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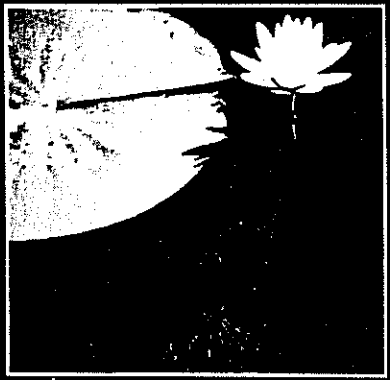
Meeting Namibia's Water Needs While Sparing the Okavango



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Meeting Namibia's Water Needs While Sparing the Okavango

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International Rivers Network

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Executive Summary

With Southern Africa's lowest average precipitation and the threat of recurring droughts, water supply is one of Namibia's most significant long-term development concerns. In an average year, water supplies can meet demand comfortably, but as the drought that ended in 1997 showed, several years of insufficient rainfall can put the country in a vulnerable position. The drought prompted the government in 1996 to accelerate plans to construct a pipeline to the Okavango River to supply water to the central area of Namibia, particularly the capital Windhoek. At the time, the Okavango pipeline appeared to be the least costly source that could be tapped in time to avoid a crisis. Fortunately, adequate rain fell in 1997, postponing further consideration of the pipeline.

New information suggests, however, that the Okavango River pipeline is no longer the only, or the best, supply option available. Indeed, a combination of existing and new sources could meet emergency water needs less expensively, and more quickly than constructing the 250 km pipeline. By augmenting water demand management efforts, expanding artificial aquifer recharge and "water banking" techniques, and by continuing to tap abandoned mines, the central area could meet growing demand and emergency supply needs for less than two-thirds the cost of Okavango River water. In addition, alternatives to the pipeline, especially demand management, artificial recharge and water banking, could be implemented much more quickly than the two-years required to construct the Okavango pipeline. This report concludes that by incorporating these alternative strategies, the government of Namibia can meet future water needs at reduced cost and time, while sparing the Okavango Delta: a win-win solution.

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Background

By early 1996, years of inadequate rainfall had left Namibia's water supply in a critical state. Water engineers predicted that unless plentiful rains fell in the 1996-97 rainy season, the central area would face a water crisis. The government responded by accelerating plans for the final phase of the central water supply system: a pipeline link to the Okavango River. Fortunately, substantial rain fell in early 1997, delaying the need to commence construction on the Okavango pipeline link. In September, 1998, NamWater announced that the Central Area[1] had adequate water supplies to last three years, even if no rain falls.

But the threat of drought and water crisis is an ongoing reality for Namibia, and the government must continue to plan for drought measures should another drought occur. This paper shows that if the Namibian government must take emergency steps as soon as 2001 to secure its future water supply, the Okavango pipeline project would no longer be the only, or best, option available. A combination of smaller measures (some already under development) could meet the central area's growing demand and emergency supply needs in a shorter period of time, and for less cost, than the Okavango pipeline.

The three year window of supply security offers Namibia the opportunity to focus on the longterm sustainable water supply for the country without the immediate threat of a water crisis. Namibian water planners can now systematically develop new and known sources that can meet growing demand and provide the Central Area with emergency supply capacity. In addition, forestalling the need to undertake drastic emergency measures could allow more renewable and environmentally cautious alternatives to become more economically competitive, either through technological advances or through creative donor-assisted funding arrangements.

The Okavango River and Delta represent a significant resource to the region, and the world. The 15,000 km2 delta supports countless birds and animals, as well as thousands of people who depend on the delta for food, water, shelter and livelihood. In addition, the Okavango Delta is a key feature of the regional tourism market, providing thousands of jobs and generating over US $250 million in revenues each year for Botswana, nearly 10 percent of its gross domestic product. The proposed Okavango pipeline and emergency extraction of 18 million cubic metres considered in 1996 represents a very small percentage of the 10 billion cubic metre inflow to the Okavango Delta. The current plan, however, calls for eventually extracting 120 million cubic metres per year. The value of the Okavango to the people of Namibia and Botswana, the growing regional tourism market and wildlife resource, warrants the utmost care and diligence in considering whether to alter the system. Similarly, Namibia's water management challenge deserves every effort to ensure that its water resources management meet the country's goals of economic, social and environmental sustainability.

