World Water Assessment Program

Case Study

Ruhuna Basins, Sri Lanka

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K. A. U. S. Imbulana, Peter Droogers, Ian W. Makin, editors

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Chapter 1

The General Context of Ruhuna Basins

Background

The Ruhuna basins in Southern Sri Lanka will face major changes over the next two decades. Ambitious development plans are indicating that the dominant role of agriculture in the region is likely to change towards much more industrial- and service- oriented activities. Obviously, these changes will have an enormous impact on society as well as on natural resources, including the issues of water management. Currently, almost all water resources that are diverted are used for irrigated agriculture with only a small percentage used for industry and drinking water. Most recent development plans show that the use of water for urban and industry will increase from the current less than 10 million m^3 to 100–150 million m^3 by the year 2025.

The ancient province of Ruhuna had extended from Kalu *Ganga* (river) in the west to Mahaweli Ganga in the north. Brohier (1935) highlights the uniqueness of the area as:

Both legend and history combine to render this part of Ceylon[1] one of the most fascinatingly interesting areas—celebrated in ancient chronicles not only as the abode of Religion and Royalty, but as the region of a magnificent cultivation under irrigation.

The origins of the Ruhuna can be traced back to the reign of King Panduvasdeva (504-474 BC) when a prince called Rohana established a settlement in the Kirindi Oya basin. Subsequently, the sub-king Mahanaga developed this area as a semi-independent state, when he had to flee the capital of Anuradhapura, in the face of a murderous conspiracy by his sister-in-law. Prince Mahanaga was the brother of King Devanampiyatissa (247-207 BC) during whose reign Buddhism was introduced to Sri Lanka (Codrington 1939). Legends surrounding the river basins are associated with a much longer time period.

Folk tales describe Ravana falls in the upper watershed of Kirindi Oya as the place where Princess Sita used to bathe, during her captivity by King Ravana. The Hindu mythology describes Kataragama in the Menik subbasin as the place where god Skanda met local a lady who later became his consort. Today, many Buddhists and most Hindus worship the god of Kataragama. Princess Vihara Devi's sea odyssey and giant Nila's construction of irrigation facilities in Kaltota area are also among the many legendary tales associated with the region.

During ancient times, Ruhuna served as a haven for kings and princes fleeing foreign invasions from the north. As a result, food production (particularly paddy) was important for the national security. However, when a new capital was founded in the wet zone after thirteenth century, irrigated cultivation fell into was neglect.

The status of irrigated rice cultivation did not improve during the early years of the European colonial rule. However, some attention was paid by the Dutch to resurrect agricultural production in the area west of the Walawe basin. The first attempts to restore irrigation works under the British in the middle of the nineteenth century included Kirama and Urubokke systems,

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[1]From British times until a new Constitution was promulgated by the legislature in 1972, Sri Lanka was known as Ceylon (editor).

immediately west of the Walawe basin. Tissamaharama tank (Tissa) may have been the first major reservoir to be restored under European rule in the case study area ordered by Governor Hercule Robinson (1865–1872). Restoration of the Kaltota scheme in 1892 and the construction of Liyangastota anicut (diversion) in 1889 are among the oldest irrigation works after the Sinhalese kings (Arumugam, 1969).

The "Ruhuna basins" defined for this case study encompass three of the main rivers that flow through ancient Ruhuna, including the longest and most important river in the region, Walawe. Today, the Ruhuna basins are important in the broader Sri Lankan context, the basins being the location of a major hydropower plant, irrigation schemes that make a significant contribution to national food production, and important nature reserves. However, even before the proposed development begin to be implemented, the basins are experiencing major water resources problems, clearly demonstrated by the recent drought that led to reductions of water supplies to agriculture, insufficient domestic water supply, and which contributed to nationwide power cuts of up to 8 hours a day.

These challenging issues motivated the Government of Sri Lanka to select the cluster of three important rivers, Walawe, Menik and Kirindi, and the smaller basins confined by them as the area for the case study for the World Water Assessment Program. Figure 1 shows the location of the basins.

The total land area of Sri Lanka is 65,600 km^2. The mean annual rainfall is about 1,900 mm, which varies from about 900 mm in driest parts of the dry zone to about 6,000 mm in the central hills. The dry zone, generally defined as the area that receives an annual rainfall of less than 2,000 mm, spreads over 80 percent of the land area. There are parts of the Ruhuna basins that are in all three of these zones.

There are 103 distinct river basins in the island, ranging in size from 9 km^2 to 10,450 km^2. The Ruhuna basins cover 8 percent of the total landmass of the country and have a population of a little over 1 million. It is situated in the southeast quadrant of the country. Figure 2 illustrates the network of rivers, streams, and irrigation reservoirs, lagoons and salterns that constitute the hydrologic features of the basins. The three main rivers each originate in the central hills.

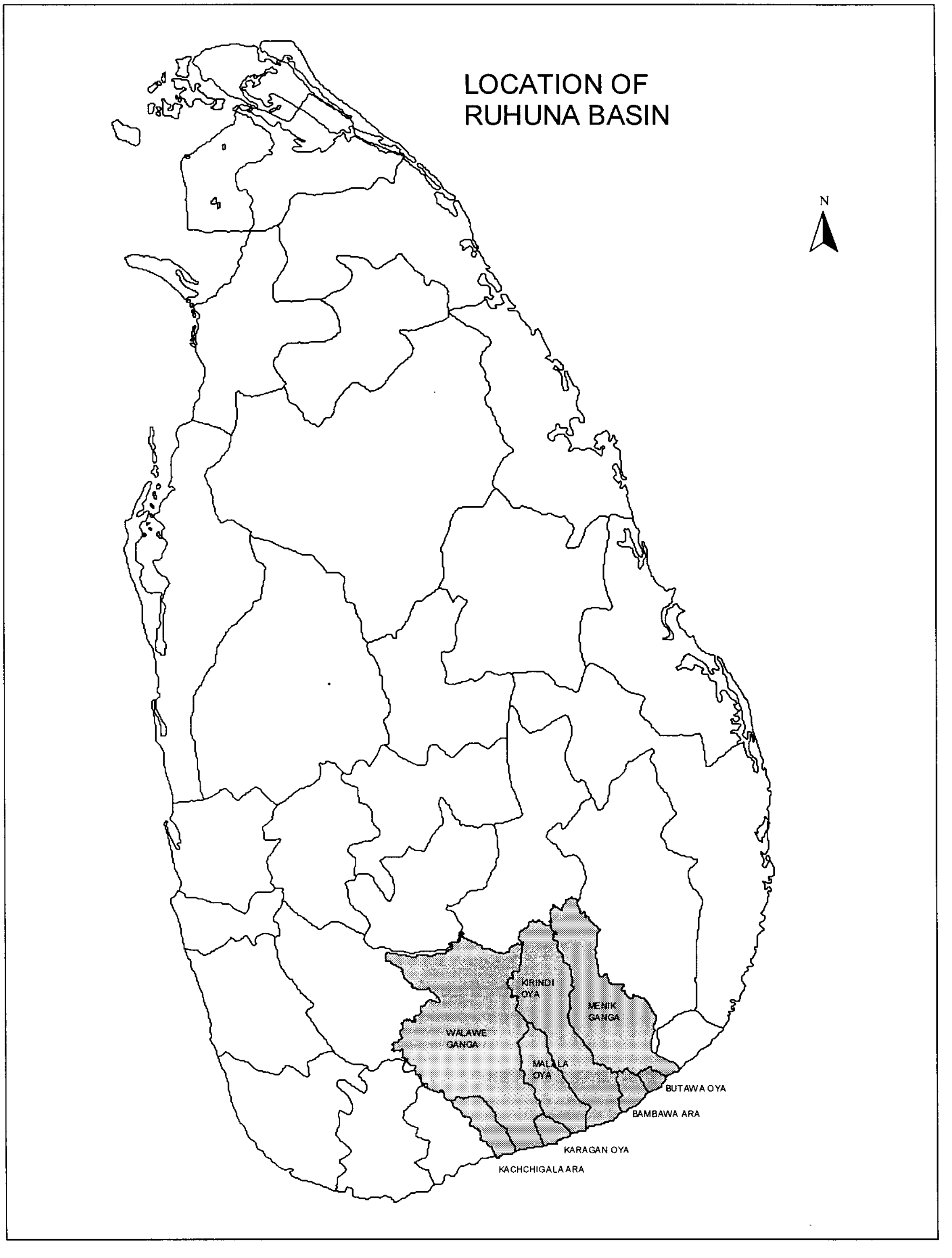

Figure 1 Location of Ruhuna basins

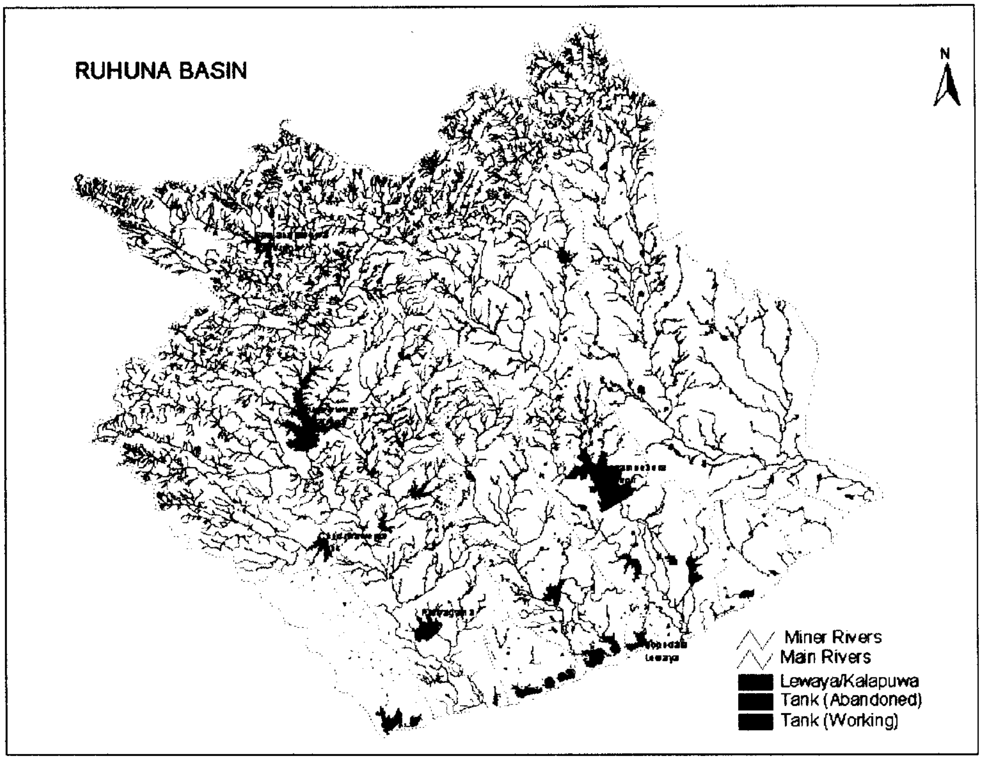

Figure 2 Major hydrological features of the Ruhuna basins

Major Physical Characteristics

Topography

The Ruhuna basins have a typical topography. The upstream areas are mountainous, relatively wet catchment areas with limited development and downstream flat plains with more developed water resources. The rivers originate from the southern slopes of the central highland massif at an elevation of up to 2,000 meters (figure 3) before flowing in to the lowlands of rolling or undulating plains dotted with a few isolated hills,

Three broad geomorphic regions can be identified in all three basins. The highland region, a complex of hill and valley landforms and a major scarp occurs at elevations over 1,000 m. A highly dissected plateau occurs at an elevation of between 300 and 1,000 m, and is referred to as the upland region. The upland region represents about 7 percent of the higher-elevation area of the Walawe basin, and around 5 percent of the higher elevation areas of the Kirindi and Menik gaga basins.

The lowland region, which accounts for more than 90 percent of the area of all three basins, is made up of the following dominant landforms:

- Mantled Plain (MP)
- Rock Knob Plain (RKP)
- Erosion Remnants (ER)
- Alluvial Plain (AP) (Panabokke, 2002)

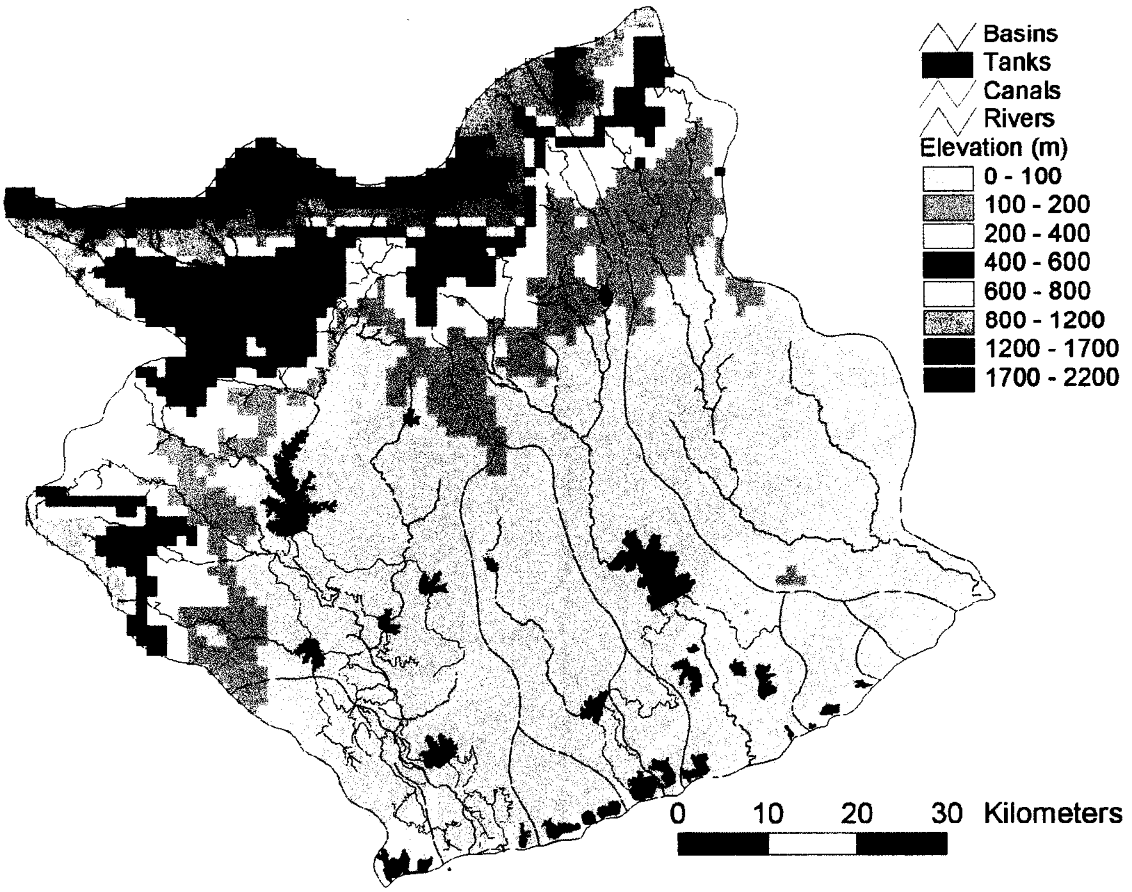

Figure 3 Topography of the Ruhuna basins

Geology

As can be seen in figure 4, a major portion of the three river basins is made up of the hornblende gneisses of the Vijayan complex of rocks, including biotite gneiss, hornblende biotite gneiss, with inclusions of migmatite and granitic rocks.

The western half of the Walawe river basin is, for the most part, made up of undifferentiated highland series of rocks with interbanded feldspar garnet granulites, quartzites, sillimanitic schistic gneiss, garnet-biotite gneisses and crystalline limestones.

The upper, higher-elevation regions of all three basins are, for the most part, various charnockites with inclusions of calc-granulite gneisses and some quartzites.

Charnockitic rocks dominate the mid and lower aspects of the Kirindi Oya, while the prominent Kataragama hill complex is made up of an undifferentiated charnockite group of rocks.

A significant extent of granitic gneiss occurs in the lower coastal plain area between the lower Kirindi and Menik gaga basins.

Well-marked bands of calc-granulites and minor marbles are found in the mid-Walawe basin, around the Kataragama complex and in the high elevation region of the Kirindi and Menik upper watersheds (Panabokke, 2002).

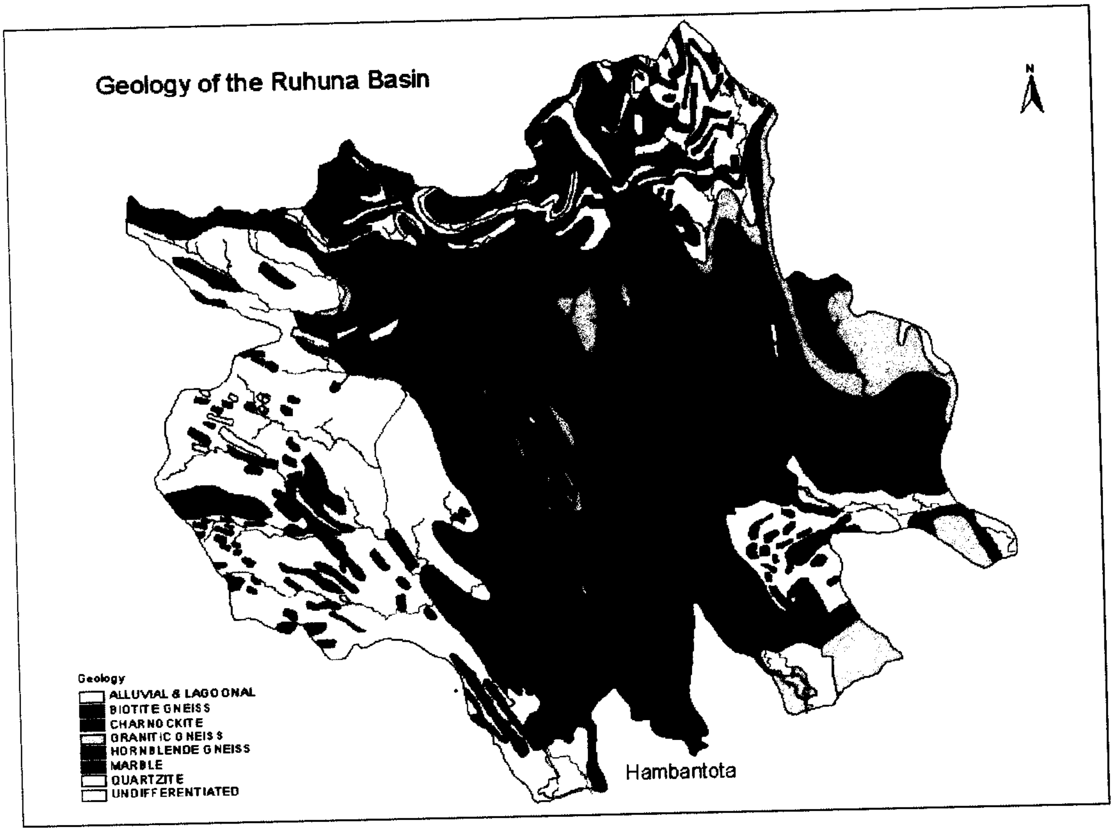

Figure 4 Geological characteristics

Soils

The soil types are important from the points of view of both agriculture and groundwater. Figure 5 shows the dominant soil types in the basins. Reddish Brown Earth (RBE) soils (soil unit no. 1) are very productive, supporting paddy, sugarcane, banana and home gardens. This soil type present in the basins is further described as a well-structured deep soil, rich with plant nutrients, with favorable conditions for root growth. The same soil type present in some other parts of the country is underlain with a quartz gravel horizon that obstructs root development, which is absent here. The Low Humic Gley soils that are often associated with RBE, and alluvial soils (soil unit no. 19) are especially suited for paddy.

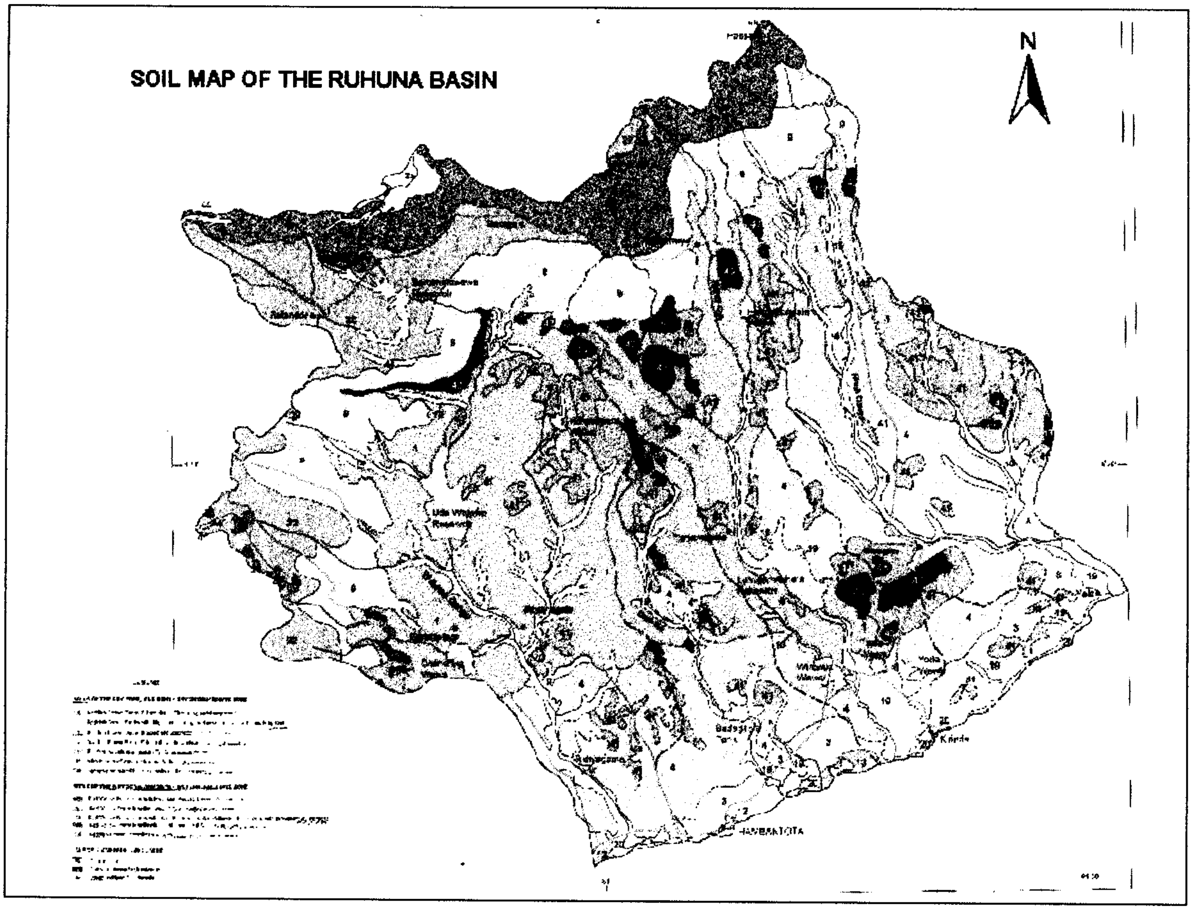

Figure 5 Major soil types
(Panabokke, 2002 and Land Use Division, Irrigation Department)

RBE soils, soil unit numbers 3 and 4 are not very productive. The solodized solonetz soils are highly sodic with a high amount of exchangeable sodium in its clay component. This is structurally unstable and subject to dispersion after rains. Many abandoned village tanks are found in the lands with this soil type.

The relevance of the soil types to groundwater is described under the section that deals with groundwater.

Ecology and Climate

General

The only source of water is rainfall. Monsoonal rains (November-March and May-September) contribute a major part of the annual rainfall, which is supplemented by inter-monsoonal rains. The mean annual rainfall for the basin is 1,574 mm. In comparison, annual potential evapotranspiration is estimated to be 1700 mm (Jayatillake 2002a). Figure 6, which is based on data obtained from the Uda Walawe scheme, compares the rainfall with potential evapotranspiration. The comparison indicates the need for irrigation in several months of the year. The depth of the rainfall reduces from the upper reaches to lower reaches and from west to east. The recent rainfall records at selected stations show a trend of decreasing annual rainfall since 1970. The decrease is not uniform or highly significant in statistical terms. The ambient temperatures in the lowland range between 25°C and 28°C and from 23°C to 25°C in the upper elevations.

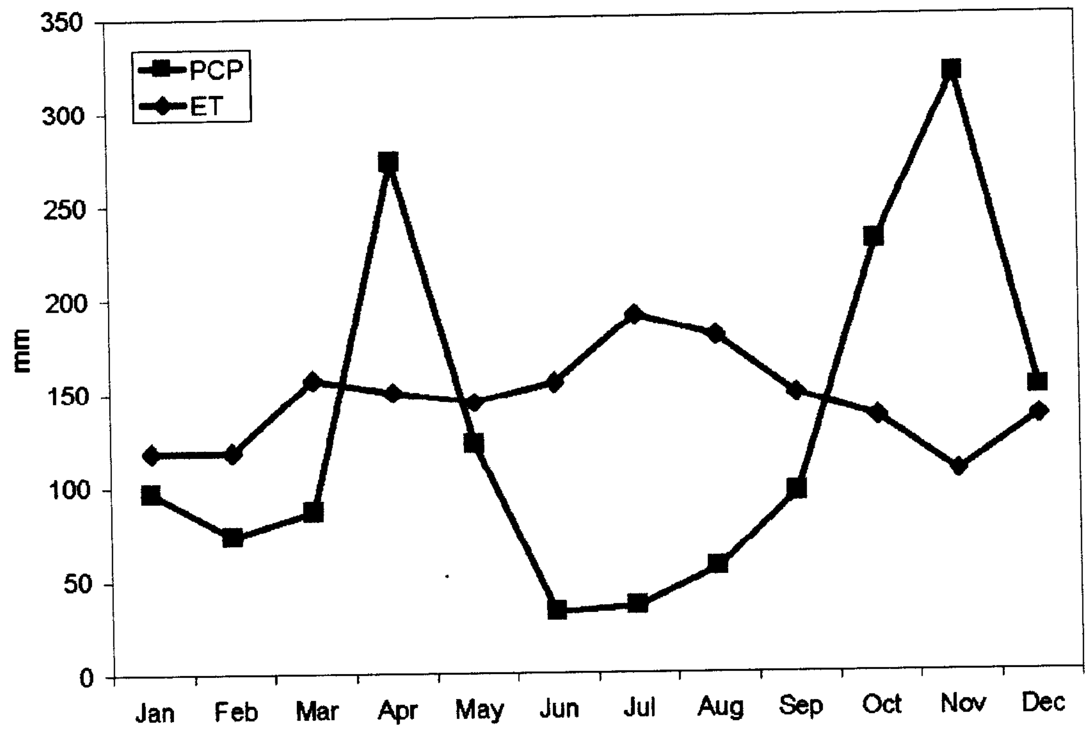

Figure 6 Rainfall and evapotranspiration in the Ruhuna basins

Spatial and Temporal Variations of the Rainfall

Rainfall in the basins is bimodel (as in the rest of the country) with precipitation from the two seasons each year, the northeast monsoon from December to February and the southwest monsoon from May to September, with intermonsoonal rains the other months. The annual rainfall pattern defines the two cultivation seasons, namely *maha* (wet season lasting from October to March), and *yala* (dry season lasting from April to September).

