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An Approach to Sustainable Water Management Using Natural Resource Accounts: the Use of Water, the Economic Value of Water, and Implications for Policy

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Abstract

A Natural Resource Accounting project is currently underway to document the status of the nation's resources and their current economic use. Accounts for water constitute a major component of the Natural Resource Accounts (NRA) since water is the limiting resource for economic development in Namibia, as it is for much of Southern Africa. The NRA include both stock and use accounts for water, as well as related environmental statistics. In order to design development strategies that are sustainable over the long run, it is essential to know the full value of this scarce resource. This is especially important for a resource like water which is used throughout the economy and must be managed to achieve sometimes conflicting economic, social, and political objectives.

A comparison is made of user fees, costs of delivery, and the economic contribution of water in different sectors of the economy as a first step toward estimating the opportunity cost of water. As in many countries, government-provided water is heavily subsidized, especially in agriculture. An analysis of two of the largest and most heavily subsidized users of water -- commercial crop irrigation and rural subsistence production -- has important implications for agricultural policy and rural development strategy. Further development of the opportunity cost approach to water pricing would greatly enhance policy analysis. There is also a need for similar, coordinated work to be carried out in other countries in Southern Africa in order to design strategies for sustainable management of resources, like water, which transcend national boundaries.

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1. Introduction: Water in the Natural Resource Accounts

With a population of about 1.6 million, Namibia is one of the world's most sparsely populated countries. It is sub-Saharan Africa's driest country; roughly 80% of its 842,000 square kilometres consist of desert, arid, and semi-arid land (Brown, 1994). Rainfall is quite low, ranging from less than 50mm to more than 700mm a year with a long-term average of about 320mm per year, less than the minimum amount considered necessary for dryland farming (400mm a year). Rainfall is not only low but extremely variable over much of the country and droughts are a common occurrence (Figure 1). In addition, Namibia's high temperatures result in high rates of evaporation of rainfall; it is estimated that only 1% of annual rainfall contributes to groundwater recharge and only 2% is retained in reservoirs (DWA, 1991a).

Namibia is highly dependent on its natural resource base -- mining, agriculture, fishing, and wildlife-based tourism -- and water is the single most important constraint to development. Consequently, water management policy is a critical component of Namibia's development strategy. At Independence in 1990, Namibian society was marked by vast inequalities of income, wealth, and access to natural resources. Two very different and separate economies had developed: the so-called communal sector in which the majority of the people were restricted to a disproportionately small land area and practised subsistence agriculture, and a commercial economy based on export-oriented mining and freehold agriculture controlled by a minority. The highly skewed distribution of income and access to resources has resulted in uneven population pressure on land and water; the pressure is most severe in communal areas where there has been historic under-investment in water infrastructure and population is growing very rapidly. In 1990, it was estimated that only 50% of the rural population had access to a reliable source of safe drinking water. Urban areas have been well-supplied with safe water, though access is limited for low-income groups (National Planning Commission, 1996).

Water use has grown rapidly over the past 25 years, from about 25 million cubic metres in 1970 to 88 million cubic metres in 1993 (bulk water supply only; Ashley et al., 1995). There is concern that water supplies are running short and are not being used sustainably: water tables have sunk and fossil water is being extracted in some areas. Increasing harvesting of ephemeral surface water diverts water from downstream users and may have negative effects on ecosystems, vegetation necessary for livestock and wildlife, and recharge of groundwater. At the same time, water is wasted through losses in the distribution network due to poor maintenance, and low water prices have discouraged water conservation measures by end users.

Potential new sources of water include desalination of sea water and long-distance water carriers to tap international rivers. Both measures are very expensive and may have negative environmental impacts. Despite having reached the limits of many domestic sources of water, water demand will continue to grow as the economy and population, especially the urban population, grow. Competition for water will intensify. In this context, it is essential to carefully examine current patterns of water use and the influence of various policies on water demand. The design of sustainable development strategies requires an understanding of the full social value of water and an assessment of the tradeoffs among competing economic activities.

In the past, natural resources were exploited with little planning for the provision of future income. The Government of Namibia has now undertaken the construction of Natural Resource Accounts (NRA) as a step toward sustainable management of its resources.

The NRA water accounts can assist in the analysis and design of development strategies that are sustainable by providing the following information:

1. The present state of water management.
   How is water currently used in the economy? What is the economic contribution of water use in each sector? To what extent is water use subsidized in each sector? What is the opportunity cost of water use by each economic sector? Does the current pattern of water use and infrastructure development represent the best use of scarce water and financial resources?

2. Future water use and management.
   What are future water demands likely to be? How do policies in other sectors--e.g., agriculture, trade, rural development, and energy--affect the demand for water? Using appropriate policy and technology, can all the development objectives be met? If not, what are the economic tradeoffs and how can priorities be established?

In this paper, the NRA are used to explore the first set of questions concerning the present state of water management. This analysis provides the basis in the next stage of the work on NRA for addressing the second set of issues, evaluating alternative water management strategies for sustainable development. The paper begins with a discussion of the Namibian NRA and data sources for water, followed by an overview of the status of Namibia's water resources, based on the NRA stock accounts for water. Section 3 provides a detailed analysis of the water use accounts for the benchmark year for NRA, 1993. The analysis examines patterns of water consumption, the economic contribution of water use in each sector of the economy, and the subsidies received by each sector (based on an analysis of user charges and delivery costs). Finally, policies affecting water use for commercial crop irrigation and subsistence production, the two largest and most heavily subsidized water-using sectors, are examined in detail. The paper concludes with the implications of the analysis for policy in agriculture and rural development, and a discussion of the direction of analysis in the future.