Context

Namibia is sub-Saharan Africa's driest country, with approximately 80 percent of its 842,000 square kilometres consisting of desert, arid and semi-arid land. Rainfall averages roughly 320mm/yr, but ranges from less than 50mm along the coast to more than 700mm a year in the northwest and Caprivi Strip. What meagre precipitation that does fall is most often quickly evaporated; it is estimated that only 1 percent of annual rainfall recharges groundwater and only 2 percent runs off and becomes available for storage in dams (DWA, 1991). Droughts are a common occurrence, and not surprisingly, water is considered the most significant constraint to development.

In an average year, water supplies can meet demand comfortably, but as the years of drought that ended in 1997 showed, precipitation can fall far short of average. By the beginning of the 1996-97 rainy season, the Central Area's water supply situation was precarious: dams stood at or below 25 percent capacity; the City of Windhoek had increased water tariffs and instituted water rationing; and aquifers were being pumped at rates beyond sustainable levels (See map in Figure 1).

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[1] The Central Area encompasses Windhoek and environs, and northwards capturing Otjiwarongo, Otavi, Tsumeb and Grootfontein. See Figure 1.

Absent significant rainfall in the 1996-97 season, Windhoek would have run out of water in less than two years (P. Heyns, pers. comm).

Such was the climate in June 1996, when the Namibian government announced they would accelerate the 1973 plan to divert water from the Okavango River to Windhoek and the rest of the Central Area. At that time, the Okavango River appeared to be the only potential water source that could meet Namibia's emergency water supply criteria: a capacity of at least 18 Mm3/yr to meet the Central Area's needs; construction time of 18 months or less; and the least cost option.

Window Before Next Water Shortage

Fortunately, the rains of early 1997 replenished many surface supplies and recharged aquifers, providing a respite for Namibia and diffusing the growing tension surrounding the project's potential downstream impacts on the Okavango Delta. Although the 1997 rains averted a serious crisis, the episode illustrated Namibia's vulnerability to drought and highlighted the need for significant planning and action before the next shortage.

Next Time, Pipeline Not Best Option

By the time the next water supply crisis could possibly occur, the Central Area's ability to meet its normal water needs and weather a drought will be significantly enhanced. Indeed, a combination of smaller measures, some of which are already near completion, could obviate the need to even consider constructing the costly pipeline to the Okavango River. At least two new sources should be added to the system by the end of 1999, including a sustainable yield of 2 Mm3/yr from the Berg Aukas Mine and 1.5 Mm3/yr from the expanded Windhoek reclamation system. Recent data from pumping tests of undeveloped groundwater sites look promising, and new tests of other potential sources are planned. Water demand management measures show potential for limiting growth in water use, thereby stretching existing supplies and delaying the need for expanding the supply system (van der Merwe, 1998). Finally, initial tests of artificially recharging known aquifers to minimise evaporation losses from dams could yield an additional 10 Mm3/yr (B. van der Merwe, pers.comm.).