The spatial distribution of the rainfall over a 30-year period from 1961 to 1990 has been estimated using the Krieging method with data from 266 stations and a pixel resolution of 0.025° x 0.025° latitude/longitude. The estimated spatial distribution was then overlaid to estimate the average rainfalls (*Source:* Meteorological Department, Sri Lanka). This method of analysis was selected to minimize possible errors due to the uneven distribution of rain gauge stations within the basins.

The spatial and temporal variations of rainfall distribution are illustrated in Figure 7 showing the Monthly distribution and Figures 8 and 9 showing the Maha and Yala mean seasonal rainfall for the basins. The figures indicate higher water availability and greater temporal variation of rainfall in the Walawe subbasin. Similar analysis shows that water scarcity in the comparatively dry yala season appears to be more pronounced in the Kirindi, Malala and Menik subbasins. Figure 10 illustrates the mean monthly variation of rainfall in the four subbasins. The rainfall distribution in the Malala Oya, mainly located in the dry zone, is indicative of the dryness of that area during the Yala season.

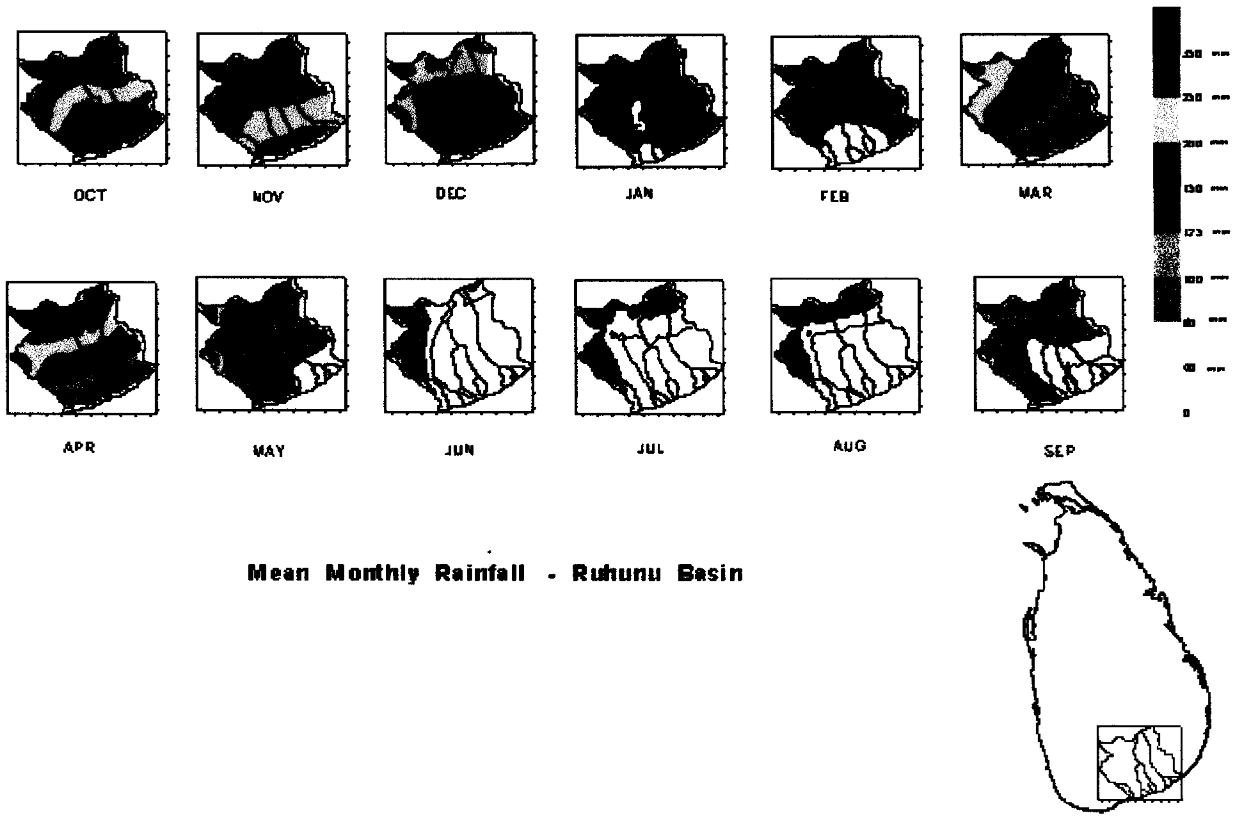

Figure 7 Spatial variation of mean monthly rainfall (mm/month).

Figure 8 Spatial distribution of Rainfall -- Maha season (mm).

Figure 9 Spatial distribution of rainfall-Yala season (mm)

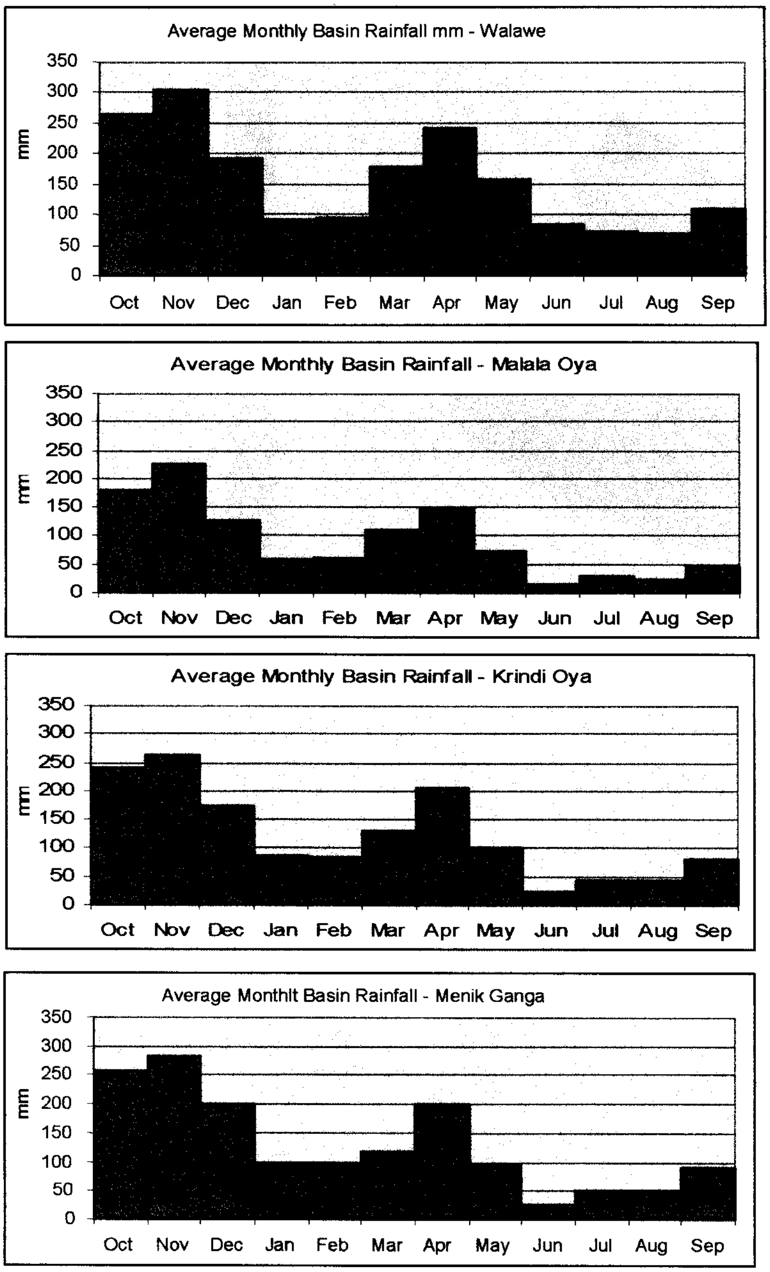

Figure 10 Annual Rainfall pattern Ruhuna sub-basins

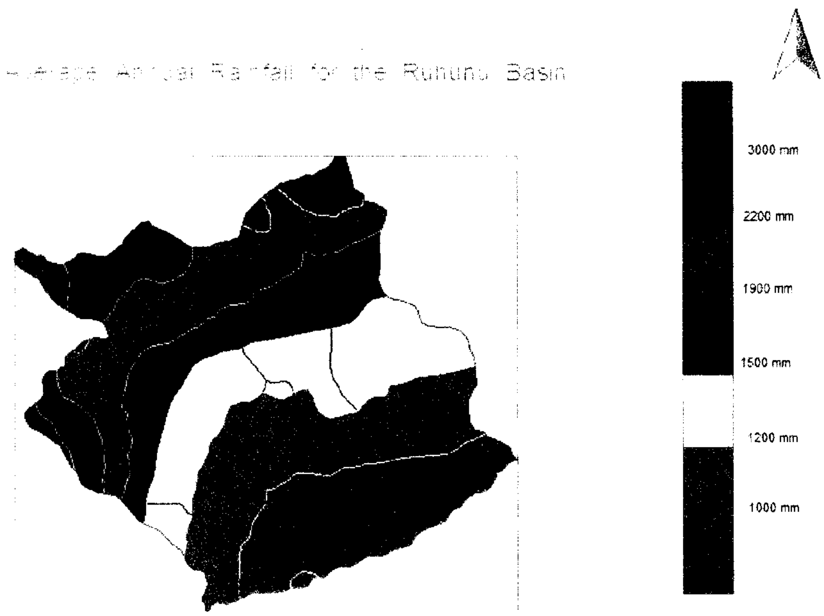

Figure 11 Mean Annual Rainfall distribution – Ruhuna Basins

Table 1 Annual Rainfall pattern Ruhuna subbasins

Subbasin	Maha	Yala	Annual	Seasonal Rainfall Ratio: Maha/Yala
Walawe	1,125	735	1,860	1.5
Kirindi	976	494	1,470	2.0
Menik	1,051	510	1,561	2.1
Malala	763	333	1,096	2.3
Total Ruhuna	1,007	567	1,574	1.8

The mean annual rainfall ranges from 1,096 mm to 1,870 mm across the basins, with an annual average for the Ruhuna basins of 1,574 mm, Figure 11. The monthly average rainfall ranges from 14 mm to 303 mm in the individual basins with a total basin monthly average ranging from 48 mm to 274 mm.

Evaluation of the *seasonal rainfall ratio,* defined as the ratio of mean seasonal rainfall of maha to mean seasonal rainfall of yala, indicates that in the yala season, the three basins of Kirindi, Menik and Malala receive only around half the rainfall received in the maha season. The highest seasonal variation is observed in the Malala basin (table 1).

The spatial and temporal variation in rainfall, shown in figure 7, and maha and yala rainfall maps (figures 8 & 9) indicate that the upper parts of the Walawe basin receive rain during both monsoon seasons. However the middle and lower potions of Walawe, and the other basins receive the major proportion of the annual rainfall during the maha season. The magnitude of rainfall reduces from the upper watersheds to lower watersheds and from west to east across the basins.

Long-Term Rainfall Trends

Figure 12 illustrates annual rainfall trends between 1901 and 2000 for selected stations in the Walawe basin (*Source:* Meteorological Department). Although a declining trend is evident from the early 1970s at the Holmwood and Campion stations, this will require further verification before reaching any final conclusion.

The importance of maintenance of long-term agro-meteorological and hydrological observation networks is clearly demonstrated by the observations in Ruhuna. As in many countries such basic data collection is receiving less than adequate resources to enable routine collection, analysis and storage of this vital information is important. Problems of access and availability of basic information has been a recurrent theme in this case study.

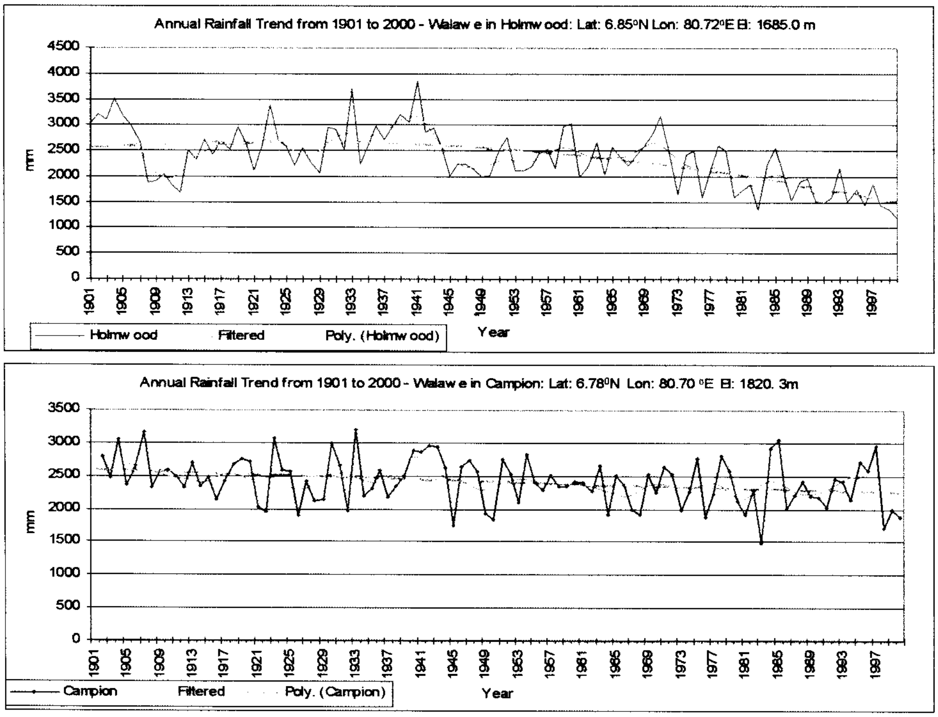

Figure 12 Trends in Annual rainfall (1901— 2000) Walawe (selected stations) (Jayathilake, 2002a)

Agro-Ecological Regions

Agro-ecological regions (AER) are characterized and defined in terms of rainfall probability regimes, elevation, landforms and soils. The main elements of the definition of AER are briefly outlined below:

The highest demarcation levels are the wet zone (W), intermediate zone (I), and the dry zone (D). The second stage of subdivision is the elevation of land: low country (L) below 300; mid-country (M) between 300 and 900 m; and up-country (U) over 900 m. The third stage is the subdivision into agro-ecological regions (AERs), which represent homogeneous climatic conditions combined with soils, landforms and land use.

The first stage of demarcation into the dry (D) intermediate (I) and wet (W) zones is shown in figure 13. The third stage of demarcation into the respective AERS. Figure 14 shows a greater part of all three basins falls within DL1 and DL5; with the balance lying mainly in IL2, IM2 and IU2; and a small portion of the upper Walawe Ganga basin classified as WM2.

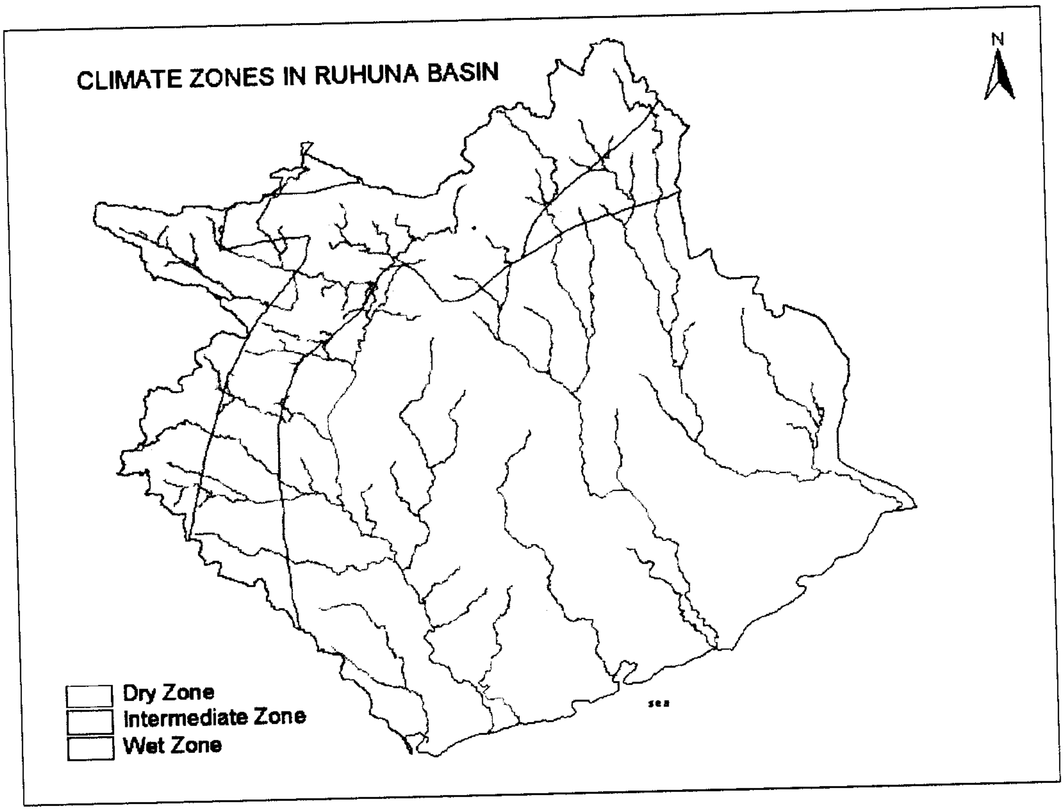

Figure 13 Climate Zones in Ruhuna Basins
(Source: Panabokke, 2002)

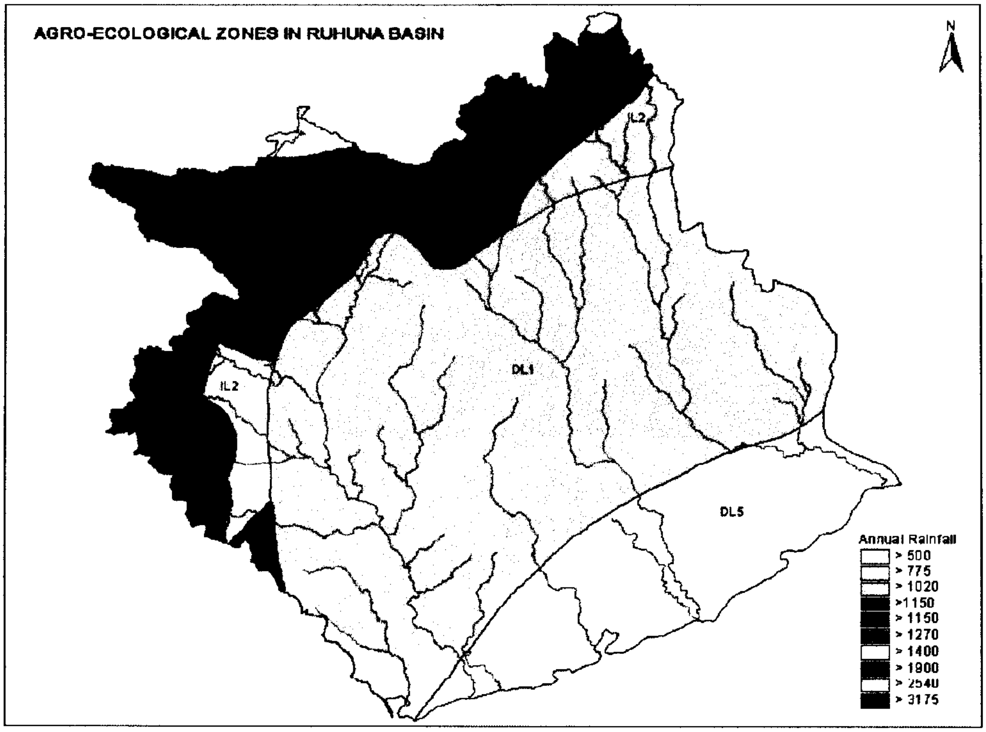

Figure 14 Agro-ecological regions of the Ruhuna basins
(Source: Panabokke, 2002)

Evapotranspiration

Representative values of potential evapotranspiration worked out based on the Penman-Monteith approach for the upper and lower Ruhuna basin is shown in figure 15. Mean monthly potential evapotranspiration (PET) of the upper catchment varies from 2.8 mm/day to 5.0 mm/day with the lowest in December and the highest in August. The PET for the lower catchment is much higher and varies from 4.6 mm/day to 6.0 mm/day with the lowest in December and the highest in March. From June to August, PET is similar in both upper and lower catchments at about 5 mm/day.

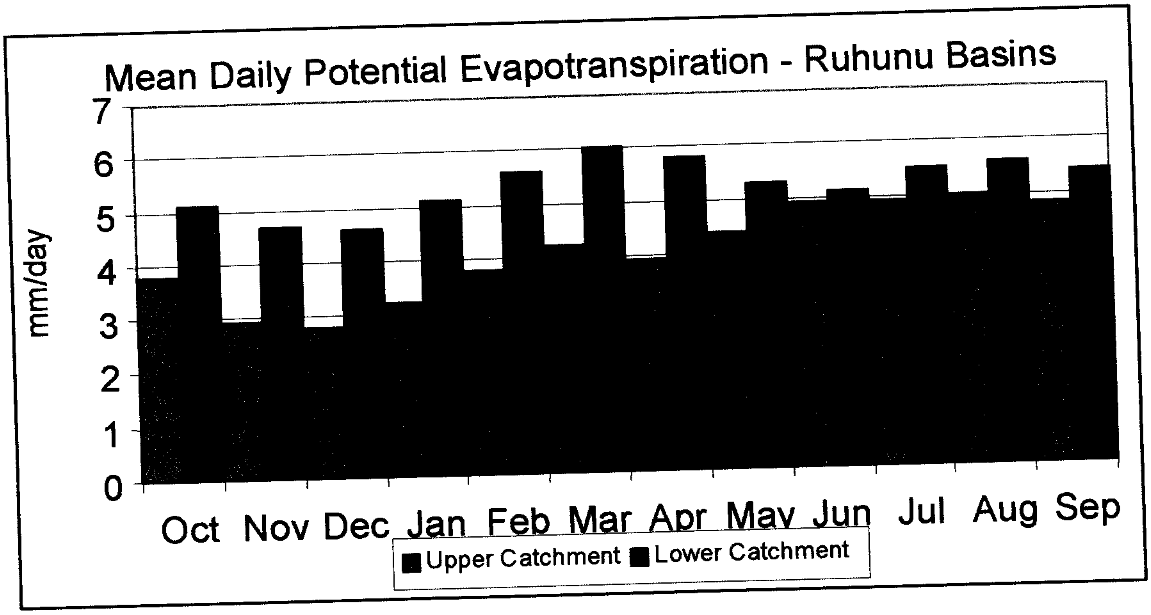

Figure 15 Mean daily potential evapotranspiration: Monthly distribution
(Source: Meteorological Department).

Major Socioeconomic Characteristics

Population

The Ruhuna basins include parts of Ratnapura, Badulla, Moneragala and Hambantota districts with population densities of 307, 291, 71 and 217 persons per km^2, respectively. The total population in the basins is approximately 1.1 million (Jayatillake 2002a). Figure 16 shows the administrative districts and Divisional Secretary Divisions (DSD) in the basins. Figure 17 shows the population density by the DSD areas. Population density is high in the upper watershed, in Haputale, Bandarawela and Ella DSD, where the plantation sector plays a major role in the economy. Similarly high population densities are observed in the lower basins where major water resources development investments have been made, notably in the DSD of Walawe and Kirindi Oya basins.

Economy

The average monthly income per household in the Badulla district (Rs 3,702) is the lowest in the country in 1995/96. Based on the district values, the average monthly income for the Ruhuna basin was Rs 4,349, compared to the national average of Rs 6,476. For the year 2000, the national average GDP per capita was US$850, but for the Ruhuna basins the per capita GDP was estimated at around $600. The ratio of households receiving food and economic support was nearly 60 percent compared to the national average of 39 percent (Department of Census and Statistics 2000).

Figure 18 shows the distribution of population receiving food and economic support. It can be seen that water resources development has contributed to people become less dependent on State support.