2. Data Sources and Methods

The Namibian NRA generally follow the United Nation's SEEA (System of Integrated Environmental and Economic Accounts) approach (United Nation, 1993), though strongly influenced by the Norwegian system (Alfsen, 1996; Alfsen et al., 1987) with its emphasis on compilation of a detailed physical database and the integration of NRA with economic models for policy analysis. In addition to water, the NRA constructed for Namibia include livestock, fisheries, land, land degradation, wildlife, and minerals.

of Namibia. Ephemeral surface water is supplied by rivers within the country that only flow after especially long rains. Perennial and ephemeral surface water accounted for 27% and 22%, respectively, of Namibia's annual water use in 1993 (Figure 2).

Two different institutions were established to deliver water to end users, bulk water supply and rural water supply, which account for 43% and 57%, respectively, of Namibia's water use (Figure 2). Bulk water supply relies on relatively large-scale dams, transport, and storage technology and delivers water mainly to urban areas and commercial agriculture. Rural water supply utilizes relatively small-scale, localized means for collection (mostly boreholes in rural areas) and does not generally transport water over large distances. While all of bulk water is provided by the government, rural water supply is partly the responsibility of the government and partly provided by users at their own expense under some supervision by the government. The latter accounts for 39% of all water use and include commercial livestock and part of commercial crop production, diamond mining and part of other mining, and part of tourism facilities.

The stock accounts for water along with some supplementary information can be used to assess the status of Namibia's water resources. Groundwater is characterized by great uncertainty over the extent of reserves, the problem of depletion, and conditions of groundwater recharge. Surface water, both perennial and ephemeral are characterized by a high degree of annual variability due mainly to variations in rainfall.

Groundwater

Groundwater is often the cheapest and most reliable source of water for much of Namibia's dispersed population since it can be tapped at the point of use and it is not directly dependent on annual rainfall. It is especially difficult and expensive to measure groundwater in Namibia since it occurs in many different aquifers of different shape and size throughout the country. In addition, the quality of groundwater, measured, for example, in terms of saline content, also varies a great deal from one aquifer to another. No comprehensive information about the total volume of groundwater is available. Estimates have been undertaken in the central area of Namibia for selected aquifers under the administration of the bulk water supply in 1992 (DWA, 1993b, 1993c; reported in Table 1, column 1). Efforts to improve and expand estimations of groundwater sources are currently underway, but are unlikely to provide a comprehensive figure in the near future.

Since groundwater supplies over half of all Namibia's water, the possibility of depletion is a serious concern. The lack of information about groundwater stocks poses a problem for setting rates of abstraction that are sustainable and for assessing the extent to which Namibia may be depleting its groundwater. However, it is prohibitively expensive to measure and continuously monitor the stock of groundwater. As a result, DWA has developed another method to estimate sustainable rates of abstraction, based on monitoring the water tables of all the boreholes under its jurisdiction. Estimated sustainable use is defined as that rate of abstraction which maintains the level of the water table over the expected cycle of rainfall (a precise number of years constituting an expected cycle of rainfall and recharge has not been established for each borehole). In addition, new boreholes are subject to pump tests to estimate the rate of recharge. In practice, rates of abstraction which result in a water table

Table 1. **Stocks of Groundwater, Perennial Surface Water, and Ephemeral Surface Water, 1980 to 1993** (millions of cubic metres)

		Perennial Surface Water Annual Runoff of Major Rivers					Ephemeral Surface Water	
	Ground Water	Orange	Zambezi	Kwando	Okavango	Kunene	Annual Runoff	Annual Dam Storage
1980	na	3,583	41,633	1,732	5,035	1,561	64	241
1981	na	3,308	23,686	923	5,105	1,980	73	164
1982	na	1,125	23,157	837	3,907	2,868	86	105
1983	na	1,592	25,595	869	9,408	11,156	437	157
1984	na	932	28,555	880	5,375	6,594	481	277
1985	na	2,200	28,996	913	4,629	7,238	367	417
1986	na	2,731	31,916	929	4,239	4,165	215	378
1987	na	21,885	28,988	787	5,393	4,191	775	471
1988	na	10,897	49,953	1,026	5,820	5,085	755	461
1989	na	2,415	19,887	1,064	4,370	4,582	161	335
1990	na	3,534	31,483	795	3,882	3,863	275	303
1991	na	2,800	17,613	661	6,607	7,404	58	184
1992	938	600	34,941	785	3,228	1,840	222	252
1993	na	1,298	24,011	844	2,998	2,516	286	293

na: not available

Notes: Annual runoff of perennial surface is reported for recording stations. These cannot be summed since some rivers feed into others.
Data about groundwater available only for selected aquifers in the Central Area of Namibia in 1992; these figures are fairly representative of the groundwater stocks in that area in earlier years.
Ephemeral surface water estimates are based on data from the major rivers, but not all rivers.

Source: column 1 (DWA, 1993b, 1993c), columns 2-8 (DWA, Hydrology Division, 1995a, 1995b).

which falls continuously over five years without recovery during periods of reasonable rain are considered to be unsustainable rates of water use.

Table 2 shows groundwater sources currently considered to be subject to depletion. Of the 87 million cubic metres of bulk water supplied in 1993, 14% came from groundwater stocks considered to be experiencing serious, long-term depletion (as evidenced by continuously falling water levels in boreholes without recovery for five or more years). The seriousness of depletion of groundwater is determined by the availability of alternative sources of water and the numbers of users served by the groundwater source. Much of the coastal region is affected, which includes important urban and tourist centres (Swakopmund and Walvis Bay), mining (uranium), and industry (fish processing).