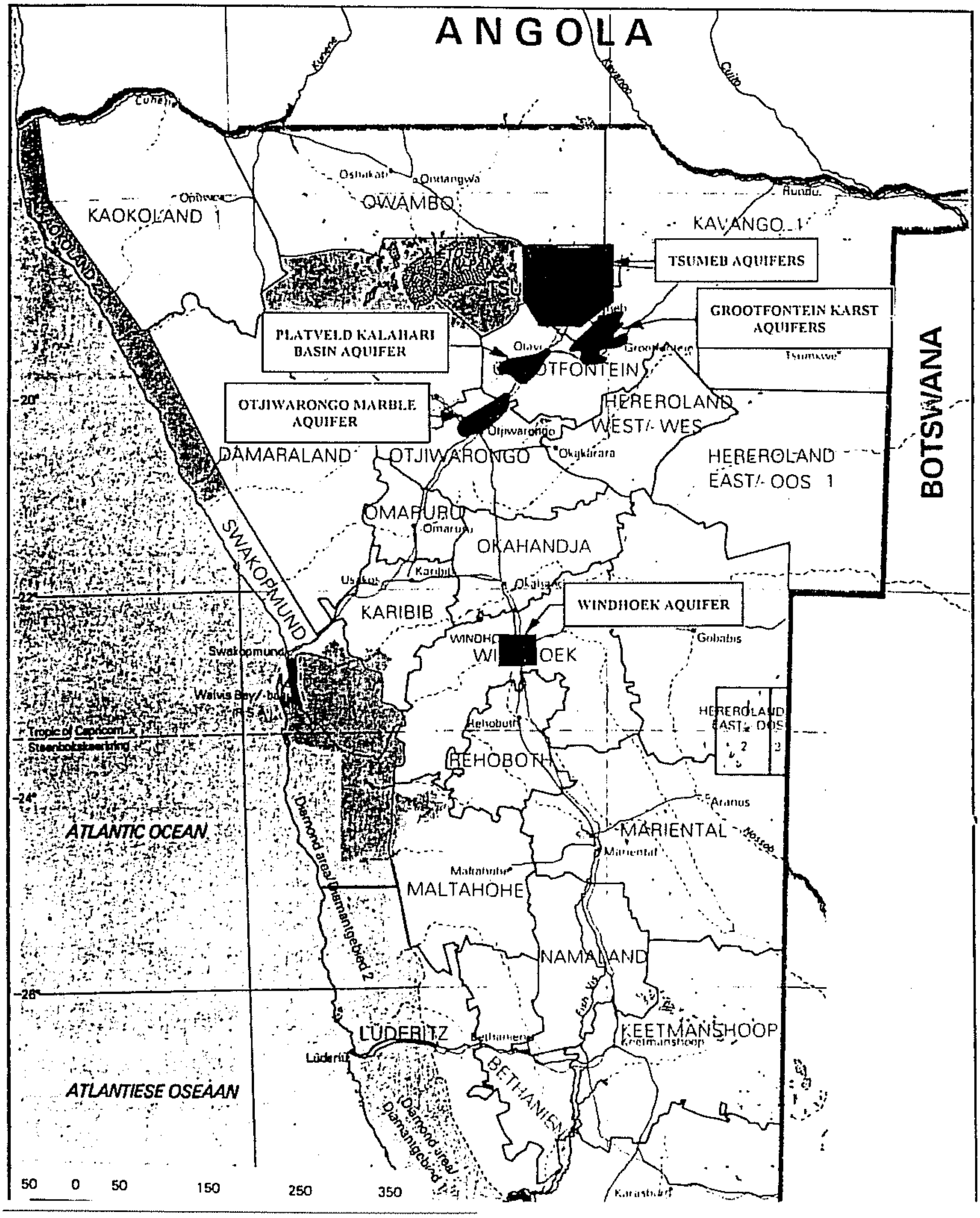
If Namibia faces another drought in the near future, the Okavango pipeline (sometimes called the Rundu-Grootfontein pipeline) likely would not represent the only, or even best, alternative for the Central Area's emergency supply. Incremental development of new groundwater sources, implementing demand management and artificial recharge could meet growing demand and enable the Central Area to weather another severe drought. Developing these three sources offers significant benefits to Namibia over the Okavango pipeline option.

New supplies would become available as each stage of development is completed, as opposed to having to wait at least 18 months for the completion of the Okavango River pipeline before water is delivered.

The total capital cost would be significantly less than the pipeline, and funding could be phased with the developments, thereby reducing the challenges of financing. In addition, delaying the construction of the Okavango pipeline would provide sufficient time to adequately understand and address the pipeline's potential impacts on the delta.

Figure 1. Map of Namibia (WTC, 1997)