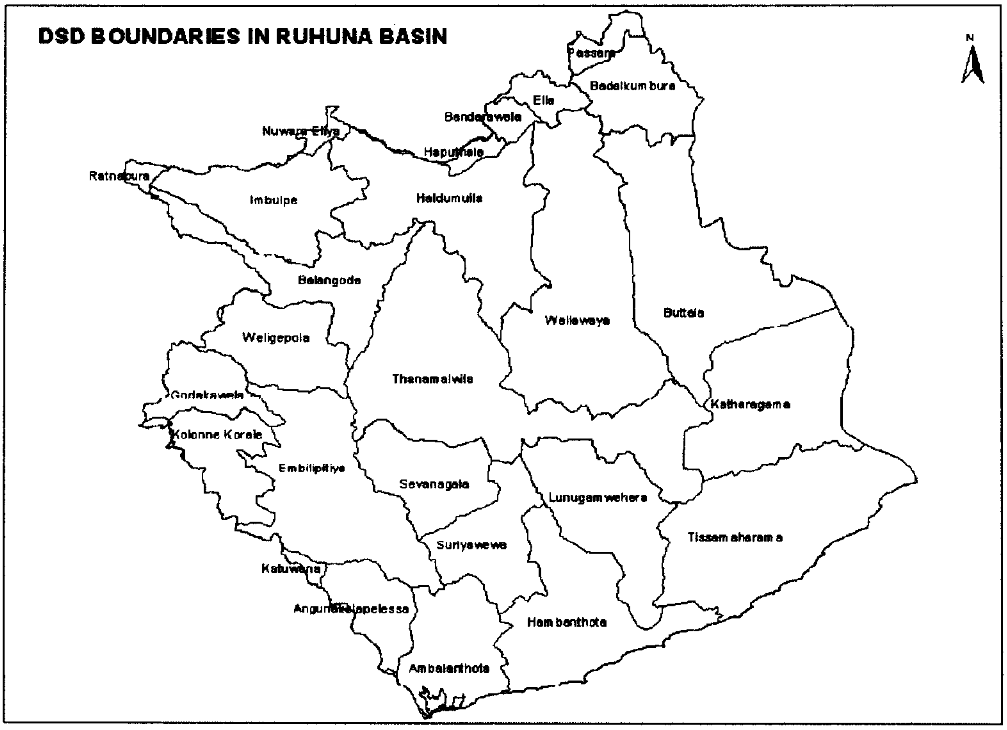

Figure 16 Administrative Boundaries - Divisional Secretary Divisions

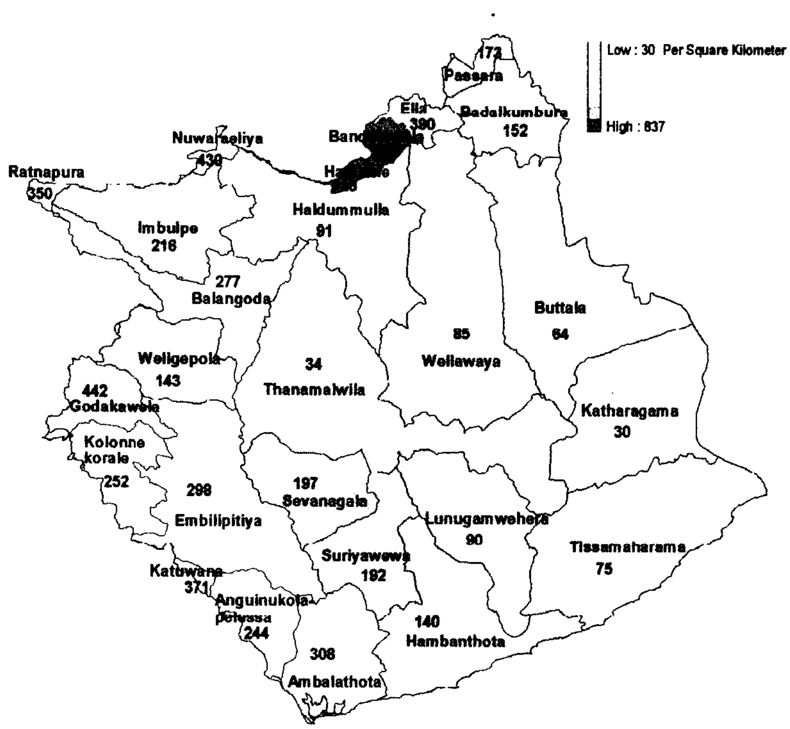

Figure 17 Population density by Divisional Secretary Division (persons/km^2)

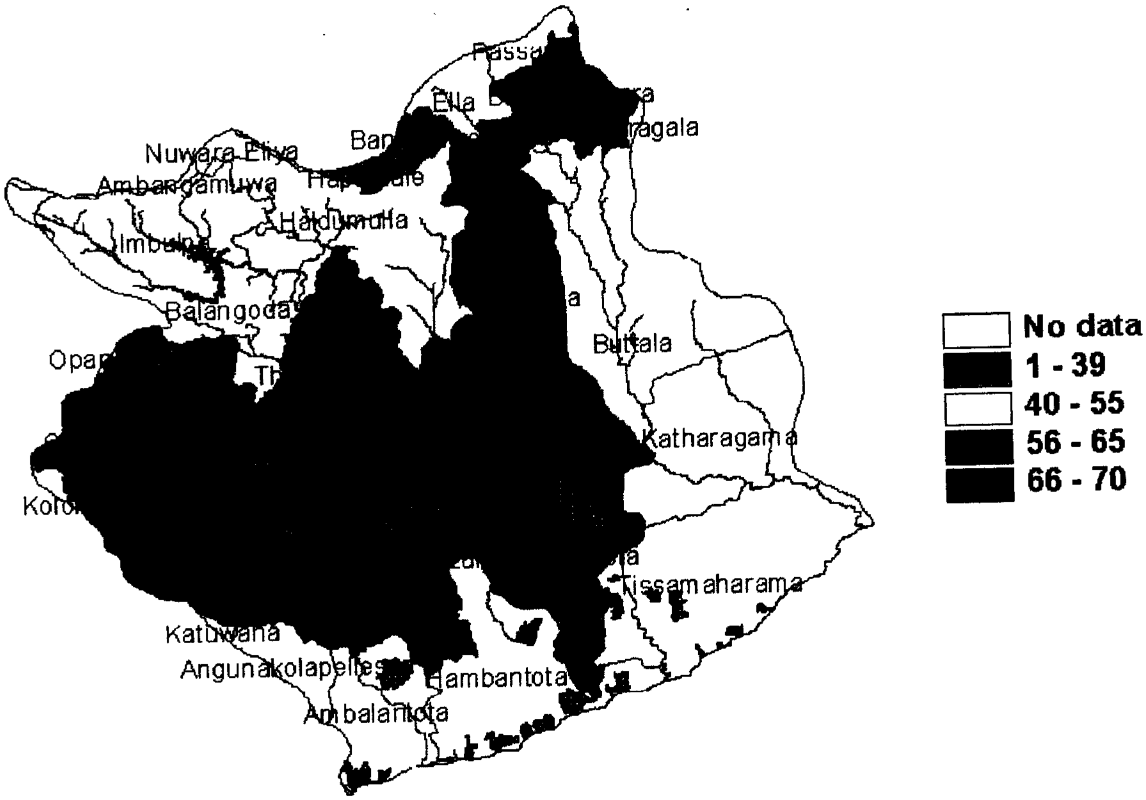

Figure 18 Distribution of people with food and economic support (percentages)

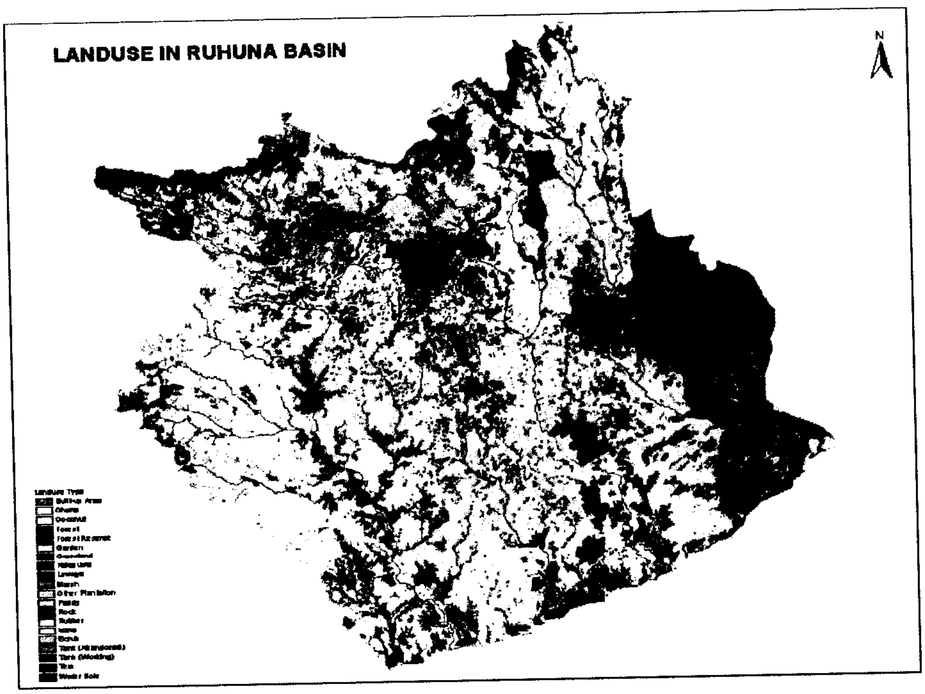

Figure 19 Major land covers in Ruhuna basins

Land Use

Tea and rubber are grown as commercial crops in the upper basin area, and rice is the major crop in the plains. The major land uses in the basins are: forests (29%), scrubland (26%), *chena* (shifting cultivation, 23%), and paddy (10%) and home gardens (12%). However, there are significant differences in land use among the main sub basins (Panabokke et al. 2002). In the Menik Ganga and Walawe basins, forests account for 57 percent and 17 percent, respectively (figure 19).

Because of the undulating nature of the landscape in the entire low-country region, namely DL 5, DL 1 and IL 2, one observes a contrasting land use pattern within each meso-basin. For example in the whole region paddy cultivation is practiced in the poorly drained bottomland inland valleys, while shifting cultivation is practiced on the adjacent well-drained upland.

Table 2 Dominant land use types in the dry zone of Ruhuna Basins

AER	**Sub-basin**	**Dominant land use type**
DL5	Walawe Ganga	Irrigated paddy and homestead settlements over the whole landscape.
	Malala Oya	Irrigated/semi-irrigated paddy bottomland/sparse chena cropland in upland.
	Kirindi Oya	Irrigated paddy in alluvial plain and also in residual plain in new area of the Kirindi Oya Irrigation Settlement Project (KOISP)/sparse chena cropland in upland.
	Menik Ganga	Natural forest cover of the National Park with sporadic settlements in the periphery.
DL1	Walawe Ganga	Irrigated paddy and settlements under the Uda Walawe command area. Rain-fed sugarcane, Sevenagala. Forest and nature reserves in the reservoir catchment.
	Malala Oya	Some small tank cascade settlements. Sparse chena cropland and scrubland in upland.
	Kirindi Oya	A few isolated small tank settlements. Sparse chena cropland, scrubland, and natural and plantation forest cover in upland.
	Menik Ganga	Rain-fed sugarcane, Pelawatta. Natural forest cover: both dense and open forest cover and protected areas of the National Park.

(*Source:* Panabokke, 2002)

Table 3 Dominant land use types in wet and intermediate zones of Ruhuna Basins

AER	Sub-basin	Dominant land use type
IL2 and IM 2	Walawe, Kirindi & Menik	Across all three basins, the dominant land use is settled homesteads with semi-perennial crops, some coconut, banana, papaw, sugarcane and mixed home-garden. Small extent of forest reserves and some pinus plantations in the steeper land. Some open natural forest and savannah and less steep land. Soil-erosion hazard is fairly high on badly aligned roadways, road banks and badly managed chena land.
IU 2	Mainly Walawe	IU 2 covers the higher elevation areas, mainly the highland region of the Walawe basin, and a very small proportions of the upper Kirindi Oya. Well-managed tea plantations, and some forest (pinus) plantations together with some eucalyptus cover most of the IU2 area. Also some steep inaccessible lands are located along the Belihul Oya and Weli Oya sub-watersheds.
WM2	Mainly Walawe	WM 2 is mainly confined to the upper and mid-western portion of the Walawe Ganga sub-basin. The dominant land use here is the typical mixed Kandyan forest garden type of settlement. Some terraced paddy fields on the moderately sloping land can also be seen east of Balangoda.

Chapter 2

Surface Water Resources

General

Based on the gross water balance for the basin (table 4) the annual per capita (surface) water resources is estimated at 2,291 m^3. The annual values however hide the seasonal variations, and water shortages during the yala season. The Kirindi Oya basin is the most water-stressed of the Ruhana basins with the lowest per capita surface runoff, relatively high flow requirements for environmental purposes and water problems faced by the farmers. The potential for further development of water resources within the Kirindi Oya basin is, therefore, negligible and several studies have been undertaken to explore the options for interbasin transfer.

Table 4 Gross water balance, Ruhuna Basins (30 year average)

Basin	**Catchment Area (km^2)**	**Annual Precipitation (Million m^3)**	**Annual Surface Runoff (Million m^3)**	**Annual Escape to the Sea (Million m^3)**
Walawe Ganga	2,471	4,596	1,524	525
Kirindi Oya	1,165	1,713	469	74
Menik Ganga	1,287	2,009	352	326
Malala Oya	402	441	78	Not available
Other	253	252	45	Not available
Total	5,578	9,011	2,468	Not determined

Source: Jayatillake 2002a.

Table 5 shows that a very small amount of water in the Kirindi Oya is discharged to the sea. The comparatively high water resources availability in the Walawe basin can be attributed to the contribution by both monsoons to the water resources, as discussed earlier. Although the major portion of runoff in Menik Ganga sub-basin flows to sea, this amount is small a percent of rainfall, indicating high use by sectors including irrigation and environment.

Table 5 Surface water resources in the Ruhuna basin.

Subbasin	Unit	Walawe Ganga	Kirindi Oya	Menik Ganga	Malala Ara + Other	Total Ruhuna Basins
Area	km^2	2,471	1,165	1,287	655	5,578
Population 2001	'000	637	225	133	79	1,074
Average Annual Rainfall	mm	1,860	1,470	1,561	1,058	1,574
Average Annual Rainfall Volume	Million m^3	4,596	1,713	2,009	693	9,011
Average Annual Surface Runoff	Million m^3	1,524	469	352	116	2,461
	% Rainfall	33	27	18	17	27
Average Annual Escape to Sea	Million m^3	525	74	326	n/a	925
Escape to Sea	% Rainfall	11	4	16	n/a	11
	% Runoff	34	16	93	n/a	38
Gross Annual Rainfall Volume Per Capita	m^3	7,215	7,611	15,105	8,772	8,390
Gross Annual Surface Water Resources Per Capita	m^3	2,392	2,084	2,647	1,468	2,291

Temporal variation of surface water resources: Maha and Yala Seasons

There is substantial seasonal variation in water resources availability of due to the high seasonal variability of rainfall and evapotranspiration. The basin has a high year-to-year, inter-regional and inter-seasonal variability of rainfall, generally greater extremes than elsewhere in the country. Tables 6 and 7 summarize the availability of water resources in the Ruhuna basins during maha and yala, respectively.

Table 6 Surface-water resources: Ruhuna basins, maha season.

Subbasin		Walawe Ganga	Kirindi Oya	Menik Ganga	Malala Ara	Other	Total Ruhuna Basins
Average Seasonal Rainfall	mm	1,125	976	1051	763	603	1,007
Average Seasonal Surface Runoff	Million m^3	1,271	345	273	130		2,019
	% Rainfall	46	30	20	42		35
Average Seasonal Escape to Sea	Million m^3	341	37	261	n/a		639
	% Rainfall	12	3	19	n/a		11
	% Runoff	27	11	96	n/a		32
Gross Seasonal Rainfall volume Per Capita	m^3	4,066	4,364	12,411	5,823		5,094
Gross Seasonal Surface Water Resources Per Capita	m^3	1,859	1,325	2,505	990		1,795

Table 7 Surface water resources, Ruhuna basins, yala season

Sub Basin	Unit	Walawe Ganga	Kirindi Oya	Menik Ganga	Malala Ara	Other	Total Ruhuna Basins
Average Seasonal Rainfall	mm	735	494	510	333	397	567
Average Seasonal Surface Runoff	Million m^3	893	159	85	60		1,197
	% Rainfall	49	28	13	45		36
Average Seasonal Escape to Sea	Million m^3	184	26	80	n/a		290
	% Rainfall	10	5	12	n/a		9
	% Runoff	21	16	94			24
Seasonal Surface Water Resources Per Capita	m^3	1,306	609	780	504		1,064

Rainfall-Runoff Ratio

There is little difference in the rainfall runoff ratio in either season other than that of Menik Ganga. However, the rainfall runoff ratio does reduce rapidly from west to east with Walawe having the highest ratio.

River Flows

Figure 20 illustrates the average annual flows of the rivers at the outfall estimated from the available hydrological data from existing river gauging stations. The figure does not show any distinct trends, however, year-to-year fluctuations are considerable.

Note that the Walawe flow series (Figure 20) is for the period 1942 to 1969 after which the gauge location was changed following completion of the Uda Walawe reservoir. The records for the other stations are for the period 1969 to 2000.

Recent field inspections have revealed that the maintenance of the gauging stations is inadequate, although observations continue. The recent hydrological records for these, and other rivers in Sri Lanka, should be used with caution. Greater attention is being focused on the needs for sustained hydrological record keeping through initiatives linked to the formation of a National Water Resources Administration and proposed policy changes to devolve river basin management to localized institutions.

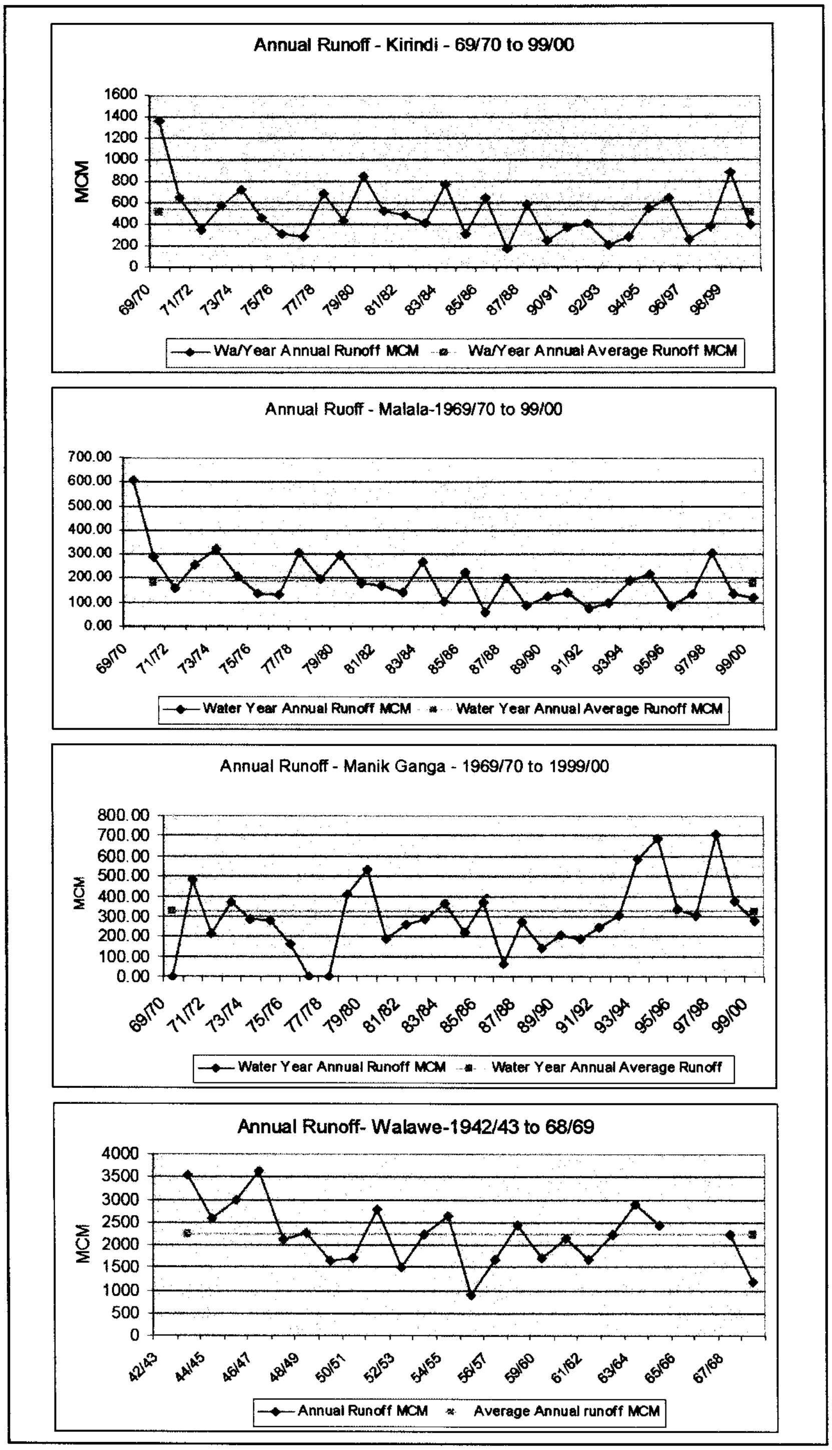

Figure 20 Mean annual flow in the main rivers

Water Withdrawals

The major user of surface water in the basins is agriculture. Using available data on irrigation water use, cultivated area, cropping intensities and assuming a reuse factor of 25 percent, the agricultural water use is estimated at 1,090 million m^3 per annum. The water used directly in industrial processes is about four million cubic meters. Use by agro-industry, such as withdrawals for Sevenagala and Pelawatta sugarcane lands, is included in the agricultural withdrawals. Accordingly, agriculture, industry and domestic water withdrawals are estimated as 98 percent, 1 percent and 1 percent, respectively. There are several abstractions along the riverbanks, which are not quantified and, therefore, result in errors in the estimates of actual water resources, withdrawals and escapes to the sea. It should also 0be noted that water nominally withdrawn for agriculture is used for many other purposes.

Chapter 3

Groundwater Resources

General

When the groundwater resources in the Ruhuna Basins are discussed, there is a heavy emphasis on the "regolith" or the shallow aquifer. This aquifer is mainly confined to the narrow inland valley systems of the undulating mantled plain topography in the DL 1 and DL 5 agro-ecological regions, as shown in figure 14.

Three major subdivisions of the regolith can be defined. The "collapsed zone" below the soil zone, extends to a depth of about 3 m and generally lies above the water table. The "saprolite" horizon, which is commonly termed as highly weathered rock; and the "saprock" horizon, which is slightly weathered and generally more open than fresh rock are the other two zones. The collapsed zone and saprolite and saprock horizons together are called regolith, the thickness of which is variable, but usually not more than 10 m in this region.

Traditional domestic wells and the more recent agro-wells usually penetrate only up to the top of the saprock horizon as hand digging using conventional tools becomes difficult beyond this layer or horizon. In a few instances, these wells have excavated a portion of the underlying fresh bedrock.

The recharge to the regolith aquifer takes place through infiltration of rainwater through the surface soil horizons during the rainy season. Based on studies conducted in DL1 agro-ecological region, but outside the Ruhuna basins, a recharge value of 100 mm could be adopted for this agro-ecological region in Ruhuna.

A deeper aquifer occurs in the fracture zone at depths beyond 40 m in the hard metamorphic rocks underlying the surface horizons. The aquifer is found wherever deeper tectonic forces have caused some degree of jointing or fracturing in the basement complex. The groundwater occurring in this zone of jointing or fracturing is referred to as the deep fracture groundwater. However, this deeper basement rock aquifer is more sporadic and related to the lineaments that occur in this hard rock region.

In the DL 5 agro-ecological region, which has a lower annual and seasonal rainfall, the recharge depends on the local rainfall. De Silva (1998) has shown that for Angunakolapelessa field station in DL 5 recharge was only 20 mm during the driest year on record (1989) when the annual rainfall was only 723 mm. During a more favorable year (1987) total rainfall was 1,040 mm and the estimated recharge was 60 mm.

Groundwater resources in the three major river basins are confined mainly to the lowland regions making up more than 90 percent of the area. Within the lowland plains, groundwater is confined to the dominant landforms of the Alluvial Plain (AP) and the Mantled Plain (MP).

As can seen in figure 5, soil unit no. 19, the Alluvial Plain is defined by the presence of alluvial soils while soil unit number 1,3 and 4 define the area of the Mantled Plain (MP). Small areas of alluvial soils also occur along the main river courses. Any useable groundwater can be ruled out in the areas of soil units 41 and 43 that define the Rock Knob Plain and Erosional Remnants (Inselbergs) (Panabokke, 2002).

Groundwater in the Alluvial Plain (AP)

The flat alluvial plain of the Kirindi Oya is located downstream of the present Lunugamvehera reservoir, and is bounded by the Wirawila wewa on its right-bank and the Tissa and Yodakandiya wewa on the left bank. The groundwater underlying this plain is recharged by irrigation water released from these reservoirs. Homesteads, dotting this flat plain, are situated on slightly raised elevations, typically one meter above the base level of the plain. These households have been settled since 1887, and traditionally draw their water supply from groundwater at about 3-5 meters below ground through open wells.

In the Walawe alluvial plain around the Ambalanthota town and its environs, the situation is very similar to that described for the Kirindi Oya flat plain, except that this Walawe alluvial plain is more dissected and is less continuous than the Kirindi Oya plain.

Within the narrow deposits of alluvial soils along the main river courses, small quantities of shallow groundwater are exploited for both domestic use and small lift-irrigation enterprises.

Formal groundwater observations are generally restricted to observation and production wells operated by the water supply utilities and the Water Resources Board (WRB). The extensive exploitation of the shallow aquifer for domestic supplies and increasingly for agricultural use remains poorly documented. No coordinated program of monitoring of shallow water table elevations, quality or use could be identified during this study. A short term study of water tables in the Uda Walawe basin reveals the dynamic interaction between surface water systems and the groundwater; however these observations should be more rigorously confirmed through routine measurement programs.

Unconsolidated Sediments

In the main unconsolidated sediments, river alluvium and coastal sands are identified in all the river basins, generally within the coastal zone (figure 4).

In the Walawe river basin, this river alluvium could be traced mainly downstream of the Ridiyagama tank. It is demarcated as extending to an area of about 100 km^2 towards the southern coastal belt, extending approximately 6–7 km along the coastal fringe. However, groundwater quality of the coastal sandy aquifer is generally saline with negligible freshwater lenses and therefore no quantification was done due to the poor potential productivity.

Investigations downstream of the Ridiyagama tank indicate variations in the sandy aquifer to include medium to coarse sand and gravel that is partially confined by clay lenses. The thickness of this aquifer decreases in both east and west directions. In some localities, this sandy aquifer is covered by hard clay with compacted iron nodules.

River alluviums are demarcated in both Kirindi Oya and Malala Oya river basins. In the Kirindi Oya basin, the occurrence of the sandy aquifer is proven by test drilling results obtained from the Water Resources Board (WRB). According to the data, a sandy alluvium aquifer unit occurs in the areas downstream of the Tissa tank and in localities around Kirinda, Koththamalli yaya and

Gangeyaya. Shallow boreholes drilled in these aquifer units are used as an additional water source for the present water supplies in Tissamaharama area. Even though, of comparatively restricted distribution and poor in quality, sandy alluvial aquifers are also found close to the coastal belt.

In the Menik Ganga basin river alluviam could be occurring within a very limited extent in Yala National Park area. However, as no data are available on these aquifer units, no quantification of groundwater potential was possible during this study. Such estimations should be undertaken when detailed Hydrogeological studies have been carried out. Finally, it should be noted those surface water bodies such as tanks (Ridiyagama in the Walawe basin, Tissa and Weerawila in the Kirindi Oya basin) recharge all the sandy alluvial aquifers, in addition to direct recharge from seasonal rainfall.

Groundwater in the Mantled Plain (MP)

As shown in figure 5, the Mantled Plain (MP) includes the following soil map units.

Soil unit no. 1. Reddish brown earths and low humic gley soils–undulating.
Soil unit no. 3. Reddish brown earths with a large amount of gravel in subsoil–undulating terrain.
Soil unit no. 4. Reddish brown earths and solodized solonetz–undulating terrain.

Cross-reference to the AER map, figure 14, shows that most of the soil unit nos. 3 and 4 fall within the AER of DL 5. This is a semiarid environment, while soil unit no. 1 falls within the AER of DL 1, which is a semi-humid environment. Since both groundwater recharge and groundwater quality are poor within DL 5 and the soil units 3 and 4, this area is discounted as a useful groundwater resource.