There is, however, a great deal of uncertainty concerning the severity of depletion of groundwater stocks assessed in this way. Namibia's highly variable rainfall can result in long periods of a continuously falling water table followed by a one-time rainfall event which

- the potentially negative impact on downstream users (ecosystem and human communities) of extensive draw-down of groundwater, even when the aquifer is recharged to its previous level by periodic heavy rainfall.

- the potential change over time in the ability to achieve recharge from heavy rainfall due to changes in the environment, e.g., siltation of riverbeds.

There is not enough information at this time to determine the appropriate cycle for most aquifers. Given the potential for permanent damage to the capacity for groundwater storage due to mismanagement, this situation warrants close monitoring.

Groundwater provided by rural water supply is also experiencing depletion in some areas. Unfortunately, rural water supply, which accounts for about 70% of groundwater use, has not been subject to the same degree of monitoring as bulk water supply. Not only are there no records about water tables of the boreholes, but, in many instance, there are no reliable estimates of the rates of abstraction from boreholes. Though all boreholes are required to be registered, it is likely that there are a significant number of boreholes which have not been registered, and consequently are not subject to monitoring. A monitoring program is being put into place, but it will take a number of years before this program will yield information which can be used to estimate sustainable rates of groundwater abstraction for the rural water supply.

Perennial Surface Water

Perennial rivers are those which do not dry out during the year. Nevertheless, the volume of all perennial rivers is subject to considerable variation over time (Figure 3). There are no water storage dams on the perennial rivers, though there is a dam used to generate hydroelectric power. While a river is by definition a flow rather than a stock, it is useful to distinguish the amount of river water potentially available in a given year from the amount actually used. The amount potentially available, measured as annual runoff for each major river, is included in the stock accounts of the NRA at this time (Table 1, columns 2-6).

All perennial rivers originate outside of Namibia and form international boundaries between Namibia and its neighbours. Consequently, the amount of water actually available to Namibia each year is subject to international agreements among the countries sharing the perennial rivers. An agreement has been concluded with South Africa and agreements are under negotiation with other neighbouring countries. At present, Namibia does not use its full negotiated quota with South Africa because there is little development along the river and the cost of transporting water to high-demand areas is prohibitive. It is likely that this situation will change in the near future if new irrigation schemes or a proposed copper mine are established.

Ephemeral Surface Water

The amount of ephemeral water in a given year depends on annual rainfall; in some instances there may be carry-over from a previous year stored in dams. For the NRA, three sets of information are collected about ephemeral surface water, the first is a stock account and the other two are supplementary statistics useful for understanding the stock accounts:

1. annual volume of water stored in a dam each year at the beginning of April (Figure 4; Table 1, column 8). April marks the end of rainy season and the time when DWA plans its water supply strategy for the next two years, i.e., DWA evaluates the ability of the dam to satisfy current rates of use should no rain fall over the next 24 months (adjusting for evaporation over that period).

2. annual runoff from the major ephemeral rivers (a measure of gross potential stock; Figure 4; Table 1, column 7).

3. annual rainfall and percent deviation from long-term average rainfall of roughly 200 meteorological stations throughout the country (Table 3).

While only dam storage can be considered an actual stock of water, the annual runoff of ephemeral rivers provides an important supplementary indicator of the gross potential addition to the stock of ephemeral water stored in dams. The stock will vary greatly from one area to the next based on the annual distribution of rainfall. Since the local availability of water is a critical factor for water supply and there is little infrastructure for moving water from surplus to deficit areas, the stock accounts are compiled separately for each of the major dams. The annual runoff is largely determined by the amount and distribution of rainfall. Rainfall data are provided for roughly 200 meteorological stations operating over the period 1915 to 1994. For the sake of brevity, they are reported here only for the years 1980 to 1994. These stations are organized according to veterinary district (to facilitate use with livestock and land accounts) and an average rainfall is calculated for each district.

Table 3. Deviation of Annual Rainfall from Long-Term Average Rainfall, 1980 to 1994

Year	Rainfall (millimetres)	Percentage Deviation from Long-Term Average
1980	197.2	-39%
1981	219.2	-32%
1982	215.7	-33%
1983	313.4	-2%
1984	269.0	-16%
1985	340.1	6%
1986	268.7	-16%
1987	338.3	5%
1988	387.0	21%
1989	287.4	-11%
1990	336.7	5%
1991	255.8	-20%
1992	277.3	-14%
1993	341.4	6%
1994	138.8	-57%
Long-Term Average (1915-1994)	321.1	

Source: compiled from unpublished database of the Weather Bureau.

4. Annual Use and Economic Contribution of Water

Annual Use of Water by Sector

Of the 200 million cubic metres of water used in 1993, agriculture accounts for 61%, households another 22%, mining 11%, and the remaining 6% is divided among all other sectors (Figure 5, Tables 4 and 5). Urban households comprise only 29% of the population, but consume more than three times as much water as rural households. Bulk water supply primarily supports urban households and commercial agriculture (irrigation), which together account for 72% of bulk water. Other commercial, urban-based activities in manufacturing and service sectors, though accounting for a small share of total water use in the economy, are also supported by bulk water supply. Only the bulk water supply system has the infrastructure (dams and water transport infrastructure) to utilize ephemeral water extensively. Ephemeral water accounts for about 50% of bulk water; most of the rest is provided by groundwater, and less than 5% is provided from the perennial rivers. Rural water supply, not surprisingly, supports rural-based activities: agriculture, some mining, and rural households. Most of the water is obtained from groundwater sources (54%) or from the perennial rivers (45%), especially along Namibia's northern border where most of the rural population lives. Less than 1% comes from ephemeral rivers.

