposium on Effects of Forest Land Use on Erosion and Slope Stability* [edited by] C O'Loughlin and A Pearce, East West Center, Honolulu: 231-239

[256] O'Loughlin, C L (1974); The effect of timber removal on the stability of forest soils, *Hydrology* **13**:121-134

[257] Rao, Y S (1988); Flash floods in southern Thailand *Tiger Paper* **15**(4):1-2.

[258] Hamilton, L S (1992); The wrong villain? *Journal of Forestry* **90**(2):7.

[259] Trustrum, N A and M J Page (1992); The long term erosion history of Lake Tutira watershed: implications of sustainable land use management.Pp 212-215 inP Henriques [editor] *Proceedings of International Conference on Sustainable Land Management*, Napier, New Zealand.

[260] Peck, A J (1978); Salinization of non-irrigated soils and associated streams: a review, *Australian Journal of Soil Research* **16**:157-168.

[261] Calder, I, (1999); *The Blue Revolution – Land Use and Integrated Water resource Management,* Earthscan, Publications London: 31-32

[262] Echavarría, M (2001);The FONAG: Quito's water fund, Personally solicited article from Echavarría, Consultant for the Regional Technical Unit, The Nature Conservancy, Quito, Ecuador

[263] Camuto, C (2001); National Forests and clean water, *Wilderness Magazine* 2000-2001:40-45.Wilderness Society, Washington, USA

[264] Hamilton, L S (2003); Red flag warnings for forest clearing, Presented at *UNESCO International Symposium on Forest Hydrology in the Humid Tropics*, Kuala Lumpur, 2000

[265] Hamilton, L S (1991); Tropical forests: identifying and clarifying the issues *Unasylva* 166(42):19-27

[266] Hamilton, L S and L A Bruijnzeel (1997); Mountain watersheds – integrating water, soils, gravity, vegetation and people, in B Messerli and J Ives [editors] *Mountains of the World: A Global Priority*, Parthenon, New York and London: 337-370

[267] Hamilton, L S with King, P N (1983); op cit

[268] Bruijnzeel, L A (1990); *Hydrology of Moist Tropical Forests and Effects of Conversion: A State of Knowledge Review,* UNESCO International Hydrological Humid Tropics Programme, Paris

[269] Hamilton, L S (1987); What are the impacts of Himalayan deforestation on the Ganges-Brahamaputra lowlands and delta? Assumptions and facts, *Mountain Research and Development* **7**(3):256-263

[270] Hamilton, L. S (2003); op cit

[271] Bruijnzeel, L. A. and L. S. Hamilton (2000); op cit

[272] Hamilton, L S, J O Juvik, and F N Scatena (1995); op cit

[273] Hamilton, L S (2003); op cit

[274] Bury, R B, P S Corn and K B Aubry (1991); Regional patterns of terrestrial amphibian communities in Oregon and Washington, in *Wildlife and Vegetation of Unmanaged Douglas-Fir Forests*, USDA Forest Service General Technical Report PNW-GTR-285:341-352

[275] Franklin, J F (1992); Scientific basis for new perspectives in forests and streams, in R.J. Naiman [editor] *Watershed Management: Balancing Sustainability and Environmental Change*: 25-75

[276] Hamilton, L S, J A Dixon, and G O Miller (1990); Mangrove forests: an undervalued resource of the land and of the sea, in E M Borgese, N Ginsburg and J R Morgan [editors] *Ocean Yearbook 8,* University of Chicago, Chicago

[277] García, J R (1984); Waterfalls, hydro-power, and water for industry: contributions of Canaima National Park, Venezuela, in J A McNeely and K Miller [editors], *National Parks, Conservation and Development*, Smithsonian Institution Press, Washington: 588-591

[278] Herrador, D and L Dimas (2000); Payment for environmental services in El Salvador, *Mountain Research and Development* **20** (4):306-309 and World Bank (2000); Payments for environmental services, *Environment Matters*: Annual Review 1999-2000:26-29.