The regolith aquifer is mainly confined to the valley bottom containing a narrow deposit of alluvial soils and extending to the whole of the low humic gley soil area. It is within the narrow inland valleys of this undulating landscape that the domestic wells of the village settlements are located. These wells are recharged during the wet season from October to January, and they have an adequate quantity of shallow groundwater for domestic needs to tide over the long dry season from May to September. However, in years of unusually low rainfall such wells tend to go dry, and hence the tube wells that have been constructed over the last 20 years by various donor agencies become very useful during such time.

Wherever there is a small village tank in the upstream portion of the inland valley it helps enhance the groundwater supply in the downstream portions. In fact, in the several small village tank cascades present within the Malala Oya basin, the groundwater supply in the village wells is substantially dependent on tank driven recharge.

In the case of the part of the Malala Oya basin above the Badagiriya tank fifteen discreet small tank cascade meso-basins can be defined. Within six of these cascades, namely, Mattala, Getakumbura, Ranmudu, Nikawewa, Indiwewa, and Gonnoruwa, there have been permanent village settlements for over 150 years. This has been possible because the shallow regolith aquifer within these cascades receives sufficient augmentation of the groundwater supply from the several small tanks that are present within the main valley of these cascades.

Groundwater Potential Zones in Alluvial Aquifers

As mentioned earlier, the main alluvial aquifers are located downstream of the Ridiyagama tank, mainly on the left bank of the Walawe river. In the Kirindi Oya basin, these aquifers have been identified downstream of Tissa and Weerawila tanks (figure 24).

Although no data are available for the coastal sand aquifers in the basins, prominent sand dunes have been identified by aerial photo interpretation. But detailed hydro-geological studies will be necessary to demarcate and quantify the groundwater potential in these areas.

Groundwater Potential Zones in Hard Rock Aquifers

Demarcation of Potential Zones

Data on the intensity of fracturing data available from borehole drilling logs have been incorporated with geo-structural features to categorize different groundwater potential zones. In this context, sufficient distribution of borehole sites could be plotted in hard rock areas with the exception of the more extreme upstream areas. Therefore, it was possible to demarcate potential groundwater zones within all river basins as shown in figures 21, 22 and 23.

In this study, observed well yields have been used to define groundwater potentialities. These zones are categorized in to four groups (Panabokke et al. 2002a):

1. Zone 1 - Well yields ranging from 0 to 10 liters per minute.
2. Zone 2 - Well yields ranging from 10 to 50 liters per minute
3. Zone 3 - Well yields ranging from 50 to 100 liters per minute
4. Zone 3 - Well yields more than 100 liters per minute

Most studies on well yields have been determined for tube wells installed to exploit the deep aquifer. The distribution of yield rates recorded for the 384 WRB tube wells are shown in figure 24. Records of yield rates for the wells in the shallow aquifer are not available. Due to the wide fluctuations in seasonal water table elevations the potential yields of shallow wells will vary significantly. Potential yield from the shallow aquifer was estimated from the estimates of temporal variations of the water table elevation; however, no consistent records are available (Jayawardane 2002).

Potential Zones in the Walawe Ganga sub-basin

Two zones with groundwater potential were identified northwest of Uda Walawe Reservoir mainly in the Balahuruwa area. Other areas are mainly found downstream of the Uda Walawe tank in Embilipitiya, Watiya, Liyangashatota and Kanuketiya areas. Of these the high potential zones in Embilipitiya area are mainly concentrated in crystalline marble rocks. Within this zone, the upper part of Katuwana and Middeniya consist mainly of a thick weathered aquifer. The recharge of the aquifers in Kanuketiya and Liyangahatota is from local rainfall with some contribution from recharge from the Walawe river and seepage from irrigation channels.

Potential Zones in Kirindi Oya and Malala Ara sub-basins

There are few high potential zones in these basins, although some areas do occur under the alluvial pans of the downstream areas of the Kirindi Oya. However, groundwater zones with moderate potential have been identified in Kuda Oya and Thanamalwila areas in the Kirindi Oya basin and Anukkangala area of the Malala ara basin, Figure 22.

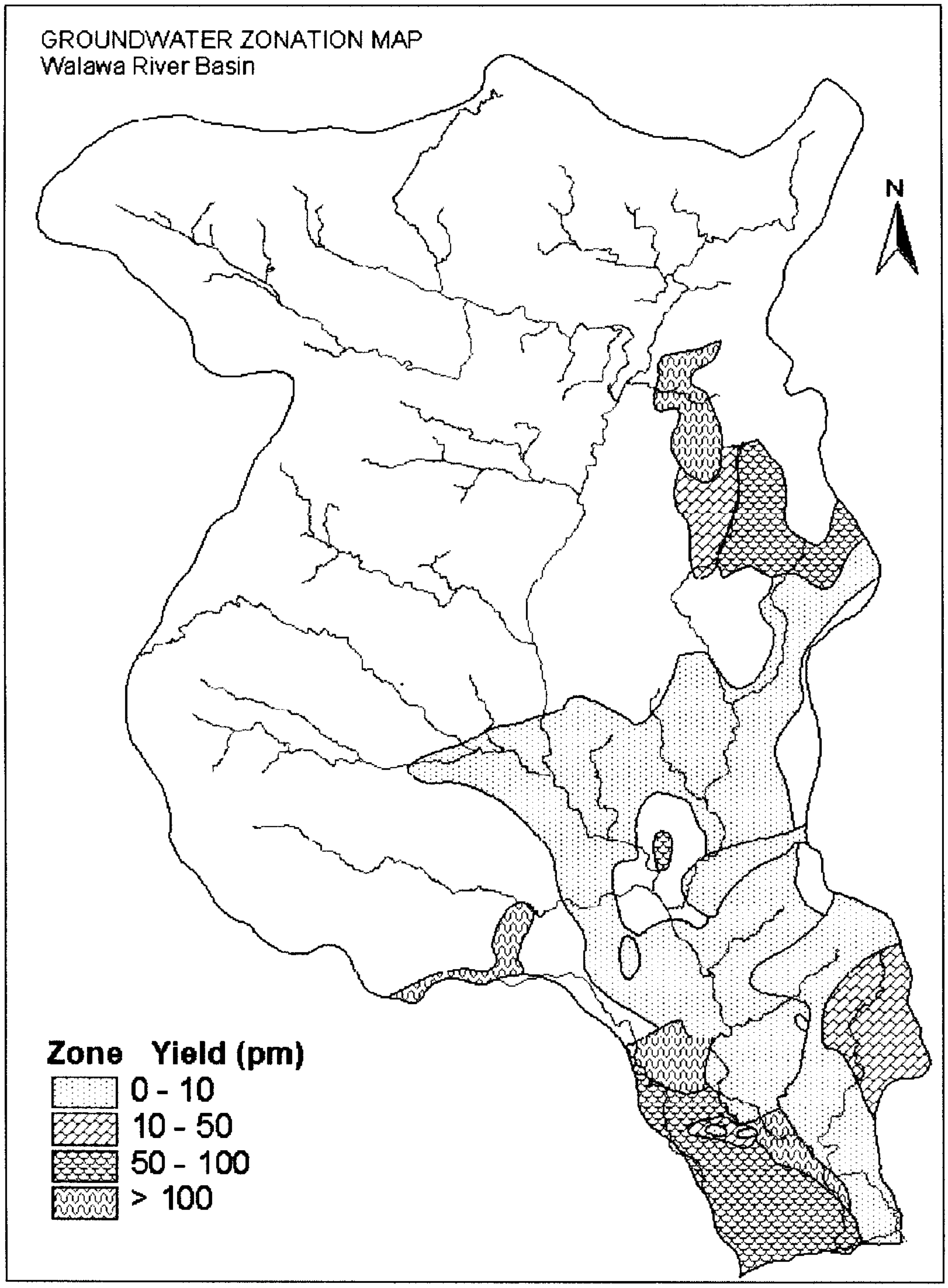

Figure 21 Zones with Groundwater Potential – Walawe Ganga
(Panabokke et al, 2002a)

Potential Zones in Menik Ganga sub-basin

The occurrence of high potential groundwater zones identified in the a) Badalkumbura area could be due to thick weathering of shallow aquifers and b) Lunugala, Buttala and Pelawatta areas due to deep fracturing as the depth varies from 30 to 50 m below ground level.

However, there is a possibility for high potential groundwater zones to occur in the Yala sanctuary area due to favorable geo-structural features according to interpretations of aerial photographs.

In addition, potential zones in Kataragama area can be explained by highly jointed tectonic features indicated in borehole data and geo-structural maps, Figure 23.

Aquifer Properties and Characteristics

Aquifer Characteristics

The geological characteristics of the basin have been discussed elsewhere in this case study. Considering the hydro-geology of the basin the ground water yielding aquifers can be divided in to two distinct groups. The shallow regolith aquifer, which is about 10 m thick and overlaying the basement rock and the deep fractured zones in the basement rock below 40 m. The shallow aquifer slopes gradually towards the southern coast. Therefore, this aquifer continuously drains to the sea under a positive hydraulic gradient. On average, at approximately 15-km inland from the coast the basement rock rises above the mean sea level. Therefore, the loss of fresh groundwater to the sea is significant and virtually uncontrollable. As such, the storage capacity of the aquifer is limited. Another significant feature of this basin is the well-distributed network of streams and rivers encouraging the rapid interchange between river and aquifer. As such, the inherent storage capacity of the aquifer is further reduced (Jayawardane, 2002).

Most tube wells drilled in the study area were constructed for installation of hand pumps. Therefore, data for only a few pumping tests could be obtained for hard rock aquifers (*Source:* WRB Reports, G.R.R. Karunarathna).

Through the recent studies carried out by WRB it was possible to collect reliable pumping test data for locations in the downstream areas of Walawe basin where a productive sandy aquifer was identified. Based on these pumping test results, aquifer parameters are tabulated in table 8.

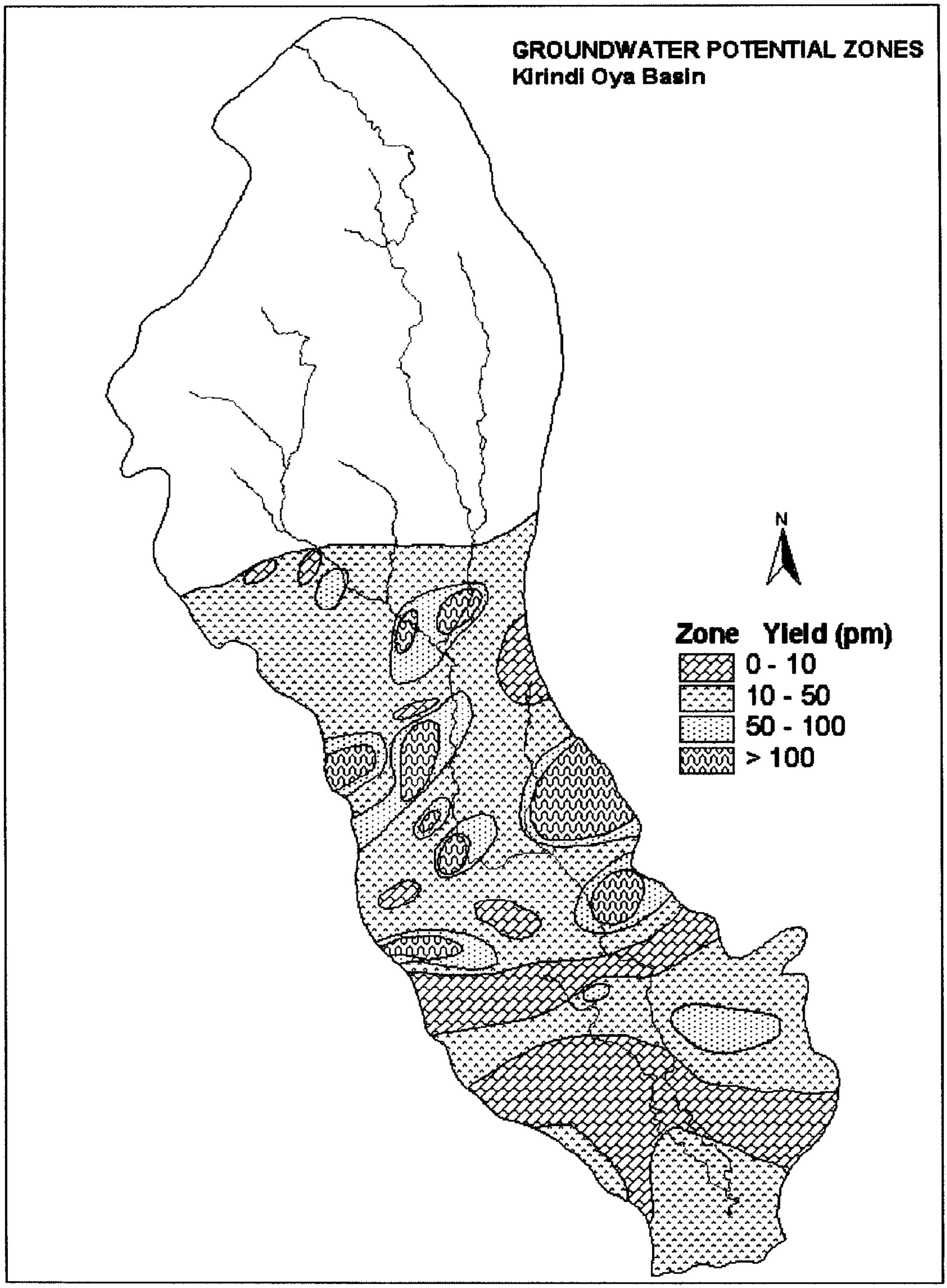

Figure 22 *Zones with Groundwater Potential – Kirindi Oya*
(Panabokke et al, 2002a)

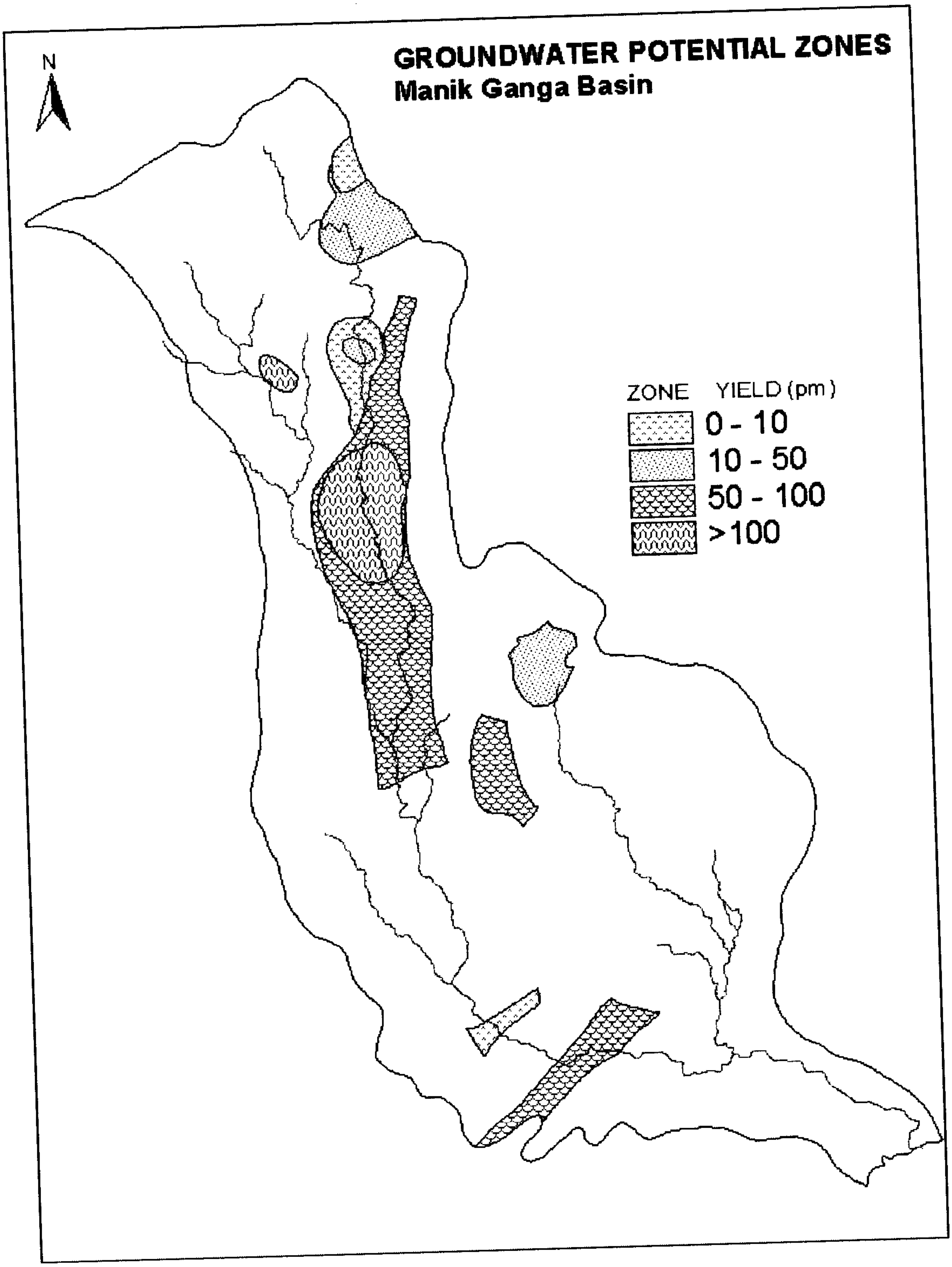

Figure 23 Zones with Groundwater Potential – Menik Ganga
(Panabokke et al, 2002a)

Table 8 Summary of pump test results

Basin	Formation	Specific Yield	Transmissivity (m^2/day)
Walawe	Hard rock	-	1–20
	Alluvium aquifer	0.12	30–60
Malala	Hard rock	-	-
	Alluvium aquifer	-	-
Kirindi	Hard rock	-	1–8
	Alluvium aquifer	0.08	5–20
Menik	Hard rock	-	1–15
	Alluvium aquifer	-	-

The high transmissivity values of the Menik Ganga basin could be explained by very high fracturing identified in and around the Pelawatta Sugar Cooperation and the Buttala town area. Comparatively high transmissivity values are also explained by the occurrence of high fracturing marble bands traced at Middeniya towards Angunakolapelessa and the western part of the downstream of the Walawe basin. Even though there are possibilities for the occurrence of moderate to high fractured aquifers in the upstream part of Walawe and all other river basins of the study area it was not possible to evaluate aquifer parameters due to the non availability of pumping test results.

Except for the high potential zones, the rest of the aquifers of the study area are poorly fractured with transmissivity values varying between 1 and 4 m^2/day. However, it is possible that other localized fracture zones occur within this poor aquifer zone.

Well Yields

There is information on a wide range of well yields available from well observations. But the majority are in the range 10 to over 100 liters per minute. Of 475 wells drilled and tested about 8 percent well found to be dry. This may be the result of poor site selection in the absence of adequate hydro-geological and geophysical surveys. However, both dry wells and those with poor yields have been incorporated when preparing hydro-geological maps to demarcate the areas with low groundwater potential.

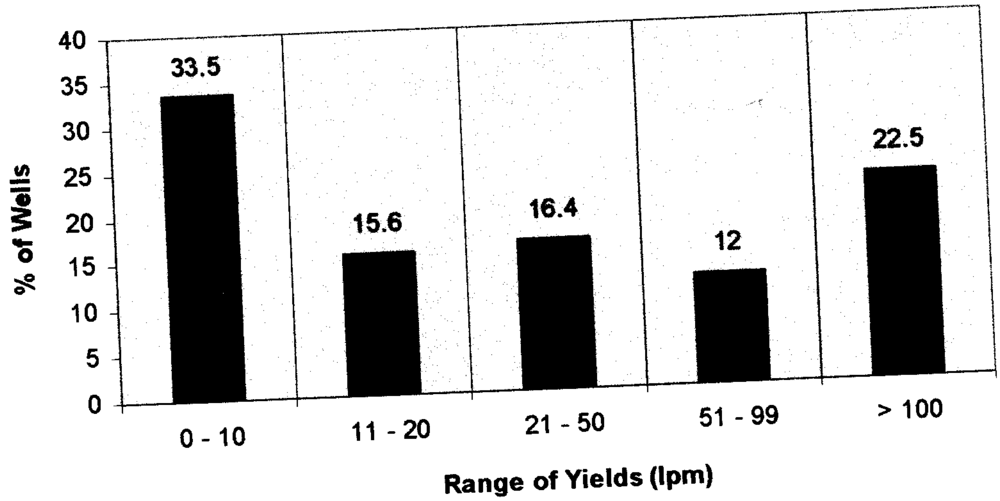

Figure 24 Distribution of recorded tube well yields (Panabokke, 2002)

About 35 percent of the tube wells tested gave yields of more than 50 liters per minute. Most of these wells are constructed within the highly fractured joint and lineament zones and most of them are production wells. However, these production wells are concentrated in a few locations and therefore may not be representative of the entire basins (Panabokke et al, 2002a).

Water Table

As noted above the observation of groundwater levels is inadequate for both the shallow and deep aquifers. Although earlier studies of groundwater in the Hambantota district have included water-level maps, these have been prepared from static water levels measured during the well construction. These maps cover the lower parts of the Walawe, Malala and Kirindi basins but give little indication of annual water table variations or long-term trends in water table elevation.

From the available observations, the subsurface flow can be generalized as being towards the southwest in the Walawe basin and towards the southeast in the Kirindi Oya basin. From these general patterns the main rivers can be defined as influent streams. The water table in the Walawe basin ranges from 1 to 5 meters, with the shallower levels being observed in the south and southeast parts of the basin. In general, the northwest part of the Kirindi Oya basin has the deepest water table at between 5 and 8 meters.

Safe Yield of the Aquifers

In the absence of long-term groundwater level observations it is not possible to evaluate the long-term trends in the groundwater regimes in terms of either levels or quality. However, in the sandy alluvial aquifer of the Walawe basin, a short time series of water levels has been obtained which illustrate the dynamics of the interactions between the groundwater and the operation of the major irrigation systems.

Without long-term water-level records it is impossible to establish normal well hydrographs, with a few exceptions for the localized observations in the sandy alluvial and hard rock aquifers observed during specific research programs. Therefore, it has not been possible to establish the safe yield of the different aquifers defined in this study.

Groundwater Recharge

In the absence of formal groundwater records, recharge has been estimated using secondary data methods as below.

Method I – Recharge assessment from rainfall. Assessment of geological and hydro-geological conditions reveals almost similar recharge characteristics across the entire river basin. Experience elsewhere, in similar hard rock terrain, indicate that about 7–10 % of the total rainfall contribute to recharge.

In addition, according to infiltration data available in similar terrains, rainfall recharge of the sandy alluvial aquifer has been considered to be about 40% of rainfall.

Method II – Recharge assessment from water-level data. The following equation has been used;

Groundwater Recharge = Change in Groundwater Level * Specific Yield

However, some variations of recharge conditions occur in hilly areas of different river basins. Therefore, the rainfall recharge calculation has been applied to the flat terrains and not to the rocky, hilly areas due to high runoff and lower infiltration rates found in these areas.

Based on the above two methods, the calculated recharges of river basins are summarized in table 9.

Table 9 Estimated Recharge of groundwater (by basin)

Basin	**Method**	**Groundwater Recharge (mm)**	
		Hard Rock Terrain	**Alluvial Aquifer**
Walawe	Method I	112	560
	Method II	-	420
Kirindi	Method I	80	400
	Method II	-	280
Malala	Method I	64	280
	Method II	-	-
Menik	Method I	72	360
	Method II	-	-

Groundwater Indicators and Indices for the Basin

Some areas of the basin undergo severe shortage of groundwater during certain periods of drought years. The conventional indicators do not reflect this and, therefore, the indicators computed are not representative of the groundwater condition and vulnerability of these areas. Further refinement of these indices is required. This can be done by improving the quality and distribution of data as well as by modifying the indices to suit the character of the aquifers in this basin.

The benefit of a well-developed set of indices and indicators for the basin should not be underestimated, as it is an important tool to forecast the sustainability of the groundwater resource, to guide the development of a groundwater policy and to monitor remedial measures to sustain this resource.

The changes to the groundwater resource and the environment as a whole occur gradually and become apparent over a long period of time, sometimes after the occurrence of effectively irreparable damage. As such, early identification would be very beneficial. The change in the forest cover of Sri Lanka from 1965 to 1992 is an example of the gradual effects of anthropogenic and natural activity occurring in the country. The development and application of indicators may enable the identification of such changes earlier. The recent shortages of water may also be due to the changes to the policy of water management. It is clear that a well-distributed system of small tanks would have contributed to a gradual recharge of the groundwater off-setting the inherent weakness of the regolith aquifer (Jayawardane 2002).

The groundwater reliance, measured as the ratio of average annual groundwater withdrawals to the total average annual withdrawals, is 3 percent (Jayawardane 2002; Jayatillake 2002). High vulnerability to declining groundwater levels and salt water intrusion exists in the lower reaches of the basins.

Chapter 4

Human Impacts on Water Resources

Water Quality

Standards

The Sri Lanka Standards Institute and the Central Environmental Authority are the national agencies that recommend standards of water quality for drinking, bathing, irrigation and other uses. The standards for the quality of drinking water are stipulated in the Sri Lanka Standards Institute Standard No. 614 of 1983. The recommended standards for chemical contents are summarized in Table 10 and for bacteriological quality as follows:

- *Pipe-borne public water supplies:*
  - In any given year, 95 percent of the samples shall contain no coliform organisms per 100 ml.
  - None of the samples examined shall contain more than 3 coliform organisms per 100 ml.
  - Coliform organisms shall not be detectable in 100 ml of any consecutive samples.
  - None of the samples shall contain E.Coli in 100 ml.
- *Individual or small community supplies (including wells, bores and springs):*
  - None of the samples examined shall contain more than 10 coliform organisms per 100 ml on repeated examination.
  - No sample shall contain E.coli in 100 ml (Wickremage, pers. comm. 2002)

Table 10 Sri Lanka chemical standards for drinking water quality

Substance or Characteristic (Unit)	Maximum Desirable	Maximum Permissible
Color	5	30
Turbidity (NTU)	2	8
PH	7-8.5	6.5-9
Electrical conductivity (us/cm)	750	3500
Chloride (as Cl) (mg/l)	200	1200
Free residual chlorine (as Cl_2) (mg/l)	-	0.2
Total alkalinity (as $CaCo_3$) (mg/l)	200	400
Free ammonia (mg/l)	-	0.06
Albuminoidal ammonia (mg/l)	-	0.15
Nitrates (as N) (mg/l)	-	10
Nitrites (as N) (mg/l)	-	0.01
Total phosphates (as PO_4) (mg/l)	-	2
Fluorides (as F) (mg/l)	0.6	1.5
Total dissolved solids (mg/l)	500	2000
Total hardness (mg/l)	250	600
Calcium (mg/l)	100	240
Total iron as Fe (mg/l)	0.3	1
Sulphate as SO_4 (mg/l)	200	400

Source: Senaratne 2002b.