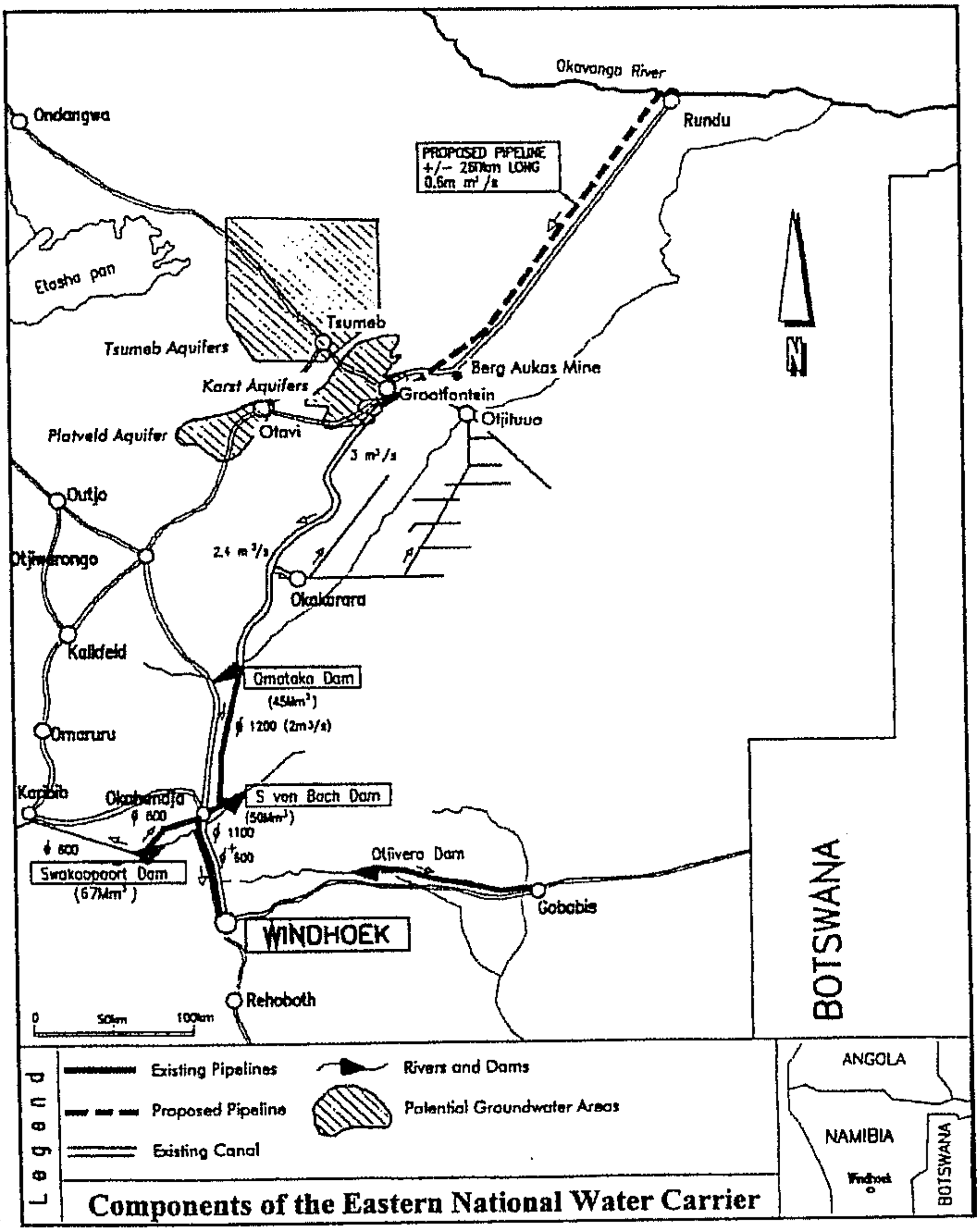
FEASIBILITY STUDY ON THE OKAVANGO RIVER TO GROOTFONTEIN LINK OF THE EASTERN NATIONAL WATER CARRIER



Namibia does not have a contemporary national water master plan (Becker, 1998). Water resources development in Namibia has been based on the 1973 Water Master Plan, which generally directed development efforts first toward Namibia's ephemeral rivers, then to its groundwater resources and finally to border perennial rivers. All three phases have to some extent progressed simultaneously, but the general approach was followed (P. Heyns, pers. comm.). Instead of revising the 1973 Plan, Namibia has, until recently, adopted the approach of developing more detailed water plans on a regional basis. Recognising the need to update the country's national water planning, however, the Namibian government committed to developing a new comprehensive water plan as part of National Development Plan 1 (NPC, 1995).

Two different systems were established to deliver water to end users - bulk water supply and rural water supply - which account for 43 percent and 57 percent of Namibia's water use, respectively. Bulk water supply relies on the Eastern National Water Carrier (ENWC), a system of dams, boreholes, canals and pipelines delivering supplies principally to urbanised areas and commercial agricultural operations of the Central Area (Figure 1). As envisioned in the early 1970s, the ENWC would eventually transport water over some 700 km from the Okavango River to the city of Windhoek and the coastal area of Walvis Bay, with links along the way for municipal, agricultural and industrial water uses.