[279] UNESCO-WWAP (2003); op cit

[280] Anon (2001); *State of the World's Forests* 2001, Food and Agriculture Organization (FAO), Rome

[281] Landell-Mills, N and I Porras (2002); *Silver Bullet or Fools' Gold? A Global Review of Markets for Forest Environmental Services and Their Impact on the Poor*, International Institute for Environment and Development, London

[282] Pagiola, S and G Platais (2003); Implementing systems of payments for environmental services: Initial lessons of experience, paper presented at *Ecosystem Services in the Tropics: Challenges to Marketing Forest Function*, Spring 2003 Meeting of the International Society of Tropical Foresters, Yale University, April 5-6, 2003

[283] Pagiola, S (2002); Paying for Water Services in Central America: Learning from Costa Rica, in S. Pagiola, J. Bishop, and N. Landell-Mills [editors], *Selling Forest Environmental Services: Market-based Mechanisms for Conservation* Earthscan, London

[284] Castro, E (2001); Costa Rican Experience in the Charge for Hydro Environmental Services of the Biodiversity to Finance Conservation and Recuperation of Hillside Ecosystems, paper presented at the International Workshop on Market Creation for Biodiversity Products and Services, OECD, Paris, 25-26 January 2001

[285] Echevarría, M (2002); Financing watershed conservation: The FONAG water fund in Quito, Ecuador, in S. Pagiola, J. Bishop, and N. Landell-Mills [editors], *Selling Forest Environmental Services: Market-based Mechanisms for Conservation* Earthscan, London

[286] Pagiola, S (2002) op cit

[287] Pagiola, S, N Landell-Mills, and J Bishop (2002); Making market-based mechanisms work for both forests and people, in S Pagiola, J Bishop, and N Landell-Mills [editors], *Selling Forest Environmental Services: Market-based Mechanisms for Conservation* Earthscan, London

[288] Pagiola, S, PAgostini, J Gobbi, C de Haan, M Ibrahim, E Murgueitio, E Ramírez, and M Rosales (2003); Contracting for Biodiversity Conservation in Agricultural Landscapes, paper presented at the Third BioEcon Workshop: Contract Mechanisms for Biodiversity Conservation, Montpellier, France, May 22-24, 2003

[289] Pagiola, S, A Arcenas, and G Platais (2003); Ensuring that the Poor Benefit from Payments for Environmental Services, paper presented at the Workshop on Reconciling Rural Poverty Reduction and Resource Conservation: Identifying Relationships and Remedies, Cornell University, Ithaca, NY, May 2–3, 2003.

[290] Department of Infrastructure (2002); *Melbourne 2030: Planning for sustainable growth*, Department of Infrastructure, Melbourne

[291] Melbourne Water (2002); *Business review 2001-02*, Melbourne Water, Australia

[292] Melbourne Water (2002); *The Water Source*, Infostream information sheet, www.melbournewater.com.au

[293] Melbourne Water (2002) *Business review 2001-02*, Melbourne Water, Australia

[294] Peel M, F Watson, R Vertessy, A Lau, I Watson, M Sutton and B Rhodes (2000); *Predicting the Water Yield Impacts of Forest Disturbance in the Maroondah and Thomson Catchments using the Macaque Model Technical Report*, Report 00/14, December 2000, Cooperative Research Centre for Catchment Hydrology and Melbourne Water, Australia

[295] Melbourne Water (2002) *Social review 2001-02*, Melbourne Water, Australia

[296] Melbourne Water (2002); *The Water Source*, Infostream information sheet, www.melbournewater.com.au

[297] Melbourne Water (2002) *Social review 2001-02*, Melbourne Water, Australia

[298] Melbourne Water (2002); *The Water Source*, Infostream information sheet, www.melbournewater.com.au

[299] Parks Victoria (2000) *State of the Parks 2000: Park Profiles*, Parks Victoria, Melbourne.

[300] National Parks Service (1996), *Kinglake National Park Management Plan*, Department Of Natural Resources And Environment, Victoria, Australia

[301] Kuczera G (1987); Prediction of water yield reductions following a bushfire in ash-mixed species eucalypt forest, *Journal of Hydrology*, **94**:215-236.