Issues Related to Drinking Water Quality

The following are the major concerns related to the quality of drinking water have been reported in the study area:

- High iron concentration in groundwater (Hambantota, Buttala, Kataragama).
- High electrical conductivity in groundwater (especially, close to the sea).
- High hardness in water (in Hambantota area).
- Inadequate treatment of water in the schemes other than those operated by the NWSDB.
- Disposal of solid wastes into or close to the water bodies.
- Discharging effluents from industries to surface water bodies, e.g., discharging a) effluents of the Embilipitiya paper mill into the Walawe river, b) water from service stations into streams and rivers, and c) discharging effluents from small-scale paddy processing industries to surface water streams.
- High fluoride contents in groundwater (Tanamalwila, Tissamaharama and northern parts of Hambantota and Ambalantota) (Senaratne 2002b) including Fluoride toxicity symptoms in the form of stained teeth evident among children and teenagers who have used water from tube wells when quite young (Handawela 2002).

Table 11 Biological water quality in the coastal area of the Ruhuna basins.

Location	**BOD (mg/l)**	**Fecal coliform cells/100 ml**
Kalametiya lagoon	8.1	120
Kachchigal ara inlet	6.7	100
Walawe Ganga (Ambalantota bridge)	6.9	50
Karagan *lewaya* (salt pan)	3.4	0
Malala ara	6.4	70
Malala lagoon	3.7	10
Bundala lagoon	9.0	60
Kirindi Oya	6.5	20
Kirinda fishery harbor	10.1	30

Source: Handawela 2002.

Table 11 indicates that the increase of population in the coastal areas degrades the background water quality.

Groundwater Quality

In general, the lower parts of all the basins have poor-quality water except in some localized pockets. The electrical conductivity of the groundwater in most places of the study area is around 1,000 μs/cm. However, there are some localized high electrical conductivity zones among the otherwise good water-quality areas.

The fluoride content of groundwater is generally high in most places of the study area and specifically the areas of Thanamalwila, Kuda Oya, Wetiya, Mamadala, Padalangala, and Malala. Field data indicate that the hardness, chloride and sulphate content and alkalinity of the groundwater are generally high. However, the availability of data is insufficient to prepare detailed geo-hydro-chemical maps for any if these parameters.

The mean annual rainfall of the basin is 1,574 mm. Although some studies show a decline in the annual rainfall in the country over the last few years, in the long term no significant change in the annual rainfall patterns in this basin has been proven (Silva 1984; NSF 2000). The mean annual rainfall distribution within the basin in the short term shows large variations, with some areas of the basin recording annual rainfall as low as 723 mm (De Silva 1998). The monthly rainfall patterns have also shown increasing variation over the years. The lowest consecutive 6-month rainfall of 148.4 mm was recorded in the Kirindi Oya and Malala Oya basins in 2001. These areas experienced a serious shortage of groundwater during this time. Although the mean annual rainfall and the consequent recharge of the aquifer within the basin are reasonably good, some areas of the basin have experienced severe water shortages of catastrophic proportions in the recent past causing hardship to the inhabitants of these areas.

At present the use of groundwater for irrigation is not very significant, however the viability of planned industrial and infrastructure development identified as essential for the socioeconomic sustainability of the region would depend a lot on the availability of groundwater. Therefore, the availability of groundwater of acceptable quality will be a key factor for the sustenance of the population and for the socioeconomic stability of the region.

Studies in the southern district of Hambantota in the Ruhuna basin have concluded that about 60 percent of the wells are contaminated with saline water (Silva 1984). Excessive depth of dug wells and overexploitation of wells may have contributed to the high salinity. Due to the geological composition, the occurrence of fluoride in groundwater is high (Dissanayake 1985). Analysis of data from limited studies of tube wells in selected areas of the basin has shown that only 21 percent of the wells have acceptable levels of electric conductivity and fluoride content according to current Sri Lankan standards for potable water (SLS 614: 1983 Parts 1 and 2). The distribution of the water quality of WRB tube wells is shown in figure 24. More significant is that, of these wells, 32 percent of the high-yielding wells with over 100 liters per minute have acceptable levels of electric conductivity and fluoride content as shown in figure 25. However, studies on shallow wells have recorded a much higher number of wells of acceptable water quality (Jayawardane, 2002).

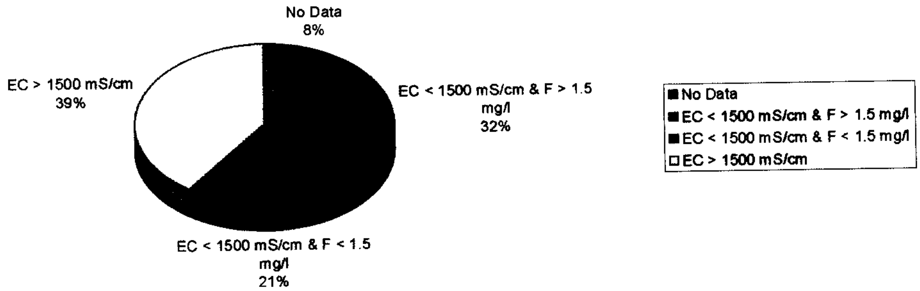

Figure 25 Distribution of Water Quality Parameters of 384 Tube Wells by WRB (Jayawardane, 2002)

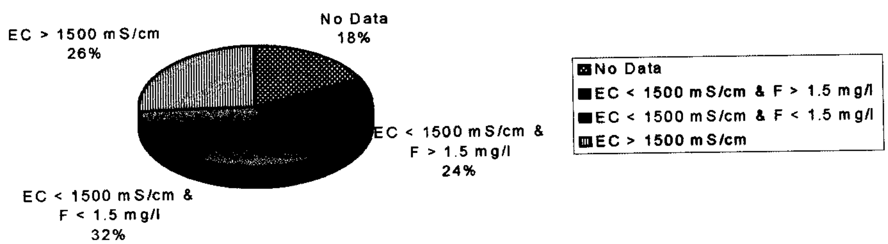

Figure 26 Distribution of Water Quality Parameters of Wells with yields greater than 100 lpm (Jayawardane, 2002)

Water Resources Development and Infrastructure

Water resources in the basins are relatively highly developed to support hydropower generation and irrigation. There are 20 large reservoirs (three having a capacity of over 100 million m^3) and about 280 smaller reservoirs, giving a total storage capacity of about 900 million m^3. There are numerous river diversion systems, used mainly for irrigation supplies, including 11 large and about 610 small cross-river structures. The storage capacity of surface water in the three main basins ranges from 57 percent of annual (surface) water flows for the Kirindi Oya, 40 percent for the Walawe Ganga and about 5 percent for the Menik Ganga.

Table 12 Degree of Water Resources Development in Ruhuna Basins

	Walawe	Malala	Kirindi	Menik	Total Ruhuna basins
Major irrigation reservoirs					
Capacity < 1 million m^3	0	2	3	1	6
Capacity > 1 million m^3	6	5	8	1	20
Minor irrigation reservoirs (village tanks)	91	41	64	90	279
Diversion structures (major)	7	0	3	1	11
Diversion structures (minor)	719	1	70	104	894
Storage capacity of major reservoirs (million m^3)	607	11.1	263.3	1.6	883
Storage capacity of Minor Reservoirs (million m^3)	3.3	1.4	2.2	15.6	22.8
Total storage capacity (million m^3)	610.3	12.6	265.3	17.2	906
Total water spread area (ha)	5002	443	1856	192	7493
Storage/annual water resources (%)	40	17	57	5	37

The density of minor irrigation reservoirs is highest in the Malala basin. Figure 2 shows the locations of more important reservoirs.

The three largest reservoirs are Uda Walawe and Samanalawewa in the Walawe subbasin and Lunugamvehera (Kirindi Oya) reservoir in the Kirindi Oya subbasin. Out of these, the Uda Walawe reservoir is multipurpose, used for irrigation and hydropower generation. The Samanalawewa reservoir is constructed for hydropower generation. The Lunugamvehera reservoir was originally designed as a multipurpose reservoir, but was later redesignated for irrigation only.

Several new programs for water resources development have been undertaken in the basins. The Mau ara project includes construction of a reservoir across Mau ara, a tributary of Walawe, and the diversion of the water to the Malala Oya basin. The diversion canal feeds a large number of medium size and minor irrigation tanks, on the way. The Weli Oya project includes construction of a diversion weir across Weli Oya, another tributary of Walawe, and conveying water to deficit areas in the Moneragala district.

Changes in land cover will affect water resources. At present, about 2,720 km^2 of land are under forest and scrubland cover (Handawela 2002). In the Walawe and Kirindi Oya basins, substantial development works have been carried out and the forest and scrub cover have been reduced by 30 percent and 23 percent, respectively, over the past 40 years, which is a higher rate of land use change than the national average.

Data and Information on Water Resources

Hydrometric Network

The currently installed hydrometric network includes 19 rainfall stations, 25 agro-meteorological stations and 6 water-level stations. In addition, there is a gauge post near the outfall of the Walawe Ganga, and a gauge post established to obtain the data required for the Weli Oya diversion structure. Tidal effects affect the accuracy of the gauge post observations; furthermore the period of record is relatively short.

Table 13 Main components of the hydrometric network.

Basin	Rain Gauges	River Gauging Stations	Station/Tributary
Walawe Ganga	8	2+2	Thimbolketiya/Rakwana Oya
			Panamure/Hulanda Oya
			Weli Oya/Weli Oya
			Ambalantota/Main river
Karagan Oya		-	N S[a]
Malala Oya		-	N S
Embilikala Oya		-	N S
Kirindi Oya	5	3	Wellawaya
			Kuda Oya/Kuda Oya
			Thanamalwila
Bambawe ara		-	N S
Mahasiliwa Oya		-	N S
Butawa Oya		-	N S
Menik Ganga	1	1	Kataragama
Total	14	6+2	

[a]N S =No station.

Several deficiencies in the hydrometric network were identified during the case study. The network for observing river water level and estimating flows is clearly inadequate to provide sound information regarding water resources in the basins. Considering the changes of topography and land use patterns of the upper and lower watersheds of the river basins, the gauging stations need to be better distributed spatially and located strategically to provide information, such as the amount of water escaping to the sea. Similarly, rainfall stations need to be distributed so as to capture the variations of different agro-ecological and climatic zones.

Groundwater Monitoring

Groundwater data collection has been focused on obtaining sufficient information to enable the exploitation of the groundwater resources. Thus investigations have been limited to the collection of data for the purpose of finding locations where groundwater of good quality is available to meet the immediate needs of the inhabitants in the area. Limited surveys of dug wells and information on tube wells, including data on pumping tests obtained during construction are available. Aerial photographs have been studied to establish areas having geological characteristics most likely to have groundwater sources. Landsat imagery has been used to a limited extent to obtain geomorphologic and geological data, lineament and bedding interpretation. Geophysical explorations have also been done in selected areas. Chemical analyses of water samples have also been done to a very limited extent. Apart from using some of this data for positioning bore holes, data have not been made collated to provide useful information for the management or improvement of the groundwater resources of the basin. As a result some data are not available for beneficial groundwater improvement programs and in other cases data are lost or duplicated by other studies. An ongoing study (JICA 2001) is attempting to collate all available data and present them in a GIS environment. The study includes some areas of the Ruhuna basin.

As noted elsewhere in this report the hydrometric and geohydrology networks for collection of basic water resources information are limited in the extent and precision of observations. Although some initiatives are underway or will commence in the near future, the status of data collection has been allowed to deteriorate over the past few decades. These problems extend beyond the Ruhuna area and require a concerted effort on the part of the Sri Lanka national agencies to reestablish a comprehensive data collection and management system. The rapid expansion of access to the Internet offers opportunities to place such basic data in the public domain to ensure that stakeholders can have access to relevant and up to date information.

Socioeconomic Data

In addition to hydrometric data, a substantial amount of socioeconomic data related to water resources is being collected at the District Secretary level, Divisional Secretary level and lower administration levels. The data include those related to health, sanitation, incomes and risk management, which would be useful when developing a comprehensive basin management plan and strategies proposed under the draft new water legislations. However, there are deficiencies of data transmission, analysis, storage and dissemination that hinder the effective use of data.

Chapter 5

Needs, Uses and Demands

Water for Food

The Department of Census and Statistics publishes data related to agricultural productivity at the District level as shown in Tables 14 and 15.

Table 14 Command area and cropping intensities in different irrigation systems

	Major Irrigation	Minor Irrigation	Rain-fed	Ruhuna Basins
Command area	38,000	8,600	4,800	52,400
Cropping Intensity	1.43	1.27	1.17	

Sources: Irrigation Department, the Department of Agrarian Development and the Department of Census and Statistics.

Table 14 indicates the dominant position of major irrigation schemes however the cropping intensities in minor irrigation and rain-fed agriculture in the basins are also higher than the national average. Paddy rice is the major food crop in the basins. Typically about 46,600 hectares (about 90%) are irrigated with only a small area cultivated with other field crops. Generally two crops can be grown during the year, one in the maha season (October to March) and the other in the yala season (April to September).

Table 15 Mean Paddy yields by administrative districts and Uda Walawe scheme.

District	Major		Minor		Rain-fed	
	Maha	Yala	Maha	Yala	Maha	Yala
Ratnapura	4.168	3.522	3.208	3.082	2.622	2.590
Badulla	4.044	4.206	3.626	3.628	2.794	3.060
Moneragala	4.242	4.208	3.384	3.202	3.116	2.865
Hambantota	4.428	4.298	3.544	3.514	3.032	2.672
Uda Walawe	4.916	4.898				

Table 15 shows the mean paddy yield over past 5 years, confirming that yields at the Uda Walawe scheme, managed by the Mahaweli Authority, are relatively high. They are in fact among the highest in Sri Lanka. The table also confirms that yields decrease from major schemes through minor schemes to rain-fed agriculture.

There are over 300 irrigation schemes in the basins and as water deliveries are not systematically measured it is difficult to estimate an accurate value for basin-level water productivity. IWMI has carried out extensive studies in the Kirindi Oya and Uda Walawe scheme, and some scheme-level values are available. In terms of water productivity, the amount of water used to produce one kilogram of crop has been shown in a study in the Kirindi Oya basin to be 0.29, 0.16, and 0.14 kg m^{-3} of evapotranspiration, net irrigation, and gross irrigation requirement, respectively.

The water used by major irrigation systems, defined as irrigation duty at the reservoir outlet, is about 1,500 mm in the maha season and 1,800 mm in the yala season. However, a proportion of these releases are used indirectly by small irrigation systems and for domestic use, so that the actual irrigation applications are lower. However it should be noted that withdrawals for irrigation account for more than 95 percent of the total volume diverted.

Studies at the Kirindi Oya project indicate that financial returns to irrigated paddy production (value of the marketed output less cash costs of production) average approximately Rs 22,053 per ha (US$315 per ha) (Renwick 2001). The costs, listed in decreasing order, are labor (35%), materials (23%), land (20%) and machinery (14%). Based on estimates of paddy water use in this scheme, the average per ha economic return to water has been estimated at Rs 16,748 (US$239).

With the realization of higher incomes resulting from cultivation of cash crops and the comparatively low water requirement, a significant portion of irrigated areas initially cultivated for paddy have been recently converted to other crops. Such changes are notable in the Uda Walawe and Kirindi Oya schemes. Banana has been one of the popular crops and, now, a part of the Uda Walawe scheme has popularly become known as the "banana kingdom."

Loss of croplands within the coastal wetlands due to salinity and waterlogging is reported in Kalametiya-Lunama: 220 ha paddy, Malala-Bundala: four village tanks and associated paddy fields, and Dorawa: about 80 ha of paddy has been lost from productive use (Handawela 2002).

Though paddy is the major crop in major irrigation schemes, studies carried out in the Bodagama cascade of village tanks (within the Ruhuna basin) reveal that rain-fed *chena* (slash and burn) cultivation as the main enterprise of the local population in that area. The staple food of some people is *kurakkan* and for some others minor millets (Panabokke et al. 2002). It is known that the landholdings under village tanks are smaller when compared to major irrigation settlements. The population served by the village tanks is proportionately higher than that in the major irrigation systems and therefore the importance of cereals, other than paddy, may be underestimated in national programs.

The Ruhuna basins produce large amounts of marine fish, inland fish, cow and buffalo milk (Weerasinghe et al. 2002). Studies in the Bodagama cascade by Panabokke et al. (2002) indicate that cattle rearing and production of curd are among the main enterprises of the villagers. It may be noted that all these activities are supported by water collected in the village tanks.

Inland fisheries are becoming popular with the support of government. These fisheries are an important source of protein for the rural population; however no detailed information is available on the productivity of inland fishery at the basin level. The total daily lagoon fish catch at Pallemalala in 1993 was 50-60 kg. In the Uda Walawe reservoir the total fish catch fluctuates but with the increasing number of fishing crafts, catch per craft has declined (Handawela 2002). IWMI has carried out studies on inland fisheries in the Kirindi Oya project. The studies show that inland fishermen operate an average of 318 days per year, and about 70 percent of the fishermen have their own boats. The catch per unit effort or per boat trip averaged about 35 kg of which about 1.4 kg is retained for home consumption (Renwick 2001). The information suggests that inland fishing constitutes a substantial source of nutrition for the rural people, keeping many of them gainfully employed.

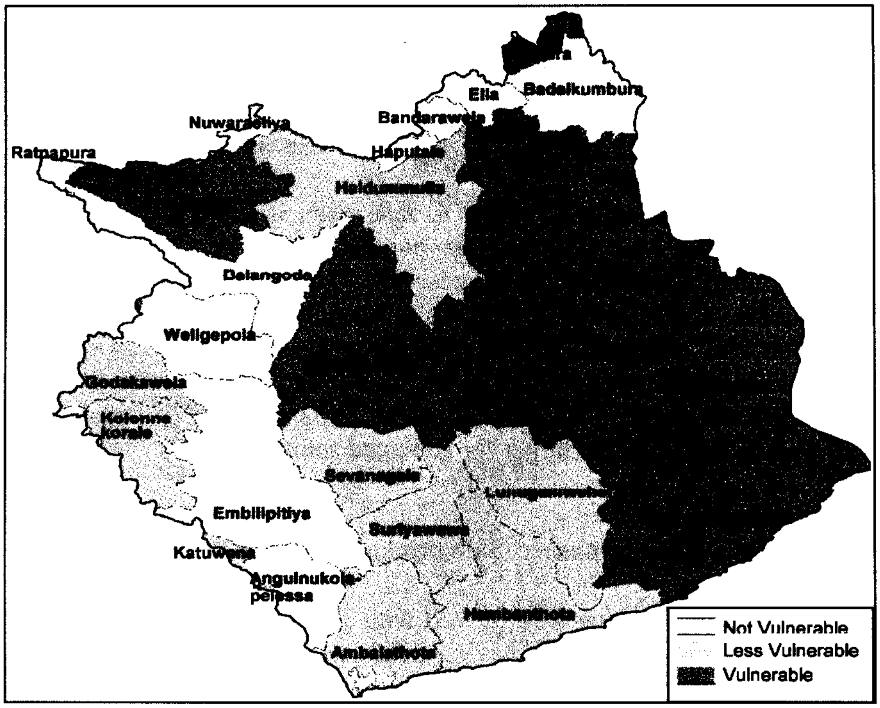

Figure 27 Food security in Ruhuna Basins

World Food Programme (WFP) carried out a study to assess the level of food security in Sri Lanka and the information for the Ruhuna Basins is shown in the figure 27. The information clearly indicates the positive impact of irrigation development on the food security in the area where the population was evaluated as not, or slightly, vulnerable to food shortages. In comparison in the Menik Ganga, the more easterly basin, dependent on rain fed agriculture the population is classified as being vulnerable to food supply problems.

With agricultural (and associated domestic) uses dominating water demands the principles adopted in planning, development and management of water resources in the Ruhuna basins are predictably dominated by considerations on improving agricultural production and productivity. Given the importance of agriculture in the region as a source of employment and income generation, agricultural considerations feature strongly in all decisions pertaining to water use.

The general thrust in planning and development of water resources in the region has been to exploit all "viable" resources for capacity expansion of irrigated agriculture. Irrigation development serves as a means of both creating opportunities for the poor to engage in gainful income-generating activities and improving equity (Atapattu 2002).

Water for Basic Needs

Access to Basic Needs

Based on the district-level data, the present level of access to safe water is about 60 percent and access to adequate sanitation is about 71 percent of the population in the Ruhuna basins. However, there are different estimates by different sources. The National Census of 2001 is expected to provide more accurate values but the results are to be published in late 2002. The national coverage of safe water and adequate sanitation is 75 and 73 percent, respectively (Shanmugarajah 2002). National targets for water supply in Sri Lanka are ambitious with the target for access to safe drinking water set at 85 percent of the population by 2010 and 100 percent by the year 2025. Similarly, the national target for adequate sanitation is 100 percent for 2035 (Wickremarage 2002).

Access to safe drinking water in the Ruhuna basins: Safe drinking water is generally regarded as:

- the water extracted from a protected dug well (a well with protected walls and an apron around the well and proper drainage facilities, having a safe means of drawing water)
- water from protected springs
- water from a tube well with hand pump
- water from a pipe-borne water system from an uncontaminated source or after treatment

Unsafe drinking water may thus be regarded as the water consumed directly from a river, streams, unprotected springs, lakes, reservoirs and tanks, and water from unprotected wells.

Some of the major towns in the basins obtain domestic water from irrigation reservoirs whilst other towns abstract water from the river. Although the return flow from agricultural lands helps maintain minimum flow requirements during the dry months in the Walawe subbasin, the water quality is low due to the presence of agrochemicals.

Population Served by Safe Drinking Water

The following table illustrates the number of persons served with safe water sources and unprotected sources in the study area.

Table 16 Access to safe drinking water sources

Divisional Secretary Division	Population within the Study Area	Population Served by Protected Sources		Population Served by Unprotected Sources
		Piped Supplies	Dug Wells and Hand-Pump Wells	
Ambalantota	50,316	21,000	28,359	957
Hambantota	53,985	36,518	14,905	2,562
Lunugamvehera	35,072	27,364	378	7,330
Sooriyawewa	40,502	7,446	8,240	24,816
Tissamaharama	75,500	13,583	10,477	51,440
Badalkumbura	32,020	2,300	8,545	21,175
Buttala and Kataragama	56,920	7,581	13,480	35,859
Sevanagala	39,450	0	9,840	29,610
Thanamalwila	23,152	4,580	8,245	10,327
Wellawaya	63,450	15,500	15,635	32,315
Haldummulla	37,666	24,142	2,857	10,667
Embilipitiya	118,307	26,937	33,140	58,230
Kolonna	54,932	20,445	19,835	14,652
Imbulpe	60,430	12,656	892	46,882
Balangoda	77,026	21,388	26,650	28,988
Bandarawela	42,044	23,690	6,845	11,509
Ella	21,808	14,804	4,934	2,070
Haputale	20,118	11,870	3,226	5,022
Godakawela	54,318	33,097	669	20,552
Weligepola	30,500	2,352	13,238	14,910
Total	987,516	327,253 (33%)	230,390 (23%)	429,873 (44%)

Table 16 shows that the ratio of population served by protected sources is 56 percent. Considering that the duration of water supply does not extend up to 24 hours in several pipe-borne water supply schemes, the above percentages should be considered as an, optimistic, upper limit of the current levels of access to "safe and adequate water supply."

Access to Adequate Sanitation

Adequate sanitation can be regarded as having means for safe disposal of excreta. Thus, adequate sanitary facilities may be defined as access to one or more of:

- latrines with septic tanks
- off-set pit latrines (single or duel pit)
- direct pit latrines with water seal
- pipe-borne sewage disposal system

Inadequate sanitary facilities include direct pit latrines without water seals, having improvised latrines or having no latrines.

Data collected on sanitation coverage reveal that within the study area the following methods of excreta disposal are used:

- direct pit latrines without water seal
- poor flush pit latrines (direct and off-set)
- latrines with septic tanks
- defecation on ground

Assessment of Population with Adequate Sanitation

Table 17 illustrates the provisions for adequate sanitation facilities in the study area, indicating about 59% of population within the study area having adequate sanitation facilities.

Table 17 Access to adequate sanitation

Divisional Secretary Division	Population within the Study Area	Population Served by Safe Sanitation Facilities	Population Using Unhygienic Excreta Disposal Methods
Ambalantota	50,316	48,267	2,049
Hambantota	53,985	44,552	9,433
Lunugamvehera	35,072	18,517	16,555
Sooriyawewa	40,502	20,688	19,814
Tissamaharama	75,500	37,182	38,318
Badalkumbura	32,020	203,46	11,674
Buttala and Kataragama	56,920	26,555	30,365
Sevanagala	39,450	16,865	22,585
Thanamalwila	23,152	9,460	13,692
Wellawaya	63,450	21,974	41,476
Haldummulla	37,666	27,594	10,072
Embilipitiya	118,307	66,748	51,559
Kolonna	54,932	49,646	5,286
Imbulpe	60,430	39,540	20,890
Balangoda	77,026	26,438	50,588
Bandarawela	42,044	31,907	10,137
Ella	21,808	16,932	4,876
Haputale	20,118	16,080	4,038
Godakawela	54,318	28,158	26,160
Weligepola	30,500	19,245	11,255
Total	987,516	586,607 (59%)	400,906 (41%)

Sources of Water

Water sources for different uses vary within the basins, depending on several factors. In urban areas, water for all uses was obtained mainly from public water-supply systems. In rural areas, water from wells is used for drinking and cooking purposes; rivers, streams, canals or tanks are used for bathing, washing clothes or watering animals.

Public water-supply systems are used for non-domestic and non-basic needs too. These uses include gardening for commercial purposes; for example tea nurseries in the hill country and small cottage-type industries. Among the non-domestic usage, the basic needs of water are found to be mainly in schools (mainly for drinking and cleaning purposes), hospitals and other medical institutions (drinking, cooking, cleaning, washing, toilet flushing), religious institutions, and other government and public institutions.

Different sources are in use within the study area for the supply of water. Most commonly used sources are:

Surface water
- rivers
- irrigation reservoirs
- village tanks
- streams

Groundwater
- protected shallow wells (individual and common)
- unprotected shallow wells
- deep wells with hand pumps
- springs
- deep wells with motorized pumps

Rainwater

Water Extraction Methods

Surface sources/spring: Surface sources such as springs are used directly mostly for bathing, washing or watering animals. Generally piped systems are supplied with treated water, however some rural systems are supplied with untreated water.