Figure 2 Components of the Eastern National Water Carrier (WTC, 1997).



Rural water supply employs relatively small-scale, localised means for collection (i.e., boreholes) and generally does not involve transporting water over great distances.

The Eastern National Water Carrier near Grootfontein.

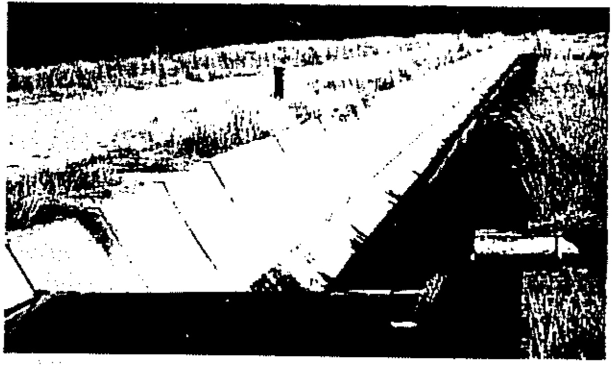


Photo: H. Castro/Conservation International

The Namibia Water Corporation (NamWater[2]) provides all bulk water, while rural water supply is partly the responsibility of the government and partly provided by users at their own expense under some government supervision. Rural water supply not provided by NamWater accounts for 39 percent of all water use, and includes commercial enterprises such as livestock, agriculture, mining and part of tourism facilities.

Following the completion of the ENWC up to Grootfontein, the DWA initiated a study of the Central Area of Namibia to revise and update the 1973 Water Master Plan. This report, called the Central Area Water Master Plan (CAWMP), established two key departures from the 1973 Water Master Plan: 1) to separate the Central Area's coastal area from the inland region in terms of developing future water supply; and 2) to replace imported water from the ENWC (eventually from the Okavango) with desalinated seawater to supply the central coastal areas.

The Central Area's Water Demand

Until a successful water demand management program was initiated in the mid 1990s, water consumption had grown rapidly over the past three decades, increasing almost 300 percent between 1970 and 1995 (Ashley et al., 1995). By 1996, demand in the Central Area exceeded 41 Mm3/yr, and countrywide demand reached 280 Mm3/yr, and (Table 1). Windhoek is the largest water consumer in the Central Area, using almost 17 Mm3/yr. The Central Area's second largest consumer category is agriculture (livestock and irrigation), at 8.3 Mm3/yr, followed by the mining sector which consumed approximately 6.3 Mm3/yr in 1996 (Lange, 1997). If demand grows at the expected rate of 2.5 percent per annum, by 2012 demand will reach 60 Mm3 per year in the Central Area and 423 Mm3 countrywide (Becker, 1998). By 2020, countrywide demand could exceed 500 Mm3 per year, the estimated total sustainable yield of domestic[3] surface and groundwater resources.

Table 1. Water demand in the Central Area and Countrywide

Water Demand Mm3/year				
Category	In Central Area		Countrywide	
	1996	2012	1996	2012
Wildlife and Tourism	0.15	0.21	0.74	1.62
Urban (all inclusive)	26.26	41.25	67.90	108.96
Rural domestic	0.17	0.28	13.10	21.02
Mines	6.53	7.74	20.00	30.00
Livestock	3.41	3.68	42.18	49.46
Irrigation	4.91	6.45	137.03	212.03
Demand TOTAL	**41**	**60**	**281**	**423**

Sources: in Central Area, WTC (1997); and Countrywide, DWA (1997). After Becker (1998).

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[2] NamWater is the parastatal water supply institution established in 1998 by the Namibian government.

[3] In this report, "domestic" means surface water (rivers) originating wholly in Namibia, and groundwater underlying Namibian soil.