Table 4. Use of Water by Source and Sector in 1993 (millions of cubic metres)

	All Sources			Ground			Perennial Surface			Ephemeral		
	Total	Bulk	Rural	Total	Bulk	Rural	Total	Bulk	Rural	Total	Bulk	Rural
Agriculture	**146.2**	**35.2**	**111.1**	**69.1**	**5.6**	**63.4**	**48.9**	**1.9**	**47.1**	**28.3**	**27.7**	**0.6**
Livestock	39.1	7.5	31.6	36.5	5.6	30.8	2.6	1.9	0.8	0	*	0
Crops	107.1	27.7	79.5	32.6	0	32.6	46.3	0	46.3	28.3	27.7	0.6
Communal	**34.8**	**7.5**	**27.3**	**16.0**	**5.6**	**10.3**	**18.8**	**1.9**	**17.0**	**0**	**0**	**0**
Livestock	17.0	7.5	9.5	14.4	5.6	8.7	2.6	1.9	0.8	0	0	0
Crops	17.8	0	17.8	1.6	0	1.6	16.2	0	16.2	0	0	0
Commercial	**111.4**	**27.7**	**83.7**	**53.1**	**0**	**53.1**	**30.1**	**0**	**30.1**	**28.3**	**27.7**	**0.6**
Livestock	22.1	0	22.1	22.1	0	22.1	0	0	0	0	*	0
Crops	89.3	27.7	61.6	31.0	0	31.0	30.1	0	30.1	28.3	27.7	0.6
Crops exc own use[a]	64.6	27.7	36.9	6.3	0	6.3	30.1	0	30.1	28.3	27.7	0.6
Fisheries	0	0	0	0	0	0	0	0	0	0	0	0
Mining	**21.7**	**4.4**	**17.3**	**20.3**	**3.0**	**17.3**	**0.9**	**0.9**	**0**	**0.5**	**0.5**	**0**
Diamonds	13.6	0	13.6	13.6	0	13.6	0	0	0	0	0	0
Other mining	8.1	4.4	3.7	6.7	3.0	3.7	0.9	0.9	0	0.5	0.5	0
Manufacturing	**5.0**	**5.0**	**0**	**3.5**	**3.5**	**0**	**0.2**	**0.2**	**0**	**1.3**	**1.3**	**0**
Fish Processing	0.7	0.7	0	0.7	0.7	0	0	0	0	0	0	0
Other Manufacturing	4.3	4.3	0	2.8	2.8	0	0.2	0.2	0	1.3	1.3	0
Services	**5.2**	**5.0**	**0.2**	**3.6**	**3.4**	**0.2**	**0.2**	**0.2**	**0**	**1.5**	**1.4**	**0.1**
Utilities	0.3	0.3	0	0.2	0.2	0	0	0	0	0.1	0.1	0
Construction	0.7	0.7	0	0.5	0.5	0	0	0	0	0.2	0.2	0
Trade	0.7	0.7	0	0.5	0.5	0	0	0	0	0.2	0.2	0
Hotels/Restaurants	1.1	0.9	0.2	0.8	0.6	0.2	0	0	0	0.4	0.3	0.1
Transportation	0.8	0.8	0	0.7	0.7	0	0	0	0	0.1	0.1	0
Communications	0.2	0.2	0	0.1	0.1	0	0	0	0	0	0	0
FIREB	0.6	0.6	0	0.4	0.4	0	0	0	0	0.2	0.2	0
Self-owned housing	0	0	0	0	0	0	0	0	0	0	0	0
Social services	0.8	0.8	0	0.5	0.5	0	0	0	0	0.2	0.2	0
Households	**44.7**	**34.7**	**10.0**	**28.2**	**22.6**	**5.7**	**5.3**	**1.7**	**3.6**	**11.2**	**10.4**	**0.7**
Rural	10.0	0	10.0	5.7	0	5.7	3.6	0	3.6	0.7	0	0.7
Urban	34.7	34.7	0	22.6	22.6	0	1.7	1.7	0	10.4	10.4	0
Government	**2.3**	**2.3**	**0**	**1.5**	**1.5**	**0**	**0.1**	**0.1**	**0**	**0.7**	**0.7**	**0**
Total	**225.1**	**86.6**	**138.5**	**126.2**	**39.6**	**86.6**	**55.7**	**5.0**	**50.7**	**43.3**	**42.0**	**1.4**
Total exc. own-use[a]	**200.4**	**86.6**	**113.8**	**101.4**	**39.6**	**61.8**	**55.7**	**5.0**	**50.7**	**43.3**	**42.0**	**1.4**

* negligible amount.

[a] It is assumed that commercial farmers use some water for irrigation of crops for own use. This amount has never been substantiated and is not included in discussions that follow. See Annex for further discussion.

Note: May not sum due to rounding

Source: author s estimates based on sources discussed in Appendix.