[302] Peel M, F Watson, R Vertessy, A Lau, I Watson, M Sutton and B Rhodes (2000); op cit

[303] Melbourne Water information sheet on forestry, on www.melbournewater.com.au

[304] Ibid

[305] ibid

[306] see CSIRO docs attached to MR's email

[307] Information from: S Haritasi www.istanbul.com.tr and www.dsi.gov.tr

[308] V Ozhatay, Prof Dr N, A Byfield, G Argun (1999); *Istanbul: Forever Green*, WWF Turkey, Istanbul

[309] Yalcin, G, Y Lise, U Zeydanli, E Can and S Kalem (2002); *Istanbul-Terkos Koruma Alanı Onerisi*, WWF Turkey, Istanbul

[310] ibid

[311] V Ozhatay, Prof Dr Neriman, A Byfield and G Gokmen (1999); op cit

[312] Bugna, S.C. (2002: A profile of the protected area system in Singapore, *Asean Biodiversity*. April-June 2002: 30-33

[313] Corlett, R T (1991) Vegetation, in: L S Chia, A Rahman and D B H Tay [editors] *The biophysical environment of Singapore*, Singapore University Press:134-154

[314] Lum, S K Y and I Sharp (1996); *A view from the summit*. Nanyang Technological University and National University of Singapore

[315] Bugna, S C (2002); op cit

[316] Tan, Y L (2002); Singapore's Current Population Trend, *Statistics Singapore Newsletter*: Sep 2002

[317] Hall, pers comm

[318] Wee, Y C (1964); A note on the vegetation of Singapore Island, *Malay Forester* **27**: 257-266

[319] Wee, Y C and R Corlett (1986); *The city and the forest: plant life in urban Singapore*. Singapore University Press

[320] Hall, pers comm

[321] ibid

[322] ibid

[323] *Straits Times*, 30 April, 2002

[324] *Straits Times*, 9 December, 2002

[325] *Straits Times* 12 July, 2002; 26 September 2002, and 22 February, 2003

[326] Brook, B W, N S Sodhi and P K L Ng (2003); Catastrophic extinctions follow deforestation in Singapore, *Nature* **424**, 420 - 426 (24 July 2003)

[327] EPA (1999); *Protecting Sources of Drinking Water Selected Case Studies in Watershed Management*, United States Environmental Protection Agency, Office of Water, EPA 816-R-98-019, April 1999, www.epa.gov/safewater

[328] Information from: www.cwconline.org/index.html

[329] Croton Watershed Clean Water Coalition – web site http://www.newyorkwater.org/

[330] Perrot-Maître, D and P Davis (2001); *Case Studies of Markets and Innovative Financial Mechanisms for Water Services from Forests*, Forest Trends, Washington DC

[331] EPA op cit

[332] Information from: www.dec.state.ny.us/website/dlf/publands/cats/

[333] Information from: www.cwconline.org/index.html

[334] New York City and the Watershed Agricultural Council (1996); New *York City Watershed Agricultural Program Overview*, New York City and the Watershed Agricultural Council

[335] Perrot-Maître and Davis op cit

[336] Perrot-Maître and Davis op cit

[337] Information from: www.cwconline.org/index.html

[338] Information from: www.dec.state.ny.us/website/dlf/publands/cats/

[339] Information from: www.venezuela.8m.com/costa.htm

[340] Information from: www.fao.org/waicent/faoinfo/agricult/agl/aglw/aquastat/countries/venezuela/indexesp.stm, www.caracas.ru/stol_i.html, and www.areasprotegidas.org/zz_venezuela_demografia.php

[341] Information from: www.cepis.org.pe/eswww/fulltext/analisis/venezuela/capit1.html

[342] Information from: www.fao.org/waicent/faoinfo/agricult/agl/aglw/aquastat/countries/venezuela/indexesp.stm