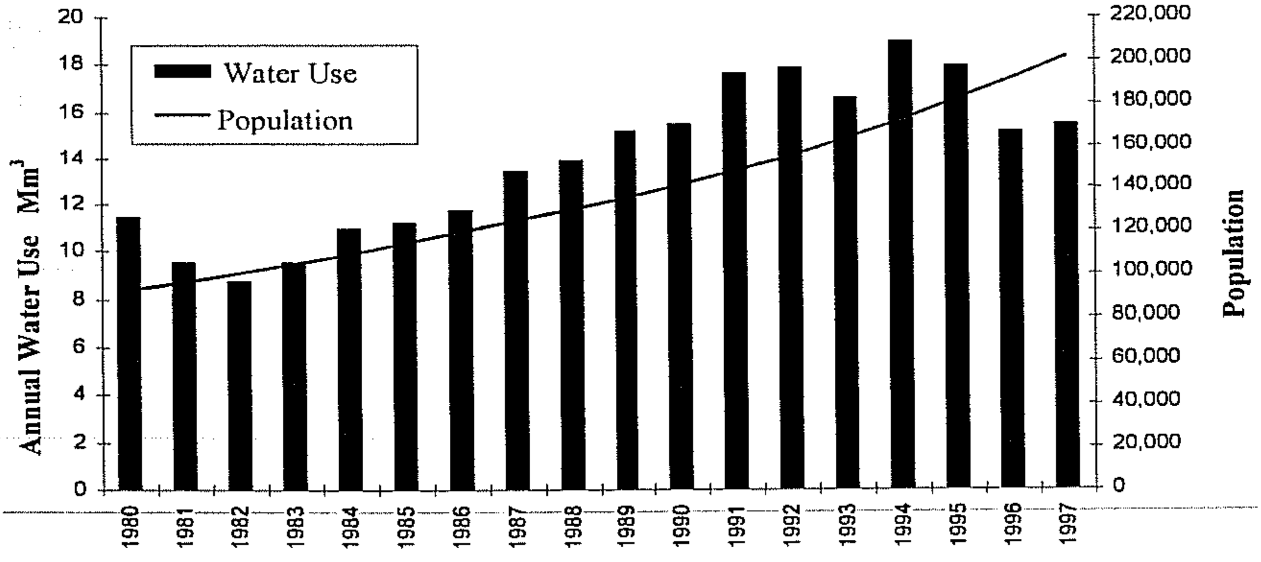
Windhoek Water Demand

Water consumption in Windhoek grew by 6.6 percent annually until 1980, and between 1982 and 1991 demand grew by nearly 8.8 percent (Water Transfer Consultants, 1993). With the initiation of a water demand management program in the early 1990s, water demand began to level off, despite a continued rise in population. Total water use (i.e., including the use of reclaimed waste water) in 1997 was roughly equivalent to the amount used in 1990, despite a 45 percent increase in population. However, when considering only the consumption of new water, i.e., without reclaimed water mixed in, Windhoek's 1997 use was equivalent to 1987 use, despite nearly a doubling of population from 105,000 to 202,000 (van der Merwe, 1998). If Windhoek continues to successfully implement water demand management strategies, demand in 2005 should be more than 30 percent below what unrestricted demand would be (Heyns et al, 1998; van der Merwe, 1999).

Managing Water Demand in Windhoek

The city's demand management programme includes:
- block tariff system,
- maximising reuse of water,
- improved urban zoning,
- water conservation guidelines for businesses
- water metering taps in hotels
- penalties for wasting water on private properties,
- prohibiting watering gardens during mid-day
- promoting dual flush toilet cisterns
- requiring pools to be covered.