Table 6. Economic Contribution of Water by Sector in Namibia, 1993

Sector	Output (10^6 N$)	Value-Added (10^6 N$)	N$ of Output per m^3 of water input	N$ of Value-added per m^3 of water input
Agriculture	**793**	**561**	**6.5**	**4.6**
Commercial agriculture[a]	617	405	7.1	4.7
Livestock	580	na	26.2	
Crops	14	na	0.2	
Communal agriculture[b]	176	156	5.0	4.5
Mining	**1,880**	**862**	**86.6**	**40.0**
Diamond mining	1,137	609	83.6	44.7
Other mining	743	253	91.7	32.0
Manufacturing	**2,006**	**656**	**403.6**	**132.0**
Fish processing	530	316	757.1	451.4
Other manufacturing	1,476	340	345.7	79.6
Services	**5,311**	**2,807**	**1,018.6**	**538.3**
Hotels/Restaurants (Tourism)	296	129	258.7	112.7
Transportation	680	245	871.8	314.1
Other services	4,335	2,433	1,317.7	739.6
Non-Agricultural Sectors	**14,419**	**7,013**	**375.0**	**182.4**
All Producing Sectors		**7,574**	**95.1**	**47.3**
Gross Domestic Product		8,860		44.3

a The subsectors Livestock and Crops do not sum to the total because of a small amount of own-account construction included in this sector.
b Communal agriculture cannot be disaggregated at this time.
na: not available. The national accounts do not disaggregate agricultural value-added between livestock and crop production.
Note: Blanks indicate that the figure cannot be calculated. Electricity and construction are included in services. The value of government and household use of water cannot be calculated in this way.

Source: Author's calculations based on (Central Statistics Office, 1996a) for economic data and Table 4.

and, not surprisingly, diamond mining generates a higher return than the mining of other resources. Fish processing and tourism -- both potentially high- growth sectors -- generate a relatively high return on water input, N$451 and N$113, respectively.

Within agriculture, the value-added generated per cubic metre of water used is fairly similar for communal and commercial agriculture, N$4.5 and N$4.7, respectively. This similarity

Namibia's rural population relies on subsistence agriculture and wage employment in agriculture is estimated at 33,000 (CSO, 1996b) which is roughly 7% of the labor force. Unfortunately, data about employment by sector are not available for 1993; the most recent data are for 1991.

5. Water Pricing Policy, Delivery Costs, and Subsidies

Water tariffs and delivery costs

Despite the scarcity of water in Namibia, no user of water provided by the government pays the full financial cost, operating plus capital costs (Table 7). Total subsidies to bulk and rural water supply amounted to N$ 67.3 million in 1993. Furthermore, no user pays the full social cost of water, even those rural users who obtain water at their own expense.

The tariffs charged for water and the costs of providing water vary enormously among economic sectors. Tariffs for bulk water in 1993 averaged N$ 0.66 per cubic metre with a low of N$0.015 in agriculture for irrigation (Directorate of Water Affairs, 1995). The average tariff for all users, excluding irrigation, was N$0.95 per cubic metre of water and ranged from a low of N$0.27 for a rural community to a high of N$1.27 for one of the mines. In most areas, the same tariff is applied to all users, regardless of how much water they consume. Windhoek has introduced a stepped-pricing system and a slightly stepped tariffs are also applied at the main irrigated farming site, Hardap.

Given the highly dispersed population, water is often quite expensive to supply, especially in rural areas. For bulk water supply, operating costs per cubic metre range from a low of N$0.12 to N$30.02 in some rural areas; capital costs range from N$0.02 to N$62.04; the average operating and capital costs were N$0.96 and N$1.38, respectively (Directorate of Water Affairs, 1995). The average total costs (operating plus capital costs) were N$2.34 per cubic metre, considerably higher than the average non-agricultural tariff of N$0.95 and two orders of magnitude more than the agricultural tariff.

As a result of the gap between the costs of providing water and the tariff, the average subsidy to users of bulk water supply in 1993 was 17% of operating costs and 71% of total costs (operating plus capital costs). Among the users of bulk water supply, crop farmers are the most heavily subsidized, paying only 21% of operating costs and only 4% of total costs. Urban households, part of mining, and transportation (mainly airports) also receive subsidies of both operating and total costs. Tariffs for other sectors cover or exceed the operating costs, though these sectors accounted for less than 4% of total water use in 1993 (other manufacturing, other services, fish processing and tourism). These sectors are also among those which generate the highest value-added per unit of water used. The total subsidy for bulk water supply was N$37.3 million in 1993. The effective subsidy is actually higher when failure to collect tariffs is also taken into account.

Until recently, tariffs have been charged only for customers of bulk water supply; there was no user charge for water supplied under the government's rural water supply scheme so users of rural water supply received a 100% subsidy. Because water supply to rural communities was undertaken out of concern for social justice, little attention was paid to cost and only very rough estimates of the cost of rural water supply are currently available, though a program has been put in place to begin to begin to track these costs. The government's annual operating budget for rural water--the effective subsidy cost--amounts to N$30 million.

Recognizing the importance of user charges that more closely reflect costs, the government introduced a new pricing policy which aims at "full cost" recovery. Under this policy, tariffs for bulk water were raised in 1995 (by an average of 30% while costs rose by about 10%) and tariffs are gradually being introduced for rural water users. However, full cost recovery is defined as recovery of operating costs and does not take into account either capital costs or any social costs that may be incurred. Omission of capital costs is appropriate in cases where water demand can be met with existing infrastructure which has already been paid for, but may be less prudent when massive new investments are required, as is the case with Namibia. Omission of capital costs can distort decision-making regarding alternative water supply strategies. For example, water conservation measures may appear less advantageous than relatively capital-intensive measures, like a long-distance pipeline or large-scale desalination plant, if the capital costs of the alternatives are not taken into account.

Even a pricing policy based on recovery of both operating and capital cost does not always reflect the full social costs of water use. There may be external costs associated with the depletion of fossil groundwater or the loss of surface water for downstream use. Because groundwater is a common property resource, its depletion can generate external costs in the form of reduced groundwater available for neighboring users. The full economic cost of using water must reflect the opportunity cost that measures the lost revenues from alternative uses. For example, a dam on a seasonal river to support crop irrigation will reduce grazing downstream: the diversion of perennial river water for irrigation will reduce electric power generation at a downstream hydroelectric plant.