[343] Information from: www.mre.gov.ve/

[344] Information from: www.elmundo.com.ve/ediciones/2003/03/10/p1-10s1.htm

[345] Inforopo.htmmation from: www.inparques.gov.ve/parques_nac/pnguatopo.htm

[346] ibid

[347] Information from: www.une.edu.ve/caracas/macarao.htm

[348] Information from: www.inparques.gov.ve

[349] Information from: www.geocities.com/Yosemite/6507/

[350] Information from: www.geocities.com/Yosemite/6507/

[351] Information from: www.champaqui.com.ar/avi.htm

[352] Information from: www.fao.org/waicent/faoinfo/agricult/agl/aglw/aquastat/countries/venezuela/indexesp.stm

[353] Information from: www.analitica.com/vas/1999.12.5/ecologia/45.htm

[354] CIDE (2002); Anuário Estatístico do Estado do Rio de Janeiro 2002. CD-Rom. Rio de Janeiro: Fundação Centro de Informações e Dados do Rio de Janeiro

[355] Maranhão, N (2001); Ajuda memória da reunião sobre disponibilidade hídrica na bacia do rio Guandu/canal de São Francisco, 16 de janeiro de 2001, UFRRJ, Seropédica, RJ. Seropédica

[356] CEDAE - Companhia Estadual de Águas e Esgotos do Rio de Janeiro (1985); Plano diretor de abastecimento de água da Região Metropolitana do Rio de Janeiro: relatório final. Rio de Janeiro: CEDAE

[357] Silva, R M da (1988); colaboração de Joper Padrão do Espírito Santo. A luta pela água. Rio de Janeiro: CEDAE

[358] Goulart, R (1991); Custos do Tratamento de Águas Provenientes de Bacias Degradadas: exemplo ETA Guandu. In: UFRRJ. Anais do Workshop Sobre Recuperação de Áreas Degradadas, julho de 1990, Itaguaí, RJ. Itaguaí: Universidade Federal Rural do Rio de Janeiro - UFRRJ, Departamento de Ciências Ambientais

[359] Flavio M quoted in Maranhão, N (2001); Ajuda memória da reunião sobre disponibilidade hídrica na bacia do rio Guandu/canal de São Francisco, 16 de janeiro de 2001, UFRRJ, Seropédica, RJ. Seropédica

[360] P Da Cunha E Menzes and L O Teixeira Mendes (2001); The mission of protected areas in Brazil, *PARKS*, **11**:3, IUCN, Gland

[361] Oliver, N (1991); Floresta da Tijuca e Cercanias, Editora Index

[362] CIDE (2003); Índice de Qualidade dos Municípios – verde. (IQM verde). 2nd ed. ampl. rev. Rio de Janeiro: Fundação Centro de Informações e Dados do Rio de Janeiro

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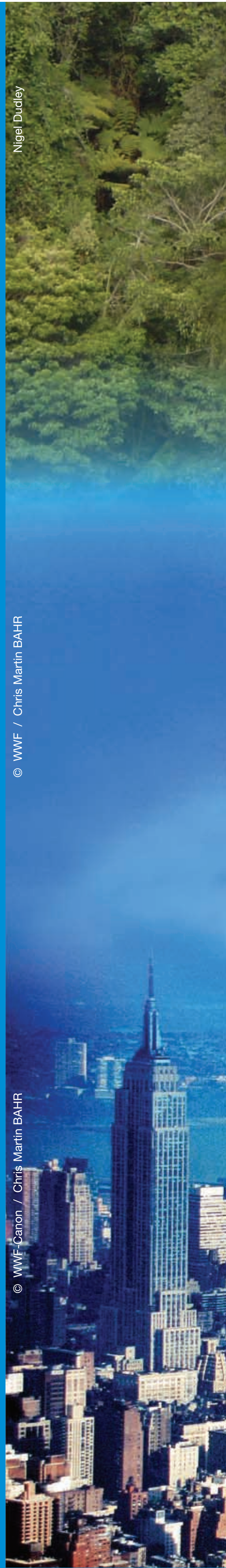

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