Water is stored in storage tanks, and is distributed to the consumers through a pipe distribution system. The use of Ferro cement technology (rich cement mortar with a wire mesh) for the construction of storage or break-pressure tanks was observed in many rural and small town water schemes. This technology has been effective in bringing down the capital investment.

Shallow dug wells: Shallow dug wells are the most common and early type of a source of water used in the country. The protected wells have the typical and characteristic features of the well stein, the inner lining and the apron around the well. These are regarded to provide adequate protection from contaminated water. Unprotected wells are often simply an open hole dug in the ground, where seepage and direct inflow of surface drainage to the well is possible. The existence of unprotected wells was observed especially in the lower parts of the basins in the study area.

Wells for individual or shared use are common. Shared wells, usually provided by a public institution, are located in accessible places and are used by about 5–10 households.

The most common arrangement to draw the water from shallow wells (both protected and unprotected) is the rope and bucket. In more affluent households and in institutions water is lifted, using motorized pumps, to overhead tanks. A few instances of the usage of rope pump, introduced by a water supply project (Community Water Supply and Sanitation Project) were also observed.

Deep wells with hand pump: The deep wells with hand pumps are a relatively new type of water supply, first introduced by the NWSDB about 25 years ago. Wells are drilled by mechanical rig and the overburden lined with a PVC casing (125-mm diameter). These wells are commonly installed with a hand pump in the villages in the lower reaches of the basin. These wells are provided as a common facility to be shared by 12-20 households.

Deep wells with motorized pumps: Deep wells of larger diameters, with motorized pumps installed are used in a few instances to provide water for piped water-supply schemes. The locations where these exist are given elsewhere in the report.

Rainwater harvesting: Rainwater harvesting is commonly used in Hambantota and Badulla districts in locations where other water sources are scarce. Rainwater collected from the roofs of individual households led to either brick or ferro-cement tanks. This is an individual household water-supply method.

Usage of different types of sources: The usage of different sources within the study area by domestic households is presented in table 16, based on the data collected by the Department of Census and Statistics (2000). Although the data have been given on the basis of the Divisional Secretary (DS) Area, they were resampled to the river basins by adopting the percentage areas covered within the basin and assuming homogeneous distribution within each DS Division.

Projects, programs and agencies

World Bank-assisted Community Water Supply and Sanitation Project, implemented from 1991 to 1995 covered the districts of Ratnapura and Badulla. The Rural Water Supply and Sanitation Project, assisted by ADB is presently being implemented (from 1999 to 2005) in Hambantota and Moneragala districts, which also cover parts of the basins. There have also been water supply components in Integrated Rural Development Projects of the Hambantota, Moneragala, Badulla and Ratnapura districts.

Community participation: It has been realized that managing rural facilities, which are relatively small and dispersed across a wide area, is difficult for centralized agencies. It is more appropriate to actively involve the beneficiary communities in the management of the schemes and in response, rural water supply schemes (i.e., schemes serving a population of 6000 or less) managed by Community-Based Organizations have been established recently.

The Community Water Supply and Sanitation Project (CWSSP), which was implemented with the financial assistance of the World Bank, has thus established CBOs to manage rural water supply schemes in Ratnapura, Badulla and Matara districts. CWSSP has implemented 131 water schemes within the study area.

The Third Water Supply and Sanitation Project (TWSSP) is being implemented in six districts in the island including Hambantota and Monaragala with the assistance of the ADB. This project also adopts similar approaches to those of CWSSP with respect to the management of the schemes by CBOs. The Third Water Supply and Sanitation Project has implemented 58 water schemes within the study area.

CBOs fund the operation & maintenance of these schemes through a tariff structure formulated for the individual scheme. These water supplies cater for small towns (with served population of about 2,000 to 6,000) and villages (with served population of less than 2,000) in the study area.

The Plantation Housing and Social Welfare Trust (PHSWT) is making a significant effort to provide water supply and sanitation to the resident plantation community in the government-owned estates with an approach similar to that of the CWSSP. However, the level of community participation is not as high as in the CWSSP and TWSSP. This innovative program is attempting to change the attitudes of the estate communities from being fully dependent into self-sustaining communities. PHSWT is presently operating in seven districts including Ratnapura and Badulla, and has implemented 23 water schemes within the case study area.

There are three Urban Councils and 17 Pradeshiya Sabhas (local authorities) within the study area, which play an important role in providing domestic water supplies. The bulk water supply to Urban Council areas is from the NWSDB schemes. Within the study basin 78 water supply schemes are owned and operated by local authorities for small towns.

Several other agencies also have implemented water supply schemes within the study basin. The National Housing Development Authority has implemented 12 water supply schemes, which are currently operated by local authorities.

Various plantation sector companies also have implemented water schemes for the estate sector. Within the study basin there are 43 such schemes and at present they are operated by private sector agencies.

Water Supply to Main Towns

NWSDB is the agency providing water to all main towns in the study area except for Wellawaya and Rakwana. The Pradeshiya Sabha is providing Wellawaya with water, whilst a CBO provides water in Rakwana.

The majority of town water supplies are abstracted from surface water sources.

However, the percentages of Non-Revenue Water (NRW) are high in main town supplies compared to the village and small town supplies. The ratio of NRW in the above schemes varies from 10% to 50%.

In terms of supply hours there are limitations and most of the town supplies have not been able to provide water for 24 hours a day. Out of 11 main town supply schemes, only four schemes, serving 42 percent of the metered connections provide a 24-hour supply.

Water-Related Diseases

A survey of healthcare carried out for World Water Assessment Program (WWAP) collected information on the following classes of diseases:

Waterborne diseases

Cholera, typhoid and paratyphoid, shigellosis, amebiasis with liver infection, amebiasis (other), diarrhea and gastroenteritis of presumed infectious origin, other intestinal diseases, acute hepatitis A, B and chronic, and other acute and unspecified hepatitis, summarized in Table 18.

Table 18 Incidence of waterborne diseases

District	Average No. of Cases	Average No. of Deaths	Cases/1,000 Persons	Deaths/1,000 Persons
Hambantota	38,811	1	7.4	Negligible
Badulla	9,224	14	12	Negligible
Moneragala	6,351	5	16	Negligible
Ratnapura	9,221	20	9.1	Negligible

Water-related diseases

Dengue fever, dengue hemorrhagic fever, malaria, filariasis, helminiasis, sequelea of infectious and parasitic diseases, and other infectious and parasitic diseases summarized in Table 19.

Table 19 Incidence of water-related diseases

District	Average No. of Cases	Average No. of Deaths	Cases/1,000 Persons	Deaths/1,000 Persons
Hambantota	1,104	0	2.1	Negligible
Badulla	2,683	4	3.7	Negligible
Moneragala	8,299	3	21.0	Negligible
Ratnapura	2,607	3	2.6	Negligible

The statistics shown above are based on the reported (government) hospital cases and deaths. However, the actual cases may be more, as the patients could seek medical assistance from other private medical institutions and doctors or could take indigenous treatments, which do not get reported.

The above reported cases are for the entire district, and hence are not strictly related to the study area. However, this indicates the general pattern of the waterborne diseases in the study area.

Water for Ecosystems

Wetlands

"The paddy fields in Ruhuna basins are the most valuable wetlands I've ever seen," according to a famous American ecologist (Galbraith, pers. comm.). Besides these agricultural wetlands, the basins include several other ecologically important reserves, including the Ruhuna, Uda Walawe, Bundala National Parks, the lagoon systems adjacent to the Bundala National Park and a large number of man-made reservoirs. The wetlands in the basins are summarized in Table 20:

Table 20 Summary of Wetlands in the Ruhuna basins

Coastal Lagoons	Area (ha)	Irrigated Lands/ Paddy Lands	Area (ha)	Irrigation Reservoirs	Area (ha)
Kalametiya	604				
Lunama	192	Major irrigation	38,000		
Sittakkala	75				
Karagan lewaya	835				
Maha lewaya	260				
Koholankala	390	Minor (village) irrigation	8,600		
Malala	650				
Embilikala	430				
Bundala	520	Rain-fed paddy	4,800		
Palatupana & other	178			Major/minor irrigation	7,500
Gonalabedde & other	15				
Total	4,150		52,400		7,500

Sources: Handawela 2002; Jayatillake 2002.

Sri Lanka's first Ramsar Convention site, the Bundala National Park, covers an area of 6,216 hectares. This area is designated as a Sanctuary under the Flora and Fauna Protection Ordinance. Five shallow, brackish lagoons form the major feature of this park. They are Maha lewaya, Koholankala, Malala, Embilikala and Bundala. These wetlands cover about 2,250 hectares (37% of the Park area). Bundala is the most important wintering area in southern Sri Lanka for migratory shorebirds, sometimes accommodating about 20,000 birds. Elephants and leopards are also found in Bundala (CEA/ARCADIS/EUROCONSULT 1999). Table 21 summarizes the main fauna that enrich the bio-diversity of the Bundala National Park:

Table 21 Bio-diversity in the Bundala National Park

Species Type	Birds	Mammals	Reptiles	Amphibians	Fish
Nationally Threatened		5	13	1	
Endemic		1	6	1	
Total	197	32	48	15	32

Source: Handawela 2002.

The Ruhuna National Park is one of the largest national parks in the country, covering some 126,000 hectares, of which about 64 percent of the park lies within the Ruhuna basins; specifically in the Menik basin. The Park is the habitat for six endangered and two threatened animal species. Wetlands in the park include Menik Ganga estuary. Most of the wetlands here are well protected. This park is a popular attraction for tourists and water scarcity generally results in the closure of the park to tourists during August and September.

Protected areas

Table 22 Protected areas in the Ruhuna basins

Subbasin	Name	Extent (ha)	Characteristics
Menik Ganga and east of it	Yala National Park	126,800	Extends beyond Menik Ganga to Kumbukkan Oya. 64% lies within the Ruhuna basins.
Malala, Weligatta, Kirindi Oya (right bank)	Bundala National Park	6,216	Overused for commercial tourism
Walawe	Uda Walawe National Park	30,821	Famous for elephants
Walawe watershed with Mahaweli	Horton Plains National Park	3,162	Overused for commercial tourism
Kirindi Oya	Lunugamwehera National Park	23,000	Not used for tourism. Treated as replacement for Wirawila – Tissa which is fading in significance as a sanctuary
Kachchigal ara fed by Walawe	Kalametiya – Lunama Sanctuary	712	Highly disturbed by irrigation returnflow
Walawe	Mandunagala Sanctuary	138	Forest hermitage and hot springs close by
Kirindi Oya	Wirawila -Tissa Sanctuary	4,170	Due to pressure of development has lost significance as a sanctuary
Kirindi Oya	Ravana Ella Sanctuary	Small area	Tourist attraction
Atulla – Palatupana	Nimalawa Sanctuary	1,065	Forest hermitage
Menik Ganga	Kataragama Sanctuary	800	Heavily visited Kataragama shrine
Menik Ganga	Katagamuwa Sanctuary	1,010	Adjacent to Kataragama
Malala Oya	Pallemalala Sanctuary	Small area	Virtually absorbed into the Bundala National Park

Sources: Handawela, 2002 and various other sources.

The total land area protected under relevant legislation is about 1,200 km^2, i.e., about 21 percent of the basin area as shown in Table 22.

Water Use by ecosystems

Water use by ecosystems is the highest in Menik Ganga, which flows through the Ruhuna National Park. Concerns about the protection of downstream lagoons exist, as the minimum base flows of the rivers are becoming inadequate to meet the requirements of ecosystems.

Water use by forests and wild life is tentatively estimated as 810 and 836 million m^3, respectively (Handawela 2002). A more detailed and comprehensive assessment using modern tools is required to assess this vital component for future basin planning.

Water for Industry

Major industry types and water use. The major industry types in the basin include hotels and rest houses, a garment industry, paper industry, plantation industry, and small industries. In terms of water usage, the existing paper factory and two sugarcane processing industries are prominent.

The usage of water by industries is categorized as follows:

- Usage category 1. For main process of production/services
- Usage category 2. For activities assisting the main process (such as cooling, heating, fire fighting, washing, etc.)
- Usage category 3. For basic requirements (e.g., for consumption of the workers, sanitary facilities, gardening, etc.)

Water use by industry in the basins is not extensive due to the limited development of water-based industries. Existing water use by industries located in the basins is listed in table 23. It can be seen that the paper industry is the single largest user in the basins. It is a potential source of pollution as well. However current use is less than 19% of total water diversions in the basin. However, the emphasis and priorities for development of the area are changing with greater emphasis being placed on development of alternatives to agricultural employment. The Southern Region Development Plan includes the following developments within the case study area:

- Harbor at Hambantota
- BOI industrial park at Walawe
- Local industrial site in Hambantota DS Division
- Human settlement activities in Hambantota DS Division
- Airport in Lunugamvehera
- Railway up to Kataragama from Matara
- Leather processing and wastewater treatment plant at Bataatha
- Rakwana Oya diversion to Chandrika wewa
- Model village for 100 families
- Fisheries village (Senaratne 2002b)

Although these interventions are designed to mitigate poverty and other socioeconomic problems prevalent in the area, they are likely to increase the existing stresses on the water resources.

The water requirement of Ruhunupura is estimated at around 100 million m^3. Studies are being conducted to use waters from the Ruhuna basin rivers to meet the demands for water from the new for industries. Construction of detention reservoirs and inter-basin transfers are being considered to capture the floodwater.

Table 23 Industrial water use in the Ruhuna river basins

No.	Type of Industry	Assessed Total Consumption (MCM) Walawe	Kirindi	Menik	Malala	Remarks
1	Hotels and rest houses	0.03	0.04	0.03	0.03	
2	Garment factories	0.03	0.03	0.01	0.01	
3	Paper industry	2.8				Presently, Embilipitiya mill is running at under-capacity
4	Sugarcane processing	0.2		0.25		
5	Paddy processing	0.03	0.01	0.01		Only some paddy processing industries use water for the production (boiling the paddy)
6	Plantation industry	0.09	0.09	0.07		Mainly tea processing
7	Automobile repair and servicing	0.01	0.01	0.01		Service stations, located in almost all town centers use water in plenty, and produce much-polluted wastewater
8	Building material manufacturing	0.03	0.01			Many brick kilns and cement-based product manufactories
9	Harbor/Fishery harbor		0.01		0.01	
10	Other	0.01	0.02	0.01	0.01	Small industries, etc.

No major industrial activities exist in the basin at present. Some small factories, mainly for the garment, paper and the hotels and rest houses associated with the tourist industry do exist. But water withdrawals are estimated as being less than 1 percent of the total withdrawals. It may be noted here that water used for sugarcane cultivation is accounted for in agriculture, although the cultivation is mainly for the sugar industry.

Source protection measures

Source protection measures are adopted by these industries only when they use their own water-supply systems and the source is located within their property. Where the industries are using water from public water-supply systems, there is no specific contribution from the industries towards source protection, apart from the payment of tariff for the consumption of water (Senaratne 2002).

However, major changes are expected when the proposed Ruhunupura City development, which will include an airport, industrial and commercial areas and a commercial harbor, is implemented. The water requirements of Ruhunupura are estimated as between 100 and 150 million m^3 annually. Studies are being conducted at present exploring the options for reservoirs to retain floodwaters from rivers to provide this resource.

Water for Energy

Role of hydropower at national level

The history of power generation in Sri Lanka goes back to about 100 years. The private sector pioneered this industry at the beginning. But the public sector took over the management in 1927 with the creation of the Department of Government Electrical Undertakings. Ceylon Electricity

Board was created in 1969, and since then this institution has been the major establishment for electrical power generation and distribution.

A public-owned distribution company titled Lanka Electrical Company (LECO) was created in 1983, and it handles distribution of electricity in selected areas close to Colombo. In 2000, the amount of electricity sales by LECO was about 16 percent of the total generation.

Private-sector participation in power generation has also increased in the recent past. In 2000, the private sector operated 11 small hydropower plants and 6 thermal plants. The total generation by the private sector including the hired plants was 1,324 Gwh out of a total of 6,686 Gwh (about 20%).

With better living standards, the demand for electricity can be expected to continue to rise (Figure 28). The available data show that per capita power consumption has been rising during the past decade.

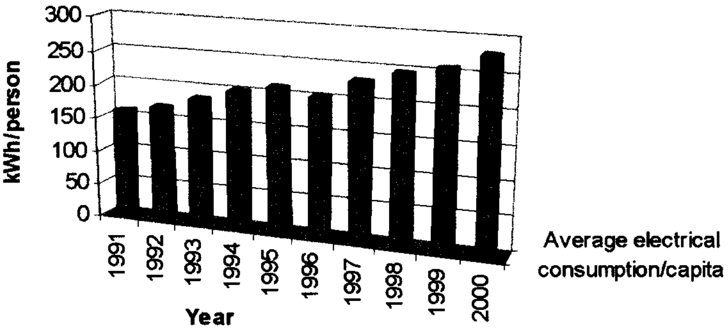

Figure 28 Average electrical consumption per capita at the national level (Somathilake, 2002)

It is obvious that power generation has to be expanded to meet the rising demand. However, the recent droughts have severely affected the generating capacity, and the government is looking for alternative means of power generation. As in the case of food security, health and sanitation, and domestic water supply, the challenge is to generate power at an affordable price for the general consumer.

Cost of production and tariff structure

The cost of hydropower generation is comparatively low. However, its dependence on favorable weather conditions has made hydropower an unreliable source. The recent droughts have resulted in power cuts, which adversely affected the national economy. The shift towards thermal sources has resulted in a higher production cost.

The overall average cost of power generation increased by 47 percent in 2000 to Rs 6.31 per kWh, while the average tariff increase was only 4 percent to Rs 4.60 per kWh. As a result, there was a net operating loss of Rs 6.728 million in 2000 (Central Bank 2001). However further adjustments to the tariff structure have been implemented during 2002.

During the past decade, dependence on hydropower, measured in terms of ratio of installed capacity under hydropower to total installed capacity steadily fell from about 80 percent to about 65 percent in 2000. Despite this, Sri Lanka faced a major power crisis, during 2001-2002, resulting in daily power cuts of up to 8 hours across the whole country. The drought that continued from the latter part of 2000 to 2002, in combination with the still high ratio of the share of hydropower to total power requirements was identified as the main reason for this. The actual share of hydropower, in terms of generation, was about 48 percent in 2000. The national targets relevant to power generation specify that reliable grid electricity is provided to at least 80 percent of the population at affordable prices and that the share of hydropower has to be reduced to about 32 percent by 2013.

Hydropower generation facilities in the Ruhuna basins are installed only in the Walawe subbasin. Uda Walawe reservoir, constructed in the 1960s, has an installed hydropower capacity of 6 MW. while at Samanalawewa the installed capacity is 120 MW, about 10 percent of the total installed capacity in Sri Lanka. Records at Samanalawewa show about 1.3 million m^3 of water were required to produce 1 GWh of energy (Somatilaka 2002). Water used for generation is recaptured downstream for reuse by irrigated agriculture, power generation and other uses in the downstream reaches.

Figure 29 shows the variations of hydropower generation with water availability. In the earlier part of the decade, the power generation was affected by leakage through the Samanalawewa dam, which was subject to intensive civil engineering studies.

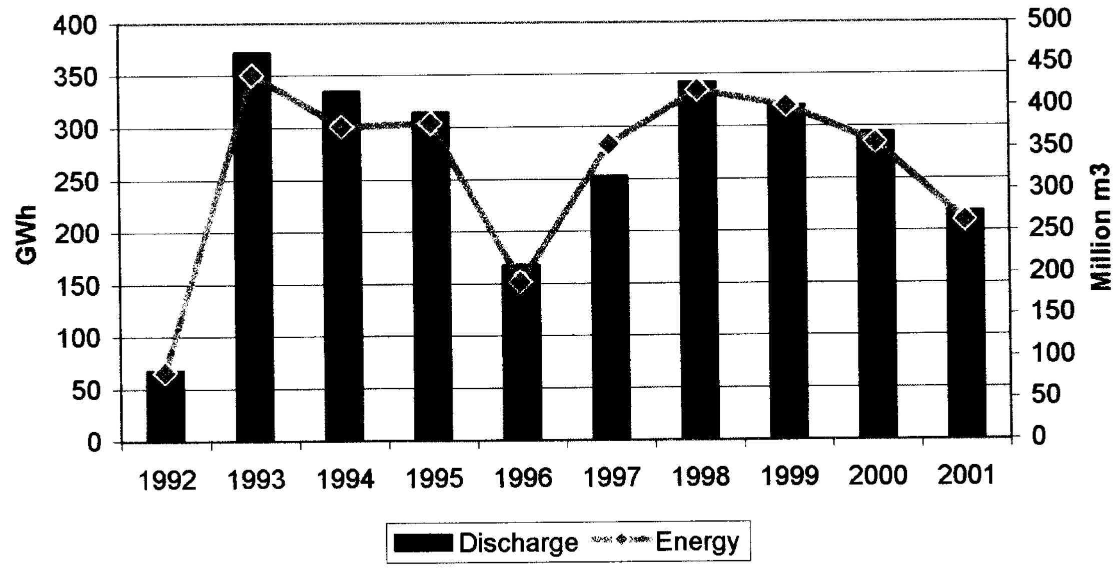

Figure 29 *Power generation and water flow at the Samanalawewa dam* (Somathilake, 2002)

The power generation in Samanalawewa has been an important case study for Sri Lanka in terms of sharing of water between agriculture and hydropower, and it also involves issues such as prior rights, economic value of water, and social and cultural values. The Samanalawewa reservoir is built at the confluence of the Walawe river with a tributary called Belihul Oya. The impounded water is taken initially along a 5.5-km long underground tunnel and finally along a surface penstock to the 120 MW power station. After power is generated, the discharge of the power station is released along the Tailrace canal into another tributary of Walawe called Katupath Oya, which conveys the water back to the main river.

However, in the process, the water diverted for power generation bypasses the Kaltota irrigation scheme. This irrigation scheme has a long history. The right bank part of the scheme was restored in 1892, and a left bank scheme was initiated in 1956. The irrigation system serves 915 hectares and about 2,000 farmer families.

The retention of water in the upstream Samanalawewa, completed in 1992, reduced the water availability to the Kaltota farmers. Considering the high economic value of electricity compared to paddy production, CEB offered compensation to farmers who agreed to forego cultivation. After a few seasons farmers refused to accept compensation, indicating that social and cultural values are not included in the original equation that compared values of electricity and agriculture. However, the agencies and farmers have now reached consensus regarding sharing of water through discussions and negotiations.

Chapter 6

Stewardship: The Management Setting

Cultural Background and Attitudes of People

The Ruhuna, apart from being a subkingdom, served as a safe haven for people fleeing from foreign invaders during ancient times. At that time agriculture played a major role in the economy as well as in the national security. Efforts on water resources development in the area, as in the case of other parts of the country, focused on irrigation. The facts that rainfall was concentrated in the two main seasons and that there was a large interannual variability in rainfall contributed to the construction of a large number of reservoirs. From ancient times water was used for recreation, sanitation and hygiene leading to the recognition of the high value of water resources to the community.

A discussion on the cultural background influencing the stewardship of water would not be complete if "Village Tanks" or minor irrigation reservoirs were ignored. Rehabilitation and restoration of irrigation works in the 20th century placed more emphasis on the larger irrigation systems as smaller systems were believed to be less efficient and thus less of a priority. However, recent studies have shed more light on the management concepts associated with these systems.

The small village tank systems were constructed and maintained by village communities with little involvement from the state for about 1,500 years (Panabokke et al. 2002b). Nearly 15,000 such systems are estimated to have been constructed, however they were constructed at different times, and it is not certain that all of them were operating at any one time. A large number of these systems are clustered into "cascades" or chains of reservoirs successively located down a common watercourse. It is apparent that water captured in the cascade systems was utilized several times with excess releases from one tank being recaptured next tank in the cascade. This recycling helped increase the overall efficiency of the system.

The operation & maintenance of these systems were carried out through the collective efforts of farmers, under the leadership of a village headman. The water that is stored in village tanks was used to satisfy the needs of settlements (Panabokke et al. 2002b).

The historical background of shared management led to the acceptance that water is a public good, in addition to being a source of livelihood mainly in agriculture. Traditions also emphasize that water is a valuable resource that is not to be wasted. A local management structure for water resources was developed, which included provisions for cost recovery and regulation. These provisions enabled a self-sustaining rural agrarian society to exist in the villages over many hundreds of years.

In the dry zone areas of the country, rain was worshipped and rituals and communal ceremonies were held annually to obtain the blessings of the rain god and regional deities. According to information received from the farmers, rituals were performed in many part of the Ruhuna basin until quite recently. However, migration of people from different parts of the country to newly established irrigation settlements is cited as a reason for the perceived drift from these traditional norms. Some of the ancient traditions are becoming less common in the case study area, although some ceremonies have been resurrected during recent, extreme, droughts. This has been led by farmer organizations (FOs), sometimes with the involvement of government agencies including the Mahaweli Authority (Jinapala and Somaratne 2002).

Cultural practices related to water in the rural society emphasized the optimum management of water. However, this management structure was disturbed during the periods of foreign colonial occupations increasing rural poverty and, thus, the dependence on state subsidies. To some extent this dependency continues under modern irrigated agriculture where, especially in major irrigation, there is a heavy emphasis on state control. Farmers are often perceived as mere beneficiaries rather than key partners in the management of irrigation and water resources. However, a considerable change in attitudes has been brought about by the recent emphasis on participatory management.

Political Setup

There is a parliamentary democracy in Sri Lanka, with a President having executive powers. The country is divided into 8 provinces and 24 districts. Rivers flowing through more than a single province, and irrigation systems that are served by these rivers, come under the purview of the Central Government. The Provincial Councils, the name given to provincial governments, have the powers to manage smaller rivers, village and provincial irrigation, and environmental issues. The Ruhuna basins fall under parts of three provinces: Southern, Uva and Sabaragamuwa.

Below the provincial council level there are the municipal councils, urban councils, town councils and Pradeshiya Sabhas, which constitute the local government setup. However, at present, there are no municipal councils within the Ruhuna basins. Local government institutions play important roles in providing water supplies for the small towns, and in environmental protection.

Institutions

Water management responsibilities in the basins lie with institutions at the national and local level. About 40 agencies with responsibility or interest in water in the river basins have been identified. These include the sector agencies dealing with domestic water supply, health and sanitation, agricultural and irrigation services, hydropower generation, groundwater development and ecosystems management. From the point of water resources, an important role is played by the Irrigation Department, which operates and maintains a hydrometric network in addition to the traditional role of operating and maintaining a large number of major irrigation systems. In addition provincial councils established after the thirteenth amendment to the Constitution, have been devolved powers for water-related functions. The Chief Secretary of the Province, District Secretary and Divisional Secretary are key government officials who make decisions on water resources management at the provincial, district and divisional levels, respectively. At the district level and scheme level, the District Coordinating Committee, the District Agricultural Committee and the Project Management Committee also make decisions on water.