Despite the shortcomings, the introduction of prices that cover operating costs is a step toward providing users a more appropriate signal about the scarcity of water and an incentive to conserve water. Several sectors already meet or exceed this pricing objective; tariffs for most other sectors would not require a large increase to meet this objective. However, two sectors would experience considerable difficulty in paying the operating costs and bear closer scrutiny:

- bulk water supply to commercial farmers for irrigation

- rural water supply to communal sector livestock farming and households

Irrigated Crop Production in the Commercial Sector

Commercial farmers provide between 30- 50% of Namibia's demand for cereals, depending on the annual rainfall (Fowler, 1996). All of Namibia's wheat and a smaller share of its white maize population. Given Namibia's low carrying capacity and highly dispersed population, it is extremely expensive to provide services to all rural households. Many rural households earn only a minimal subsistence living and rely on pensions and remittances from family in urban areas (Adamchak, 1995; Central Statistics Office, 1996b). They could not afford to pay the full costs of water.

A number of rural development schemes have been initiated based on irrigated crop farming. These agricultural schemes are particularly costly and have so far proven unable to pay even their operating costs (for an evaluation of the scheme at Etunda, see Low, 1996). In part, this is due to the emphasis on the production of low-value cereal crops which do not generate enough revenue to pay for water. Not only do cereal crops generate lower incomes per hectare irrigated and per cubic metre of water input than other crops, but they also generate lower levels of employment. Consequently, the emphasis on cereal crops reduces the effectiveness of these development schemes in alleviating rural unemployment and poverty. Alternative crops would generate higher incomes and employment (though extensive transportation and marketing infrastructure would be needed). For example, citrus generates more than 20 times as much income per hectare as maize (N$17,200 v. N$780) and grapes generate 47 times as much income as maize. Citrus production requires 340 person-days per hectare and grapes require 1,150 person days while maize generates employment of only 20.5 to 44.5 days per hectare (Fowler, 1996).

Furthermore, the opportunity cost of using water for the Etunda irrigation scheme was not taken into account in the planning stage. Not only is the Etunda project unable to cover its operating costs, but it results in losses to other sectors of the economy. The Etunda irrigation scheme is up-river from the hydroelectric power generation plant at Ruacana. The use of water for irrigation reduces the water available for electricity production, reducing revenues for Nampower and affecting Namibia's international trade in electricity.

6. Policy Implications:Sustainability of Current Patterns of Water Use

Given the economic objectives outlined in the First National Development Plan (National Planning Commission, 1996), water demand is likely to increase by nearly 20% from 1993 to 2000 in the absence of water conservation measures (preliminary estimates by the author). Sound water policy is critical and needs to be examined from both an ecological and an economic perspective.

Ecological Sustainability

Ecologically, growth of water demand under current practices raises serious challenges. Groundwater supplies about 62% of rural and urban household water requirements and 85% of the water for communal area livestock. These users together account for roughly one-third of total water use and constitute the fastest growing users of water as well. Groundwater depletion, already a concern in selected areas of Namibia, is likely to worsen because of the recent drought. Drought diminishes the amount of surface water available, which increases the use of groundwater while at the same time reducing the recharge of groundwater sources.

that the introduction of higher-value crops combined with water conservation measures would make irrigated farming profitable with full cost recovery, but further study of these options is needed. Decisions about water pricing need to be coordinated with other policy decisions which affect agriculture, such as trade liberalization. Policies are needed to assist in a transition to agriculture which is more sustainable both ecologically and economically.

It is a widely-supported position that the population of communal areas merits assistance to help reduce the sizeable inequality of income and access to resources in Namibia. This analysis raises concerns about the most effective means to provide that assistance, recognizing that there are tradeoffs inherent in any development strategy: the more money the government spends on one program, the less it will have to spend on others. The current rural development strategy provides water at great expense for activities which are not economically sustainable and may not make the greatest contribution toward reducing rural poverty. Analysis indicates that, at the very least, the kinds of crops under irrigated cultivation needs to be more closely examined in terms of the impact on rural poverty. An example of an alternative development strategy would be the promotion of more rapid growth of regional towns where infrastructure and services like water as well as education, health, and other social services could be provided more cheaply. This policy would then have the advantage of increasing the financial resources available for additional development projects and might allow the government to improve the standards of living of a greater number of people.

No sector of the economy pays the full private costs of water, even under the new system of tariffs, and there is little information about the real social cost of water. Regardless of whether Namibia's development objectives for specific sectors are primarily economic, or a combination of economic, political and social factors, a better understanding of the scarcity value and opportunity cost of water would improve the ability to assess alternative development strategies. A couple of alternatives to current policies in commercial agriculture and rural development were mentioned to illustrate shortcomings of current policy. Additional, realistic alternatives need to be identified and evaluated in a multi-sectoral framework that takes into account the full range of development objectives and the sectoral strategies for achieving them. This multi-sectoral analysis, for which NRA are ideally suited, will help reveal the opportunity cost of resource use and provide the basis for identifying sustainable development strategies.

Namibia is now undertaking the institutionalization of NRA and has assumed a leadership role in NRA in the Southern African region. An initial workshop was held to discuss a regional strategy for developing environmental accounts. One key element of the strategy is to link the construction of NRA with their use for macroeconomic policy analysis and planning. A second important element was the adoption of a common framework and a common set of definitions for NRA so that the NRA will be comparable among the different countries and, consequently, will be appropriate for addressing regional resource management issues. This is especially important for water management since all countries in the region rely on international sources of water. The construction of similar water accounts for Namibia's neighbors will make it possible for Namibia to explore alternative domestic water strategies, taking the regional consequences more fully into account.