Such a multitude of institutions demand provision for effective coordination at different levels. At the national level, the Central Coordinating Committee on Irrigation Management provides a forum for policy issues in irrigation management. A similar forum is the Steering Committee on Water Supply and Sanitation. The recent formation of the Water Resources Council (WRC) addresses the need for coordination of issues on water resources. Moreover, the proposed formation of River Basin Committees would address the existing inadequacy in addressing Integrated Water Resources Management (IWRM) issues at the basin level.

Nongovernmental organizations (NGOs) make a significant contribution to water resources management. Several NGOs have invested in minor irrigation and a significant number play a vital role in protecting ecosystems and in promoting rainwater-harvesting activities. NGOs are actively engaged in building river basin organizations in pilot basins, as well. Better coordination of NGO and government agency actions will be beneficial.

Legislation

Over 50 Acts of Parliament deal with management of water resources (Ratnayake 2002). The implementing authority for these enactments is split between a large number of agencies, each dealing with different sectoral interests such as irrigation, water supply, sanitation, industries and environment. The District Secretary carries out several important functions related to the enforcement of the regulations.

Although some of the legislation is over 100 years old, they have been amended several times to suit changing needs. The Irrigation Ordnance and Agrarian Development Acts, for example, have been amended to facilitate participatory management and empowerment of water users.

Legislation that is already in place extensively covers many aspects of water resources management. However, there have been problems in the actual implementation and failures in enforcement. The reasons cited include inadequate institutional capacity, overlapping functions and interference by political elite and other powerful individuals. The proposed Water Resources Act is expected to address gaps and implementation problems in the existing legislation. It is expected to be operational in 2003.

Finances

Public investment

The financing of water resources development has by popular tradition remained the responsibility of the state. While there are legitimate public interest concerns about newly proposed mechanisms, for water allocation and cost recovery, there is a growing consensus that government involvement is not appropriate in all aspects of service provision. The need to recover the costs of providing water services, primarily in the community water supply schemes is a widely accepted concept today. The National Water Supply and Drainage Board (NWSDB) has been levying taxes for water in urban areas services for many years. The recent expansion of community management of water services through local councils, etc., would transfer part of the infrastructure development and management cost to the beneficiaries.

Public investment in water resources concentrated on the development of irrigation infrastructure from 1950 until the 1980s. Subsequently, the emphasis shifted towards investments in rehabilitation of existing infrastructure and improvement of water management. In 2000, national investments in agriculture and irrigation remained at around 8.5 percent of the total capital expenditure. The corresponding figure for the energy and water supply sectors was a round 16.5 percent (Central Bank 2001).

Estimates of financial requirements for water-related investments suggest the need for, and identification of, alternative sources of finance, which will be a major challenge. The Public Investment Program (PIP), 1997-2001 envisaged an investment of Rs 9,146 million for irrigation, Rs 9,040 for the Mahaweli Area Development and Rs 23,535 million for water supply and sanitation activities, the major water-related investments. An assessment of financial requirements for water-related investments carried out by the Sri Lanka Water Vision 2025 estimated a financial outlay of Rs 115,160 million for 2000-2005 and Rs. 339,170 million (US$4,800 million) over the full period, 2000-2025 (SLNWP 2000). Compared to the actual present level of investments, these estimates indicate the need for a substantial increase in funding over a short period requiring participation of the state, the private sector, the beneficiaries and the donors to meet the need (Atapattu 2002).

Financing domestic water supply

The main investors in urban water supply and sanitation have been the public sector including the Central Government, the NWSDB, Provincial Councils and Local Authorities. Investments by Community-Based Organizations (CBOs) and private individuals are significant in the rural areas.

Cost-recovery mechanisms for urban water supply focuses on the recovery of operation & maintenance cost of the services. The level of recovery is lower in water supply schemes managed by local authorities. Private investment by individual families for the construction of protected wells and latrines is considerable (Wickremarage 2002).

Information gathered on water schemes located within the basins reveals that the investment on drinking water supply in the study area has increased significantly over the past 10 years, the main reasons being as follows:

- increased demand on safe water due to the population increase and the other developments in the area
- introduction of community-based rural water supply projects
- investments made in the improvement of water supply facilities by the government

Capital investment on the water schemes has been borne/shared by the following key agencies.

- international funding agencies (e.g., World Bank, Asian Development Bank, etc.) mobilized through the Government of Sri Lanka
- funds from the Government of Sri Lanka
- contributions made by the beneficiary communities by way of labor and (sometimes) cash

A survey for this case study gathered data from 373 water supply projects within the basins. Out of them, the beneficiary communities have contributed 20-35% of the capital investment for 212 projects, setting an example for the other communities in the country, (Senaratne 2002b).

Tariff structure of domestic water supply schemes

The NWSDB applies a uniform tariff structure to all water supply schemes in the country. However, the cost recovery of some smaller schemes is inadequate to cover the operation & maintenance cost of that particular scheme. This has been addressed through cross subsidies between schemes. Generally, meters are fixed in the residences of all consumers. Standposts are not metered. The rates are volume-based, and different slabs of rates have been introduced where the rates increase with larger volumes of consumption. The objectives are evidently to secure minimum access to the less-affluent sections of the society and to discourage over use.

There is no such uniformity among the water supply schemes operated and managed by the local authorities. There are some town schemes where the meters are fixed at the residences of consumers, and the cost recovery is made based on a tariff structure similar to that adopted by the NWSDB, with variations in rates. There are other schemes where the charges are levied on flat rate per month, allowing any amount of water consumption. There are also schemes where there is no cost recovery from the consumers, but the operation & maintenance is being done with the earnings of the organization by other means.

A rapid survey of a sample of schemes operated by local authorities yielded the following results: No scheme generated sufficient revenue to cover the operation & maintenance.

- The possibility of cross-subsidizing among water supply schemes does not exist.
- Most of the schemes operated and maintained by Pradeshiya Sabhas are found to run with the revenue earned from other means.

A sample survey of CBO-managed pipe-borne water supply schemes revealed that some schemes have adopted good cost-recovery methods through tariff systems based on consumption. This situation is common in gravity-fed schemes where the cost of operation is quite small.

In the case of hand pumps regular collections of fees from each consumer are to be deposited with the Pradeshiya Sabha, however in many cases the fee collection is not implemented. However, when hand pumps breakdown, consumers generally collect the amount required to cover the cost of the repairs.

In the case of common shallow wells, there is some form of collection of revenue from the consumers in facilities recently constructed by rural water supply projects. However, such collections are not maintained in old facilities.

Other organizations do not adopt cost-recovery systems from the consumers. In the case of state plantations, the operation & maintenance cost is usually borne by the management of the estate. In the case of hospitals and schools with independent supplies, the cost is borne by the parent departments.

Funding for irrigation development

Substantial portions of irrigation projects are foreign-funded. Two major irrigation rehabilitation projects and one comprehensive groundwater assessment project funded by donors are ongoing in the basins. The Hambantota Irrigation Rehabilitation Project funded by the Kuwait Fund for Arab Economic Development envisages rehabilitating 11,000 hectares at a cost of Rs 1218 million. The Walawe Left Bank Irrigation Upgrading and Extension Project is funded by the Japanese Bank for International Corporation (JBIC).

At the same time, the project for the Diversion of Mau ara to Malala ara was funded entirely funded by the Government of Sri Lanka, at a cost of Rs 725 million. This project used entirely local expertise, and the evaluation of the methodologies employed for the project would be useful for formulating future strategies.

Beneficiary contribution has been sought for in the recent irrigation rehabilitation projects. Examples in the basins are the recently concluded National Irrigation Rehabilitation Project and the ongoing projects. The expected contribution by the farmers was 10 percent of the cost, a target that has been met with varying levels of success.

There have been several, unsuccessful, attempts to recover the cost of operation & maintenance of irrigation services. An ongoing program of turnover of irrigation systems to the users has resulted in substantial contributions from farmers in system management meeting and to operation & maintenance costs.

Financing Integrated Water Resources Management (IWRM)

Despite the recent emphasis and wide discussion of IWRM, the finances for this vital issue are comparatively low. One positive indication is the Japan Agency for International Corporation (JICA) has funded a Comprehensive Groundwater Assessment Program in Hambantota and Moneragala districts. The World Water Assessment Program funded by UN has created a degree of awareness about aspects of IWRM and the deficiencies in management that have to be overcome. The Water Resources Management Project funded by the Asian Development Bank will address important policy issues.

Management Approaches

Integrated approach: the national perspective

It can be argued that Sri Lanka has been implementing IWRM principles for many hundreds of years, although formal recognition of IWRM as state policy is yet to be received. As an example of the attention given to IWRM principles, irrigation development projects in environmentally sensitive areas have to undertake an Environmental Impact Assessment (EIA) and obtain EIA approval before implementation is approved.

The National Environmental Act was promulgated in 1980, and a ministry dealing with specific environmental issues was set up in 1991, with powers to proscribe activities that adversely impact the environment. The Water Resources Secretariat was established in 1996 charged with formulating a National Water Resources Policy and relevant Water Resources Legislation. A ministry to deal with Water Resources Management was set up in 2000. The commitment of the Government to the principles of IWRM was further emphasized by the establishment of a Cabinet Ministry in charge of Irrigation and Water Management and a non-Cabinet Ministry in charge of Water Management in December 2001.

Agriculture and environment

Although no detailed studies on agrochemical contamination of surface water are available, the available studies indicate overuse of chemicals that poses a potential threat to the environment. Recent efforts of the Department of Agriculture to reduce the use of pesticides for crop protection by promoting the use of better cultivation practices as well as integrated pest management have been fairly successful with paddy farmers. According to agriculture extension officials, pesticide application rates have been reduced (Handawela 2002).

Demand management

Demand management has been given special attention in recent government policies. Targets of the domestic water supply sector include minimizing *unaccounted water* and introducing demand management measures. More attention is being paid by the government to activities, such as rainwater harvesting, which have been carried out by NGOs at a small scale until recent times.

In irrigated agriculture, there is an increasing focus on introduction of micro-irrigation methods and improved monitoring of agricultural operations. Recent studies have shown that the land preparation period in paddy cultivation consumes a lot of water, and some savings can be achieved if the land preparation period is minimized. The relevant agencies are monitoring the land preparation period to identify the constraints for achieving the desired time targets. Optimal water use is a major focus for the ongoing irrigation rehabilitation projects in the basins. Depending on the suitability of soil and other relevant factors, perennial crops and less water-consuming crops have been introduced in several water-short irrigation systems.

In the energy sector, there are campaigns to reduce power consumption.

Public participation

Following a number of pilot experiments, starting in the late 1970s, Sri Lanka adopted participatory management (in irrigated agriculture) as state policy in 1988. A program of irrigation management turnover (IMT) to FOs is ongoing. Although no systems have been completely turned over to farmer management, there has been a significant increase in the role of farmers in the management of irrigation systems over the past two decades. Most major irrigation systems in the basin are partially turned over. As mentioned before, farmers have traditionally managed minor irrigation systems (having command area less than 80 ha). Empowerment of the communities and the removal of legal and administrative constraints are some of the issues currently being addressed. Public participation in domestic water supply schemes has been discussed elsewhere in the report.

There are three ongoing national programs in the basins that aim at turning over the management of irrigation systems to beneficiaries. They include the Integrated Management of Agricultural Systems (INMAS) Program implemented by the Irrigation Management Division, the Waphaula Program implemented by the Irrigation Department and the Mahaweli Participatory Management Program.

Attempts have been made to catalyze community participation in environmental protection; however, these efforts are still at an early stage of evolution. The Upper Watershed Management Project, implemented by the Ministry of Forestry and Natural Resources, is actively promoting the participatory forestry program in the focus area including the upper catchment of the Walawe Ganga.

Public/Private partnerships

The concept of farmer companies is being pilot-tested at two irrigation systems in the country. One site, the Chandrika Wewa Farmer Company is in the Walawe system. This company is involved in promoting agricultural production and other rural business activities, while the public sector manages the irrigation system. A full evaluation of this pilot project has not been undertaken as yet. The other pilot farmer company, outside the case study of the Ruhuna basins, is involved in the operation & maintenance of irrigation systems, in addition to agricultural input and output marketing and is being considered as model for future public/private partnerships.

Apart from the above, several programs that call for active private-sector participation in water-related development have been initiated in the recent past. The introduction of micro-irrigation systems at irrigation scheme level is promoted with the participation of the private sector, where private companies provide irrigation application systems to farmers and recover the cost by installments. The proposed Granary Area Program envisages private sector investments to expand stores for agricultural produce and to improve input supply.

Water resources development strategies

The significance of new water resources development projects has to be measured not only in terms of economic returns but in terms of new policy directions and strategies. The Mau ara project and the Weli Oya project discussed in the preceding chapters have several features in common. There is a heavy emphasis on water resources development as a strategy for alleviating poverty. The reliance on foreign funding has clearly diminished, and local expertise has been extensively used for design and construction works. The administrative demarcation of minor irrigation systems has been ignored, and the diversions are likely to result in more equitable distribution of water resources. These interventions have to be investigated in terms of their impact on poverty and environment, and useful lessons would have to be replicated.

Gender Issues

Gender disaggregated data linking landownership and FO membership is not available with the key line agencies dealing with water management, the Irrigation Department and the Mahaweli Authority. However, in studies in Irrigation Management Transfer it has been observed that participation of women is generally very low in FOs. The reasons are thought to include:

- fewer number of female landowners in irrigation systems
- social and administrative constraints for women to become members in FOs
- inadequate interest by women in participation (Atukorale 2002)

These questions cannot be easily answered using currently available sources of information though they are essential to understanding the gendered participation in water management.

In the past, in traditional villages women did not enter the threshing floor until the paddy had been measured, as it was feared that the pollutive nature of women may affect the harvest (Leach 1971). Older and conservative farmers recalled the fact that in their traditional "purana" village homes, women were even forbidden to walk through the ripening paddy fields, which was seen as a male domain. Female-headed households and female landowners now largely ignore the exclusion of women from the threshing floor. Male-headed households are also increasingly ignoring these old traditions. Traditional gender ideology in this instance is perceived as being eroded by financial constraints experienced by farming communities (Atukorale 2002).

There are a number of households in irrigated settlements where the actual farmers are women whose husbands are involved in other activities, sometimes outside the system. Some are recognized as almost solely responsible for all farming and irrigation activities and decisions and as better farmers than the men by the community. As female landowners, they express a keen interest in water management and agency decisions. Yet, even these women have limited their participation in FOs thereby being unrepresented in vital decision making.

It is seen that in every system researched, the nature of gender tasks for which labor is hired is a reliable indicator of prevailing gender norms. The use of female family labor in nontraditional tasks for work in the family's own land is not seen as a major contravention of norms. But in the use of hired labor both parties under contract are seen to approximate to the norms subscribed to in that system. Studies outside the basins reveal that gangs of "contract women" work on land preparation including nontraditional tasks, such as leveling and building bunds. In the systems studied in the Ruhuna basin, planting, infilling and harvesting were seen as tasks for hired female laborers but hired labor women were not used for land preparation. There seems to be a difference in the gender norms relating to labor participation in the wet zone and the dry zone systems, the North Central Province and the Southern Province. However, this area needs further study to arrive at firm conclusions (Atukorale 2002).

In all socioeconomic groups, women are seen to play a key role, especially in the domain of financial management and decision making in irrigated agriculture. Women are seen to be active in financial accounting for domestic and production purposes, in arranging, giving, and taking loans within the community, though not in negotiating with banks. They are foremost in organizing and mobilizing savings and often maintain secret savings, which are made available to the family in times of crises. They are seen to take the lead, especially in settlement schemes, in accessing agri-financing and mobilizing labor using their social networks. Their characteristic involvement in this area of irrigated agriculture makes them an important, but under used, asset to FOs.

Socio-cultural perception of women's roles by communities and the attitudes of line agency decision-makers influence the participation of women in agriculture (Atukorale 2002). This is in sharp contrast to other activities in rural communities, especially in the field of micro-credit. In 2001, a study of micro-credit was undertaken where it was seen that in irrigation systems of Moneragala and Giribawa women were the most active and successful group in micro-credit organizations and played a prominent role even outside the community. But there is no corresponding activity in the crucial decision making forum related to water (Atukorale 2002).

The Management of Risk

Major risks to be managed

The major part of the basins is located in the dry zone, receiving less than 1,250 mm rain annually, and therefore the major natural hazard is drought.

Hambantota district is classified as drought-prone with the maha season drought index of 28% being the highest in Sri Lanka. In the yala season the probability of drought increases to 32%. Other parts of the Ruhuna are not classified as a drought-prone, although some areas of the Moneragala district were severely affected during the recent drought.

The majority of Ruhuna basins are at little risk from landslides, coastal erosion, cyclones and earthquakes. However landslips have occurred on the upper slopes of the central highlands, with some loss of life, in the basins. Some localized coastal erosion does also occur but is generally managed adequately. The basins are also subject to occasional localized floods.

Drought impacts

The drought in 2001 was very severe and extended. Problems over domestic water supply prompted the provision of relief (water and food) to the residents in Lunugamwehera, Tanamalwila, Sevanagala and Suriyawewa and Hambantota DS divisions. More than 52,000 families in Hambantota district were affected. Many wild animals, particularly deer and elk, were also affected as were many over-wintering birds in the Bundala National Park and other wetlands. Some of the impacts on the mostly aquatic birds was said to be drastic (Handawela 2002).

Drought management

The recent droughts severely affected many parts of the basins. The government initiated a range of measures to mitigate the impacts of future occurrences of droughts. These include short-term emergency measures, such as the development of groundwater for emergency domestic supplies; medium-term interventions, such as introducing better water management practices; and longer-term studies on the possibility of inter-basin water transfers and integrated development of surface water and groundwater.

Drought management decisions in agriculture are taken in the seasonal cultivation meeting where farmers and officials participate. Typical decisions include the cultivation of a reduced proportion of the command area and sharing the land. In general, domestic water needs are given the highest priority during droughts, a policy that will be formalized with the proposed National Water Resources Policy.

Recent government initiatives include the development of groundwater and surface water resources in an integrated manner with the objective of providing sustainable and reliable water supplies.

Health-risk management

Agricultural areas are often subject to waterborne and water- related diseases. Malaria, Japanese Encephalitis and Dengue are some of the water- related diseases that have increased significantly in the recent past. Drying up of the paddy fields for about a day to control mosquito breeding has been practiced in some locations.

As many of the rural drinking-water supplies are self-managed, the management of health risk in the basins requires a high level of awareness among users. The Ministry of Health includes monitoring of drinking water quality as a regular activity for their field staff. Public water-supply schemes undertake monthly campaigns to promote the use of boiled water. In addition, promotion of sanitary latrines through education and enforcement, monitoring refuse-disposal and health standards in food production, work places, etc. are implemented by various agencies. Current legislation requires all new houses to have toilet facilities to obtain approval from local authorities (Shanmugarajah 2002).

Traditional methods

As people in this agrarian economy experienced water-scarcity problems off and on they tried to take maximum use of available water resources. Because of this reason agricultural practices in the dry zone were based on the principle of maximum use of rainwater for agriculture. For example, the farmers start cleaning jungles for *chena* (slash-and-burn) cultivation in July and Augusts and were ready for sowing and planting of crops with the onset of rain in October. Immediately after the highland crop cultivation was over they started paddy cultivation activities in small tank commands. Through their experience they knew that the delay in paddy cultivation activities would lead to water shortage problems and also to pest attacks. They adopted timely cultivation practices due to this reason. However, some of these practices are on the wane due to various socioeconomic reasons and need to be resurrected.

Village tanks as drought-mitigation measures

Studies by IWMI, quoted by Panabokke et al. (2002) indicate that there is a linkage between shallow groundwater bodies and surface water stored in the village tanks. It has been observed that rapid increase of agro-wells has affected the sustainability of groundwater resources. Although such observations are not common in the Ruhuna basins, exploitation of groundwater for drought mitigation could draw lessons from the studies carried out elsewhere.

Valuing Water

Multiple values

The centuries-old water traditions in Sri Lanka recognize that water has social, environmental and cultural values in addition to the economic value. With a considerable number of people still living below the poverty line, this is very important. In minor irrigation, the systems provide water for domestic use and livestock, and also for recharging the groundwater. The traditions in water sharing and multiple use in small irrigation systems relegate the practice of estimating water productivity in terms of the weight of produce or the market or economic value of production. These multiple dimensions of the value of water must be considered equitably in water-resources planning, development and management. The social and cultural norms established within the society have, for a long period, placed great emphasis on the optimum use and prevention of wastage of this vital resource.

Economic value of water

Economic value of water has been the subject of intensive discussion in the recent past. A draft policy document, making reference to water as an economic good, was rejected after strong pressure from the public and the media. Leading politicians made statements to the effect that water would remain a free good for the foreseeable future.

In actual use, water can be both a social and an economic good. Water satisfies several basic human needs and services, which are classified as life-support functions. Access to safe water is fundamental to the maintenance of life, and many ecological and environmental services of water are critical for the existence of living systems including those of human beings. But in many other instances, water has a definite use as a market good in which the efficiency of use and benefits can be maximized through competitive allocation.

Water allocation decisions had been usually kept outside the market due to their special nature. However, growing problems of the allocation of water through traditional mechanisms have prompted analysts to look for other means of allocation. At present, the recognition that water has an economic value and the treatment of solutions to water allocation problems within an increasingly market-based approach has been recognized as one of the aspects in formulating policies.

Agriculture dominates abstractions of water for economic uses, with water resources in the relatively drier sections of the basin developed for irrigated agriculture from ancient times. All except two reservoirs, i.e., the Samanala Wewa and Uda Walawe, are operated almost exclusively for irrigation. But, in general, farmers pay no water supply or service fees. Cash contributions to

OPERATION AND MAINTENANCE costs are minimal and farmers sometimes pay through provision of labor for cleaning canals. This is similar to ancient practices.

There is plenty of evidence that the value of water has been recognized throughout the history of Sri Lanka. Ancient records indicate that irrigators had to pay a fee to the king for water. A rock inscription in the ninth century by the king dictates fines for the overuse of water, late land preparation, etc. (Atapattu 2002). In comparison, the rock inscriptions specify that murderers are not to be fined but to be handed over to the king's officers. The fact that the punishment for water-related offences was a fine indicates the recognition of the economic value of water.

The practice of paying water fees has ceased sometime during the long history of Sri Lanka. Various reasons are cited for this. Due to repeated foreign invasions, people migrated to the wet zone where agriculture was mainly rain-fed. Agriculture was neglected in the early periods of European rule. When new colonization schemes were started, settlement of people in the irrigated areas became a national or government need rather than the needs of the settlers. The government provided the new settlers with many facilities, such as housing as incentives to migrate to the new schemes. The settlers had to face many problems such as malaria, social shock due to relocation, etc. In such circumstances charging for water was seen as impracticable.

However, the economic situation and priorities have changed over time. The emphasis in national policies on welfare has waned, and the principles of market economy have become well established in the recent past. The government has found that financing the entire cost of irrigation water supplies is no longer possible. Similarly, the contribution to the management of water by beneficiaries is found to be more cost-effective.

Social and cultural values

The social and cultural values of water are widely recognized and entrenched in social customs. In villages, community wells for water supply for drinking and bathing, washing, etc., were shared resources. Until recent times, at the wayside resting places, a pot of water was provided for travelers to quench their thirst. In both cases, the water was provided free but the value, which was not charged, was recovered in terms of the returns due for the noble deed ("merit or pin") (Atapattu 2002).

Water-related rituals continue to be important components of village life. The first transaction with the well during the Sinhala-Hindu New Year highlights the intimate relationship with the source of domestic water supply (Jinapala and Somaratne 2002). Customs associate water with prosperity, fertility and purity. Pouring water and tying the fingers of the bride and bridegroom are symbolic of the eternal bond. When offering flowers in homage to the Buddha people wash flowers as a means of purifying themselves. One of the major religious festivals held in the basins is the festival in Kataragama in July, where the "water-cutting ceremony" is one of the most important events. The customs and traditions add value to water that is not easily ascribed an economic value but which are important to the community and individual.

Sharing the Resource

Water resources and developed infrastructure often provide water services for multiple uses. For example, water delivered for irrigation is a common source of domestic supply for major towns and villages in the basin. During periods of water shortages, allocation of water between different uses becomes an issue.

Sharing water between sectors is being widely discussed in relation to the prior water rights of the Kaltota farmers and the alternative use of power generation through the Samanala Wewa Power Station. The hydropower station, upstream of the irrigation scheme discharges water from the powerhouse downstream of the irrigation diversion structure. As a result, farmers at the Kaltota scheme have had to face occasional water shortages. After a period of intensive negotiations and bargaining, a consensus is being built among the farmers and the authorities dealing with irrigation and hydropower.

Several studies carried out in the Kirindi Oya project highlights the water-sharing aspects in major irrigation systems. It has been observed that water is used for paddy irrigation, irrigating other field crops and for domestic use. Domestic use is through both piped water supply (depletive use) and in-stream use for bathing and washing (non-depletive). As mentioned earlier, the use of water for inland fisheries has been increasing in importance in recent times.

According to Panabokke et al. (2002b), the main use of water in small village tanks was for domestic water supply and for livestock. Rice irrigation was practiced when the rains were good and water was available. Water in the tank was used for livestock, bathing, washing and supporting inland fishery, in addition to conventional irrigated agriculture. Village tanks were traditionally managed by farmers with little state intervention, and water sharing methodologies adopted by them deserve careful study in future policy formulation (Panabokke et al, 2002b).

Evaluation of the Knowledge Base

There is a considerable range of data and knowledge about water and natural resources in the Ruhuna basins and in Sri Lanka in general. However, the available data and information are scattered amongst the different agencies. The WWAP case study has catalyzed a broader recognition of the need for greater access to the available information and sharing of knowledge resources amongst the involved agencies. A start has been made to the design and implementation of a comprehensive database. The database will be structured to enable monitoring of the WWAP challenge areas. Sharing of data among the agencies will improve once the database is completed and made available.

A survey carried out on groundwater data (Jayawardane 2002) is summarized in Table 24.

Table 24 Status of data for groundwater resources assessment

Physical Framework	Status
Topographic maps showing the stream drainage network, surface-water bodies, landforms, cultural features, and locations of structures and activities related to water.	Available. Should be implemented in GIS.
Geological maps of surficial deposits and bedrock.	Available. Should be implemented in GIS. Details of well logs also to be incorporated.
Hydro-geologic maps showing the extent and boundaries of aquifers and confining units.	Not defined.
Maps of tops and bottoms of aquifers and confining units.	Not defined.
Saturated-thickness maps of unconfined (water table) and confined aquifers.	Temporal data not available.
Average hydraulic conductivity maps for aquifers and confining units and transmissivity maps for aquifers.	Should be implemented in GIS. Details of well logs also to be incorporated.
Maps showing variations in storage coefficient for aquifers.	Not available.
Estimates of age of groundwater at selected locations in aquifers.	Not available.