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APPENDIX. Derivation of the Use Accounts for Water[1]

Water use accounts consist of water supplied through bulk water supply and rural water supply from ground, ephemeral surface, and perennial surface sources to 20 economic sectors, two categories of households, and a government sector. There is no comprehensive information about water use that provides all the detail by origin and destination required for the NRA. Fairly detailed information about bulk water supply is available (from an unpublished database), but very little information is available for rural water supply. Even the information about bulk water supply is not available in a form that allows easy integration with economic data because use is identified by geographic location, called a water supply point. In some instances, a supply point can be directly associated with an economic use, for example, the water supply point, Windhoek airport, can be assigned to the Transportation sector. In other cases the relationship is not at all clear, for example, the water supply point for Windhoek city covers many different economic sectors as well as urban households and government.

A variety of different data sources and assumptions was used to compile water use accounts. The starting point was (DWA, 1991a) which provides a comprehensive estimate of water use by five major users of water from each of the three natural sources for 1990 (shown here as Table A1). It does not distinguish delivery by bulk and by rural water supply nor does the classification of users match the more disaggregated economic classification of the IO table. Despite these limitations, Table A1 was used as a guide for constructing detailed water use tables because it is the only comprehensive source of information available for any year. The figures of Table A1 are derived in part from official records of water use and in part on the basis of assumptions about sectoral water needs and are considered reasonably accurate.

The accounts for 1990 were used as control totals (with some adjustments discussed in this annex) and disaggregated to match the economic classification and the institutional classification of the NRA use accounts. The 1990 accounts were then updated for 1993 using official records and the assumptions used to construct the 1990 table of water use. The steps taken and sources used to produce the disaggregated 1990 table of water use and the estimated 1993 table are discussed in this section, organized by economic sector. The major sources of information include the *Annual Reports* of the Directorate of Water Affairs for various years (DWA, 1990, 1991b, 1992), a special report on water supply policy prepared for the First National Development Plan (DWA, 1993a), a two-volume Master Plan for the Namibia's Central Area which includes the major cities (DWA, 1993b, 1993c), and unpublished worksheets which record the use and cost of water provide by bulk water supply in 1993 (DWA, 1995). These data sources are almost exclusively devoted to bulk water supply; little information is available about rural water supply at this time.

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[1]Martin Harris, Acting Deputy Director of the Planning Section of the Directorate of Water Affairs at the time of this work, provided a great deal of assistance and insight without which this work could not have been done.

Table A2. Water Requirements for Livestock

	Cattle, horses, and donkeys	Sheep and goats	Total
Litres per day per head	30	9	
Estimated water use in 1990 (millions of cubic metres)			
Commercial livestock	12.4	11.7	24.1
Communal livestock	12.9	5.4	18.3
Total	25.3	17.0	42.4
Estimated water use in 1993 (millions of cubic metres)			
Commercial livestock	12.5	9.6	22.1
Communal livestock	12.7	4.3	17.0
Total	25.2	13.9	39.1

Note: Figures may not sum due to rounding.

Source: Row 1: personal communication with M. Harris, DWA. Rows 2 and 3, author's calculations based on data from the NRA for livestock and row 1.

for livestock was 42.4 million cubic metres in 1990 but only 39.1 million cubic metres in 1993, reflecting de-stocking that took place in response to a drought (Table A2).

2. **Total Water Use by Natural Source.** To estimate total water use by natural source, the figures for total livestock water use for 1990 and 1993 in Table A2 were distributed among groundwater, perennial surface water, and ephemeral surface water in the same proportions as reported in Table A1. No ephemeral water is used for livestock.

3. **Water for Commercial Livestock by Institution and Natural Source.** As the first step to disaggregate water use by institutional source, it was pointed out by DWA staff that the commercial livestock sector supplies virtually all its own water from groundwater sources (except for a negligible amount where DWA's long distance water carriers cross commercial farms) so the entire commercial sector requirement was attributed to rural water supply from groundwater.

4. **Water for Communal Livestock by Institution and Natural Source.** The water used for communal livestock is provided partly by bulk and partly by rural water supply, from both groundwater and perennial rivers. The amount provided by bulk water supply in

Table A3. **Water Use for Crop Irrigation in Commercial and Communal Areas, 1990 and 1992**
(millions of cubic metres)

	1990					1992	
			Water Use by Source				
Commercial Areas	Hectares	Total	Ground	Ephemeral	Perennial	Hectares	Water
Orange river	1,800	27.0	-	-	27.0	1,681	25.2
Fish river (Hardap)	1,500	30.0	-	30.0	-	1,400	28.0
Auob river/Stampriet	610	9.2	9.2	-	-	570	8.5
G-T-O	100	1.5	1.5	-	-	93	1.4
Omaruru	60	0.9	0.9	-	-	56	0.8
Subtotal	4,070	68.6	11.6	30.0	27.0	3,800	64.0
Communal Areas							
Okavango	700	10.5	-	-	10.5	-	-
Caprivi	60	0.9	-	-	0.9	-	-
Damaraland	60	0.9	0.9	-	-	-	-
Kaokoland	10	0.2	0.2	-	-	-	-
Owambo	10	0.2	0.2	-	-	-	-
Subtotal	840	12.6	1.2	-	11.4	1,190	17.9
Total	**4,910**	**81.8**	**12.8**	**30.0**	**38.4**	**4,990**	**81.9**
Stock farms	2,150	24.7	24.7	-	-	2,150	24.7

Source: Figures for 1990 from DWA, 1991a and personal communication with M. Harris. Figures for 1992, personal communication with Martin Fowler, Ministry of Agriculture (for hectares under irrigation) and author's estimates described in text.