Hydrologic Budgets and Stresses	Status
Precipitation data.	Available. Should be implemented in GIS.
Evaporation data.	Limited data available. Inadequate. Should be implemented in GIS.
Streamflow data, including measurements of gain and loss of streamflow between gauging stations.	Available. Inadequate to compute loss or gain. Should be implemented in GIS.
Maps of the stream drainage network showing the extent of normally perennial flow, normally dry channels, and normally seasonal flow.	Availability of temporal data not known.
Estimates of total groundwater discharge to streams.	Temporal data not available.
Measurements of spring discharge.	Not available.
Measurements of surface water diversions and return flows.	Available.
Quantities and locations of interbasin diversions	Available.
History and spatial distribution of pumping rates in aquifers.	Temporal data not available.
Amount of groundwater consumed for each type of use and spatial distribution of return flows.	Available. Inadequate. Should be implemented in GIS
Well hydrographs and historical head (water level) maps for aquifers.	Not available.
Location of recharge areas (aerial recharge from precipitation, losing streams, irrigated areas, recharge basins, and recharge wells) and estimates of recharge.	Available. Inadequate. Should be implemented in GIS.

Chemical Framework	Status
Geotechnical characteristics of earth materials and naturally occurring ground water in aquifers and confining units.	Available. Not well defined. Should be implemented in GIS.
Spatial distribution of water quality in aquifers, both aerially and with depth.	Available. Should be implemented in GIS.
Temporal changes in water quality, particularly for contaminated or potentially vulnerable and unconfined aquifers.	Temporal information not available.
Sources and types of potential contaminants	Information not available.
Chemical characteristics of artificially introduced waters or waste liquids	Information not available.
Maps of land cover/land use at different scales depending on study needs.	Available. Should be implemented in GIS.
Streamflow quality, (water-quality sampling in space and time), particularly during periods of low flow.	Temporal information not available.

Chapter 7

Conclusions

Identification of Critical Problems and Opportunities

Problems and Opportunities Related to the Nature of the Resource

Analysis of meteorological and hydrological data confirms the high temporal variability of rainfall and river flows. Of the three main rivers, the Kirindi Oya is already heavily exploited with a very high proportion of the available water resource already developed and little scope for further exploitation of the in-stream flows. In comparison, the water resources in the Menik Ganga basin are largely undeveloped, but, concerns about the impact of abstraction from this river on nature and wildlife resources currently restrict development plans. However farmers are increasing the pressure on the authorities to implement a trans-basin diversion from Menik Ganga to Kirindi Oya.

Investigations show that the quality of groundwater is poor in the lower reaches of the basins, which lie in the dry zone. Hardness of water and fluoride, chlorides, sulphate and alkalinity contents is reported to be high in several places. The shallow groundwater in areas not recharged by irrigation is reported to be falling in some locations due to increased use of agro-wells.

The significant character of this basin is that the phreatic aquifer (regolith) on which there is a high dependence, is only about 10 m deep, sloping continuously towards the coastal boundary of the basin. As such, the temporal distribution of groundwater recharge becomes very significant. The seasonal distribution of rainfall and the spatial distribution of surface water bodies affect recharge setting the upper limit of sustainable use. The influence of the temporal distribution of rainfall on the groundwater condition can be clearly identified and therefore must be considered in the assessment of vulnerability indices. The spatial and temporal varieties of vulnerability value must be considered as an indicator of the influence of mitigation programs that are required for the sustainable use of the groundwater resource in this basin.

As mentioned earlier, the shallow aquifer gradually slopes towards the southern coastline and continuously drains out to the sea under a positive hydraulic gradient. The loss of fresh groundwater to the sea is reduces the storage capacity of the aquifer. The well-distributed network of streams and rivers encouraging quick inflows to them from the surface runoff and the base flow reduces the storage capacity of the aquifer further (Jayawardane 2002).

Several water resources development projects are ongoing in the Walawe subbasin, and other proposals for further development of water resources are being studied. As the major part of rainfall is confined to few months of the year, there is a potential to harness these water resources with necessary infrastructure. In this regard, the recent experiences in Mau Ara development Project (within Ruhuna Basins) is very encouraging, and further studies are required to assess the direct and indirect benefits. Such studies will reveal the opportunities available for low-intensity water resources development programmes in the basins.

With scientific investigations and planning, there is a potential for further development of groundwater, as well. Potential investors in the proposed Ruhunupura industrial complex have also indicated to the Ministry of Southern Region Development their willingness to invest in desalinization of seawater as an alternative source.

Problems and Opportunities Associated with Uses

Agricultural uses

The main water user in the basins is agriculture, principally flood-irrigated paddy, the dominant staple food crop. Paddy cultivation on highly permeable soils has contributed to high water use and thus to water shortages and environmental problems. Studies carried out in selected irrigation schemes indicate that many farmers overapply pesticides, herbicides and nitrogen fertilizers (Renwick 2001). The coastal lagoon system, which forms an important segment of the Ruhuna basins' ecosystem, receives a large volume of irrigation drainage flow during the irrigation seasons, thus carrying the residual wash-off of these agro-chemicals. Reduction of dry- weather base flows, by irrigation abstractions and increased groundwater use, is reported to have increased concentrations aggravating the impacts of drought on the lagoon systems.

In village irrigation systems, the communities are solely dependent on agriculture-related activities supported by resources available within the village. With the increase of population, both land and water have become limited for further expansion of agriculture in the village systems. There is little forest, outside protected areas, left for chena cultivation. On the other hand, it has become extremely difficult for people to depend on agriculture alone due to land fragmentation, high cost of inputs and many other market factors that have reduced their income from agriculture. This situation has led them to involve themselves in a large number of livelihood activities, in addition to agriculture. In their pursuit of additional sources of income many fail to make maximum use of rainfall and cultivate their paddy lands in time.

The land under irrigation tank systems is cultivated with stored water and rainwater utilization for highland cultivation has shown rapidly decreasing trends. Under the water- scarcity conditions people in areas like Tanamalwila tap water from the Kirindi Oya using water pumps. There are a large number of farmers doing lift irrigation in an unregulated manner enhancing water-shortages in irrigation schemes like Lunugamwehera in the downstream areas. Other than the construction of ridges to retain water in the farm after pumping of water from the river, there are few interventions by these farmers to save or use water efficiently (Jinapala and Somaratne 2002).

Industrial uses

At present, the discharge of effluents to watercourses becomes a problem only in periods of low flows, however there is a need to address these problems urgently before planned large-scale industrial development takes place.

In addition to environmental problems from agro-chemical use, minor industries in the basin also contribute to pollution of water. The paper mill and sugar factories in the Walawe subbasin were identified as specific pollution sources of concern.

Opportunities

Several opportunities exist for improving the water use in agriculture. Increased reuse of irrigation return flows, diversification of crop patterns to include a higher proportion of less water-consuming crops, the improvement of conveyance systems, better canal operations and field-application methodologies are being introduced in the basins. Two donor-funded rehabilitation projects promote initiatives to increase productivity of the irrigation systems and water use efficiency.

It is argued that the village tanks should not be considered merely as water sources and production systems but rather as a central part of the socioeconomic and cultural system in the rural area. The contribution of the village tanks to groundwater recharge and, therefore, to securing domestic water supplies have been mentioned earlier. It is understood that minor irrigation systems, being spread over a large part of the basin, are capable of more equitable distribution of the water resource. However, the transfer of technology innovations to minor irrigation and rain-fed farming is less intensive than in the major irrigation schemes. Opportunities do exist to promote higher productivity in the rice and other traditional cereals in the small irrigated and rain-fed areas, and to contribute to sustainable water resources development. Ongoing work for new irrigation facilities does appear to have taken these opportunities into consideration.

The agro-ecological conditions in comparatively dry areas of the basin area are well suited to intensive crop production using drip irrigation and fertigation technologies that have become popular and profitable elsewhere. The scarcity of water for large surface irrigation systems, high evaporation losses and minimal conflict with community and ecological needs should act as incentives to promote such technologies in these areas.

The reservoirs in the basin enable regulation of the impacts of high temporal variations in river flows. Although farmers in irrigation schemes have reported adverse impacts of the development of water resources for other uses, for example for hydropower, better coordination and cooperation between sectors have provided for more reliable water services to agriculture. Improving agricultural practices and coordination are likely to further ease pressures on basin ecosystems. The proposed River Basin Organizations will provide a stronger institutional framework to better integrate the concerns of different users in resources planning and management.

Other opportunities to address the issues associated with water and ecosystems use include:

- The use of paddy husk, a byproduct of rice mills, as a substitute for fuelwood could reduce the pressure on national parks being exploited for fuelwood.
- Increasing the use of organic fertilizer, currently promoted by agencies, would reduce the contamination of water by agro-chemicals.

Problems and Opportunities Related to Management

Major issues

Inadequate policies and poor coordination among agencies dealing with water, the deficiencies in regulating mechanisms and lack of a forum to discuss integrated water resources management issues at the basin level are the main management problems identified in the basins. The major issues to be confronted in developing policy and implementing strategies include poverty, multi-sectoral use of water, and the coordination of a large number of agencies with responsibility for management of water and related resources. Major water resources development projects have focused on agriculture, and inter-sectoral reallocation is a sensitive issue. There are a large number of legal enactments that deal with the safety of infrastructure, water allocation and watershed management. However, implementation of these is the responsibility of several agencies weakening actual field implementation.

Irrigation and agriculture

Provisions in the "National Water Resources Policy and Institutional Arrangement" towards granting of water entitlements to farmers and introduction of levies for irrigation water were resisted by farmers, politicians and various interest groups during 2001. The proposals to issue entitlements, and the introduction of cost recovery mechanisms, were not preceded by an effective public consultation or awareness program. This raised suspicions regarding the intentions of the planners. A failure to provide adequate consultation led a widespread misunderstanding that cost recovery proposals were introduced solely due to the donor's recommendations. The reasons for poor acceptance of the policy, quoted by various sources include: *a purely institutional approach that paid little attention to social or cultural aspects*; and *failure to satisfactorily address the causes leading to water system inefficiencies.*

There are several constraints to implementing charges for irrigation water. The very large proportion of small farms with no survey plans makes fixing of rates a challenging exercise. The design of ancient irrigation systems enables most of the water to be reused. It is argued that the same water should not be charged several times. The ability to pay and multiple uses of water in irrigation systems are other issues that make the subject even more complicated.

As a result, a quick resolution of issues based entirely on economic and social considerations is not possible. However, several positive trends are emerging. A large number of irrigation systems are being turned over to farmer groups for (partial or complete) management. This strategy promotes a concept of Farmer Companies taking control of all aspects of management including irrigation system operation in smaller schemes. Where conflicts between demands for power generation and irrigation are severe, improved water management practices leading to demand management are pursued, e.g., the Kaltota scheme. There are plans to implement better water management practices island-wide.

Gender issues

Participation of women in decision making in Farmer Organizations (FOs) is low. An estimate of the proportion of female membership in FOs is about 22 percent in the Ruhuna basins (Atukorale 2002). As women are concerned about health, sanitation, domestic water supply and securing food, the sharing of water among users would be positively influenced by greater participation of women in water management.

Water supply and sanitation

In the water supply and sanitation sector, policy issues of concern include general cost recovery and service provision to the poor. Present cost-recovery in urban water supply systems cover only the recurrent operation & maintenance costs and a small part of the capital cost. With government plans to reduce investments in these services the service providers must, in future, recover the operation & maintenance and capital cost through water charges for urban water supply and sanitation. However, about 40 percent of the urban population is considered to be poor and increases to water charges would not only adversely affect their access to safe water and sanitation, but also hinder achieving the national targets for service provision. Experience elsewhere indicates the poor often pay more for poorer services than those provided with formal supplies.

Nature of the resource leading to management problems

The high spatial and temporal variation in water availability directly impacts the economic life of the inhabitants of the basin. These impacts are reflected in all aspects of development in the basins. Patterns of residential development, distribution of agricultural activities to location of industries are determined by water resources availability. Current developments will impact on the future strategies for resources development and management in the region. Key problems observed in the region are outlined below.

a. Agricultural productivity: The primary variations in agricultural productivity arise from the availability and utilization of water resources in the irrigated and nonirrigated areas. Irrigated agriculture has imparted some certainty to agriculture as evidenced by the crop selection, dominated by rice in the ancient major irrigation schemes, and cultivation of cash crops under lift irrigation in new schemes. Food crops, of secondary importance, dominate the more vulnerable highlands under rain-fed cultivation.

   However, productivity within the irrigated systems is subject to significant spatial and temporal differences. Cropping intensities and average yields of rice across major and minor irrigation systems, as well as across different agro-ecological regions, within the basin bear evidence of wide differences in the reliability of water supply. Cropping intensities in irrigation areas vary between major and minor irrigation systems and agro-ecological regions.

   A recent development is the expansion of the exploitation of shallow and deep agro-wells for agriculture. Unplanned and unregulated groundwater exploitation for agriculture for commercial crop production is becoming a potentially serious problem. Decreased yield and threats to perennial crops in the area due to unregulated exploitation lead to lowering of the water table remain potential hazards.

b. Water availability is a serious constraint for domestic and livestock needs in the plains bordering the coastal south, particularly during the annual dry months. Domestic water supply schemes presently confined to the small townships and urban areas, also face constraints during the dry period. With a widely dispersed population in areas prone to serious scarcity, there are constraints to using community water supply schemes as a solution to water supply problems faced by many residents.

c. Other nonagricultural uses of water, including industry, power generation and the recreation/tourism sectors, are not serious problems at present. However planned developments require careful attention to provisions to mitigate pollution and environmental degradation. Deforestation from chena cultivation and illegal timber harvesting pose severe threats to the sustainability of the natural ecosystems in the region with potential long-term impacts on water resources (Atapattu 2002).

Therefore, except for problems arising from the inability to overcome constraints of spatial and temporal variation of water availability, human interventions have led to few serious management problems. This is partially the result of the relatively low level of industry and other nonagricultural resource uses in the area. Sound water resources development and planning will contribute significantly to the success of development plans for the area.

Industrial development

The government has plans for industrial development that would increase employment opportunities and enhance the rural economy. High tariffs on industrial water supplies, the need for more efficient water use by industries, including reuse and recycling, and pollution control are important policy issues.

Traditional knowledge

Inadequate use of traditional knowledge about conservation practices has been cited as a cause of environmental degradation (Handawala 2002). However, traditional technology has been found to be unavailable in most recent irrigation settlements (Jinapala and Somaratne 2002). The state has concentrated on improving management of irrigated agriculture with little attention being directed towards rain-fed farming. Even in the irrigated sector there are administrative demarcations in the management of minor and major irrigation schemes, even though the systems are often hydrologically linked and difficult to manage in isolation from one another.

Collection and dissemination of information

A lack of adequate routine hydrological observations has led to a number of ad-hoc attempts by agencies to collect data, mostly in response to the immediate requirements of development projects. Data collection intensifies during project studies but generally frequency and quality of data observation fade away when the project is completed.

IWRM in the basins clearly suffers from this lack of a consistent, continuous and accurate hydrometric network. Moreover, data access and data sharing between different agencies remains limited, restricting the benefits obtained from the existing data network.

A management constraint frequently identified and discussed is the inadequacy of a data collection network. This deficiency may have contributed to some water resources development projects not meeting the desired targets. A widely reported example is the Kirindi Oya project. This was originally planned to cultivate 9,600 hectares of land at a cropping intensity of 200 percent. However, the achievement has been about 157 percent of cropping intensity, and the newly settled area has performed even worse (Renwick 2001). The inability to meet the targets has resulted in many social, economic and political problems. Among many other reasons, inadequate or inaccurate data has been quoted as one that contributing factor. It has been pointed out that the recorded annual inflow to the Kirindi Oya reservoir has been 207 million m^3, when estimated design inflow ranged from 298 to 347 million m^3.

Specific cases

In addition to the general problems discussed above, there are some issues related to specific locations.

The Kirindi Oya Irrigation Project is one of the most discussed and studied irrigation projects in the country. This irrigation and settlement project has faced many challenges, especially during the initial stages, since commissioning in the mid-80s. The cropping intensity has been very low, which has severely affected the farmers' income. Several reasons have been cited for this: inflow rates were less than what was estimated at design time and seepage and percolation rates were higher than previously assumed.

The management interventions adopted in the Kirindi Oya project provide lessons for other water-short irrigation systems. They include improving the reuse of drainage water, crop diversification, improved operation & maintenance of the system and farmer participation in management. Although the situation is not perfect, it has improved significantly.

The provision of water supply and sanitation facilities to Kataragama sacred city is a management challenge for the domestic water supply and sanitation sector. The city is located on the banks of the Menik river. The main annual festival of Kataragama falls in July, which is one of the driest months. The water supply system has a design capacity of 5,400 m^3/day. It has 3,400 connections including 2,800 for domestic, 245 for commercial and 43 for religious places. This city also has a sewerage system having 195 connections, which is the only public sewerage scheme in the basins. The system caters for about 22,000 inhabitants and over 10,000 seasonal visitors. The system is stressed during the festival periods and intensive cultivation upstream increases the difficulty in maintaining the delivery and disposal services.

Opportunities

The basins do have the opportunity to establish sustainable water management systems. These opportunities are based on key characteristics of the basins and the local population:

- High literacy that allows effective communication.
- Potential to expand the role of existing farmer institutions to contribute to integrated management of water and other resources.
- Few of the industries at present reuse water, and therefore there is potential for industries to reuse their water. Similarly, there is a possibility to improve reuse of return flows in agriculture.
- The assessment carried out for the WWAP identified that there is a considerable volume of "unaccounted" water in the entire water resources system. When the temporal distribution of available water resources and withdrawals are estimated with greater accuracy, there may be opportunities for further development of water resources.
- The WWAP Case Study Workshop held in April 2002 identified the availability of long-term rainfall and weather data as a strength. This could be transformed to an opportunity.
- Based on the research findings that link groundwater recharge and village tanks, there is an opportunity to scientifically site agro-wells as a sustainable water source. The present emphasis on micro-irrigation would contribute to improving the efficiency of agro-wells. Experiments outside the basins have shown that commercialization of the small farm agriculture can contribute to higher incomes and better management by the beneficiaries.

Threats to the Systems

Threats to agriculture include the increasing competition for access to water resources by other sectors and the exit of lands from agriculture due to salinity and land degradation. Therefore, programs to improve the irrigation efficiency would have to be planned in such a manner that does not result in environmental problems. Threats to the water supplies for basic needs include pollution by industries and agriculture, and problems of distribution of water during drought periods.

The management of planned industrial development in the basins will be a challenge for the future implementation of the Ruhunupura program. Withdrawals for both domestic and industrial use will rise. Similarly, threats to the environment through pollution and encroachment of protected areas could increase. The coastal lagoon systems in the basins are close to areas of high population density and further expansion of industries is planned in these areas. The major challenge is managing competing demands whilst protecting the ecosystems. Unless legislation and support for implementation are adequate, degradation of the ecosystems is likely to increase in the future. The WWAP Case Study Workshop (April 2002) identified seawater intrusion as a threat to the ecological system. As the depletive use of water is likely to increase due to more intensive agriculture and greater withdrawals by other sectors, there is a possibility for these problems to increase proportionally.

The quantity and quality of water available in the basin may restrict choices for industrial development. The proposed Southern Area Development Project, led by Ruhunupura, covering parts of three river basins will demand the development of a more assured water supply for successful implementation. Water demands for the proposed harbor in Hambantota and the airport at Sooriyawewa in particular will test the capacity of the water resources development strategy in the basin.

Although the production of rice exceeds consumption within the basins, malnutrition continues to be a challenge for some groups. The numbers of stunted, wasted and underweight children in the Hambantota and Moneragala districts remain comparatively high, although substantial improvements have been made during the last decade.

NWSDB applies a cross-subsidy system, where the additional income generated over the OPERATION AND MAINTENANCE cost in large water supply systems is used to cover the losses in the smaller systems. However, it has been proposed to decentralize and privatize some of the larger systems, and as such, the sustainability of smaller systems may be threatened.

High levels of poverty will affect the sustainability of water resources management interventions, leading to a vicious circle where water and land degradation restricts income, leading to further poverty. A survey carried out in Hambantota has shown high levels of indebtedness occurring during illnesses (Shanmugarajah 2002). Water-related diseases such as malaria and dengue adversely affect the productivity of farmer families. Studies elsewhere have shown that farmers' investment in agricultural management is restricted by the poor returns from agriculture. Poor investments, in turn, contribute to low productivity and thus to lower incomes.

Setting Priorities within the Case Study Area

The water resources in the Ruhuna Basins are fairly highly developed. Therefore, increasing productivity of water use in all sectors will be a high priority for the foreseeable future. As agriculture is the largest bulk water user, it is clear that improving water use management in irrigation will lead to higher productivity in the sector and will, potentially, free resources for the other users.

Despite the high percentage of water resources already developed, there is a potential for further development in several subbasins. It is essential that these resources be developed in a manner that does not negatively affect the sustainability of ecosystems and other existing uses. It is also important to improve the storage capacity of the river basins, as a large volume of water is not effectively used during the rainy season.

A considerable amount of data is being collected within the basin, although improvements are required as noted in the preceding sections. Improvements to the hydrometric network and establishing the systematic maintenance of the database are required to enable monitoring the performance in the challenge areas in Ruhuna and elsewhere in Sri Lanka. To a large degree, the problems identified in the basin are mainly related to management, which can be improved with capacity building and making available necessary hardware and software for better access to up to date information for policy makers and managers.

As identified above, the sustainability of any water resources management interventions will be adversely affected by poverty. All water resources development programs must give due attention to the alleviation of poverty. Interventions are needed to enhance the purchasing power of the community, so that benefits of improved productivity are made available to them.

Development of Indicators

Indicators are the cornerstones to effective management of water resources in the basins. A set of primary indicators has been identified that is effective in describing the basins according to only a few key numbers. Indicators presented (Table 25) are the result of several stakeholder meetings, discussions amongst experts and analysis of available data. Limited availability of data will be a constraint to replication of these calculations for other basins and therefore enhanced data collection, processing and storage will be a priority follow-up action.

The indicators in this series of case-studies for the WWAP are either descriptive or present a numeric snap-shot of average conditions. However, as data sets become more available and the reliability of the data is improved, many of the quantitative indicators should be redefined to a probabilistic format. Dependence on mean values for the indicators will disguise the variability and risks associated with extremes.

As the basins come under increased development pressure, and with the potential impacts of anthropomorphic climate change, it will be the capacity to manage the extremes that should characterize water resources stewardship. The WWAP should lead the development of appropriate tools to analyze the effectiveness of the arrangements to manage water resources put in place by the participating Governments.

Table 25 Summary of WWDR indicators for Ruhuna basins

Theme	Situation in the Ruhuna basins in relation to the indicators proposed by the WWDR
1. Surface water indicators	Withdrawals = million m^3/year, Annual Water Resources (AWR) = 2460 million m^3 Annual rainfall= 9010 million m^3
2. Surface water in support of Water for rain fed agriculture	Precipitation : 1524 mm (basin average) Evapo-transpiration : 1700 mm
3. Water Quality	Water quality measured at specific locations. Measurements are not continuous. Poor quality experienced in estuaries and coastal lagoons.
4. Ground water	A Comprehensive Groundwater assessment is being carried out. Groundwater recharge = 7 to 10% in hard rock terrain. Groundwater reliance= annual groundwater withdrawals/total annual withdrawals= 03 percent
5. Risk management	Dry season drought probability= 32% Wet Season drought probability= 28.4% Risk of Malaria and other water related diseases exist.
Use of Water	
6. Meeting Basic Needs	Access to safe water= 60% (the available data do not indicate whether there is sufficient water) Access to adequate sanitation = 71% Hours of water supply/day as an indicator has been suggested, but data are not available yet.
7. Securing Food Supply	Average paddy yields: Major irrigation (> 80- ha) = 4.6 T/ha Minor irrigation (< 80 ha) = 3.6 T/ha Rainfed = 2.9 T/ha Water Productivity (selected scheme) = 0.14 kg/m^3 (for paddy)
8. Water for Ecosystem	Present estimation of the surface area of wetlands :. Total protected land area = 1200 km^2 = 21% of basins Forest cover = 1418 km^2 = 25% 01 RAMSAR sites
9. Water and Industry	Annual water use (estimated)= 04 million m^3 Water re-use is not very common. Effluent discharge to open drains observed.
10. Water and Energy	Total installed capacity is about 126 MW About 1.3 million m^3 is used for generating 1 GWH Basin produces about 245 GWH annually.
11. Water and Cities	No major cities at present. However, water for cities is a major issue for the future. With the planned industrial development, water needs for domestic and industry expected to increase to 100-150 million m^3
Management of Water	
12. Sharing Water	Agriculture is the major user; estimated use is about 95-97% Industry use is about 1 percent. Domestic water use is about 1-2 percent. In drought situations domestic water is the priority. Formal policy is being prepared.
13. Valuing Water	Economic, social environmental and cultural values are considered in planning water resources. Pipe borne water supply is charged. (more information is being collected). Irrigation water is not directly charged. But part of the management cost is recovered through participatory management.

Theme	Situation in the Ruhuna basins in relation to the indicators proposed by the WWAP
14. Governing Water Wisely	Participatory management in irrigated agriculture became national policy in 1988. A large number of Agencies involved in water management and related activities. Coordination effected at various levels. Participation by women considered inadequate. Farmer Companies concept is being promoted.
15. Ensuring Knowledge base	Hydrometric network consists of 19 rainfall stations, 25 agro-meteorological stations and 6 water level stations. This number and locations are considered inadequate for comprehensive water resources assessment. A considerable amount of data is collected, but not readily accessible.

Surface Water Indicators:

Average annual escape to sea = 11%
(Varies from 4% to 16% in main sub-basins.)
Gross annual surface water resources per capita= 2,290 m^3
Withdrawals/Water Resources (annual, surface) = 45%

Surface Water Storage Capacity/Annual water resources = 37%
(varies from 5% to 57% in main sub-basins.)

Water for eco system

Area of Wetlands:

Coastal lagoons	=	3593 ha	=	36 km^2
Irrigation reservoirs	=	7500 ha	=	75 km^2
Paddy lands	=	52000 ha	=	520 km^2
Total				= 631 km^2
				= 11% of total basins area

Bundala National Park (Ramsar Site)- species

Nationally threatened, endemic or rare birds (either category)	= 56
Mammals	= 32
Nationally threatened or endemic reptilian species	= 17
Amphibians	= 15
Fish	= 32

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