Forestry and Fisheries

Forestry is not yet included in either the national economic accounts or in the natural resource accounts. No information is available about any water use associated with this sector. No water use by fisheries is recorded; water use is considered so low in this sector as to be negligible.

Mining

The mining sector is separated into two subsectors: diamond mining and all other mining. Diamond mining provides its own water and its water use has not been a subject of concern since diamond mining operations occur in a remote area with no competing or downstream users. This use of water is not included in any official estimates of water use. However, an estimate of annual water use in 1990 of 13.6 million cubic metres is given in (Biesenbach & Badenhorst, et al., 1994). For lack of data, the same figure is assumed for all years. Since

Table A4. Water Use by Mines According to Alternative Sources in 1990 and 1993
(millions of cubic metres)

	1990 From 2 sources and a combined estimate			
Mine	DWA, 1993c	DWA, 1991b	Combined	1993
Kombat	-	-	-	-
Navachab	1.046	1.046	1.046	0.97
Okarusu	0.350	-	0.350	-
Otjihase	0.392	0.392	0.392	0.40
Rossing	4.367	4.367	4.367	2.20
Tsumeb	3.360	-	3.360	*
Uis	0.314	0.314	0.314	0.09
Rosh Pinah	-	1.344	1.344	0.75
Rural water use not identified by mine				3.70
Total	**9.830**	**7.464**	**11.174**	**8.10**

* negligible.
-: not reported.
Notes: (DWA, 1993c) reports both bulk and non-bulk water supply.
The combined figure is obtained by pooling estimates from both sources.

Source: (DWA, 1991b, 1993c, 1995).

Table A5. Water Used for Fish Processing in Walvis Bay, 1990 to 1993
(thousands of cubic metres)

Year	Water Use
1990	457
1991	387
1993 (estimated)	690

Source: (DWA, 1993c, Table B.3, page B-3).

Service, Other Industrial, and Institutional Sectors

The major sectors discussed here are: Restaurants and hotels, Transportation services, Other commercial sectors, Industrial sectors, and Institutional sectors. The sector, Restaurants and hotels, is generally treated as the tourism sector in many data sources, though many tourism activities are left out, notably transportation. Except for Tourism, (DWA, 1991a) does not report water use by any of these sectors; these sectors are combined under the category domestic use and other documents are required to determine how much of the water attributed

Table A6. Water Use for Tourism in 1990 and 1993 (millions of cubic metres)

Tourist Site	1990 from two sources		1993
	DWA, 1993c	DWA, 1991b	DWA, 1995
Etosha	-	0.488	0.575
Others	-	0.330	-
Daan Viljoen	0.043	-	0.065
Gobabeb	0.007	-	0.008
Gross Barmen	0.052	-	0.059
Von Bach Dam	0.022	-	0.026
Waterburg	0.085	-	0.085*
Ai-Ais	-	-	0.033
Hardap tourist resort	-	-	0.069
Total	0.209	0.818	0.920

-: not reported
*: not reported, assume same as in 1990 and 1991

Source: (DWA, 1991b, 1993c, 1995).

Table A7. Water Use for Transportation in 1990 and 1993 (millions of cubic metres)

Location	1990	1993
Rooikop airport	0.34	0.20
Windhoek airport	0.09	0.09
Portnet (port authority of Walvis Bay)	0.13	0.13*
Mpacha Airport	na	0.13
Ruacana airport	na	0.17
Ondangwa airport	na	0.06
Total	**0.56**	**0.78**

na: not available
*: water use at Portnet in 1993 is not reported separately from total water use in the area; it is assumed that water use is equal to the amount used in 1990.

Source: 1990 from (DWA, 1993c pp. B-3 and B-6). 1993 from (DWA, 1995).

It is assumed that all manufacturing and services use bulk water. Water use for these sectors was similarly calculated for 1990 to assist in the calculation of domestic water use described in the final part of this Annex. Water use was disaggregated by natural source according the following rules of thumb: generally, coastal areas use all groundwater, Tsumeb and Grootfontein in the north use mostly groundwater, Windhoek and remaining areas in the Central Area use roughly 90% ephemeral surface water and 10% groundwater (personal communication from M. Harris).

Domestic Use of Water

The estimation of domestic use of water is divided into two parts: urban use from bulk water supply, and rural use mainly from rural water supply.

Urban Households

All urban centers are supplied by bulk water supply. Some estimates of domestic use are reported for 1990 in (DWA, 1991b) and estimated for 1993 in (Ashley et al., 1995), but these reports are not very useful for the NRA accounts because domestic use is defined to include manufacturing, service, and government water use in addition to residential use. An alternative approach to estimating domestic, defined as only residential, water use was needed. Urban household water use was calculated by subtracting from total bulk water in 1993 (DWA, 1995) the use of water by all non-residential sectors that has already been estimated in previous sections of this annex. This water is distributed by natural source according to the average distribution for all bulk water: 65% groundwater, 30% ephemeral surface water, and 5% perennial surface water (personal communication, M. Harris).

Rural Households

There are no comprehensive data about water use in rural areas. Based on periodic studies of specific villages, rural water use is estimated at 25 liters per person per day. Rural water use was calculated as the product of the average water use per person (in rural areas) and the rural population. Given the very crude method of estimation, water use was rounded up to the nearest million. Roughly two-thirds of the population lives in rural areas, for total rural water use of 9 million cubic metres in 1990 (total population 1.4 million) and 10 million cubic metres in 1993 (total population 1.6 million).

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