Figure 3 Water Consumption and Population in Windhoek



Source: B. van der Merwe, 1998

Water Supply

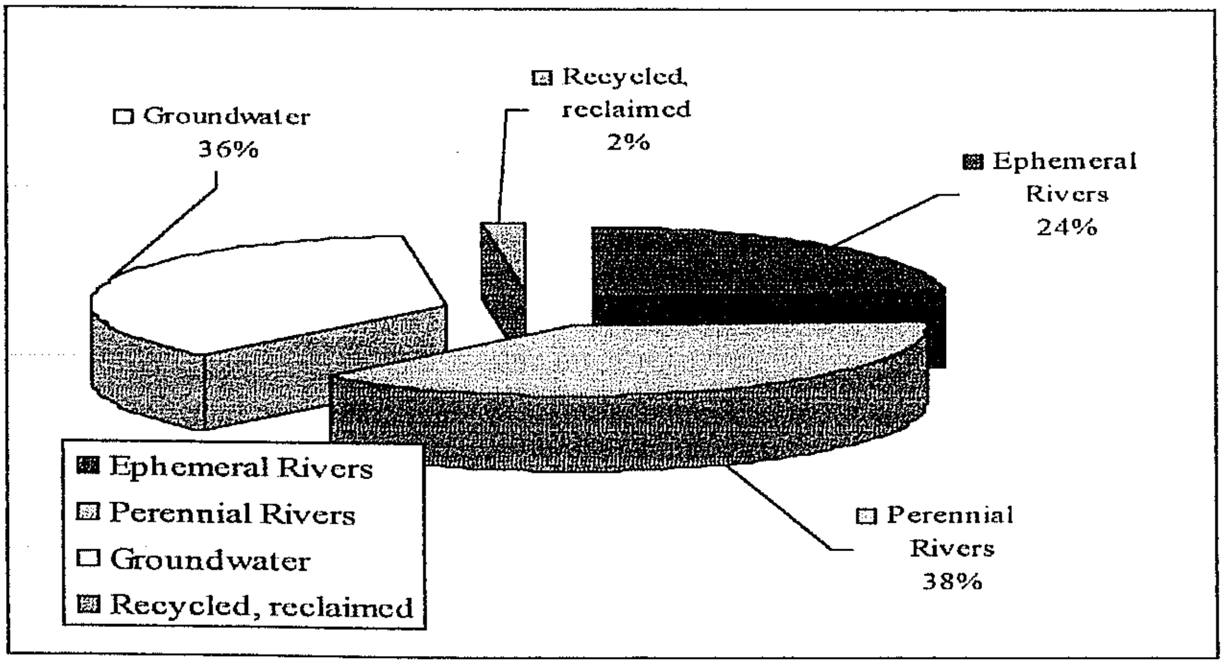
Namibia's water is supplied from three natural sources: groundwater, ephemeral surface water and perennial surface water (Lange, 1997). Wastewater reclamation in Windhoek represents another "source" of water, providing roughly 3.5 Mm3/yr of Windhoek's annual supply. Namibia's total potential safe yield[4] of domestic water sources is estimated to be 500 Mm3 per year, made up of 200 Mm3 of surface water and 300 Mm3 per year of groundwater. The portion of the annual water supply coming from each source varies from year to year depending on rainfall. Groundwater is found throughout the country and commonly accounts for about half of Namibia's annual water use. Perennial[5] rivers, which form the northern and southern borders of Namibia, account for about 27 percent of annual use, while ephemeral[6] rivers typically provide approximately 22 percent.

The total water supply in 1996 was made up of 36 percent groundwater, 38 percent perennial surface water and 24 percent from ephemeral rivers (Figure 4). The Okavango River currently supplies approximately 22 Mm3/yr to Namibians living along the river, which represents about 7 percent of the countrywide demand (Becker, 1998; Hatutale, 1994).

The source of water depends on whether it is used for rural supply or bulk supply intended for urban centres and certain industrial and agricultural enterprises. For example in 1993, 45 percent of the bulk water supply came from groundwater, while ephemeral rivers provided almost 50 percent and perennial surface water about 5 percent. Groundwater made up about 63 percent of rural water supply in 1993, perennial surface water over 35 percent and ephemeral surface water about 1 percent (Figure 5).

The mix of water sources supplying any given area of Namibia varies by location. Figure 6, depicts the general distribution of water sources and supply systems in Namibia, and shows the Central Area supply coming from a combination of surface and groundwater; reclaimed water from the Windhoek reticulation system also contributes a significant amount. The Eastern National Water Carrier system distributes water to the majority of people living in the Central Area.

Figure 4 Water Sources Used in Namibia in 1996 (van der Merwe, 1999)



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[4] Safe yield in this case refers to the amount of water that Namibia can depend on from surface and groundwater sources in 19 out of 20 years. In the strict groundwater context, safe yield is usually defined as the average annual amount of water that seeps into an aquifer that can be withdrawn without producing some undesirable result, such as lowering the water table, reducing the total amount of water available or allowing the ingress of low-quality water into the aquifer.

[5] Perennial rivers are those that continue to flow all year long, from year to year.

[6] Ephemeral rivers are those whose flow is naturally interrupted for a period each year, or up to many years at once.

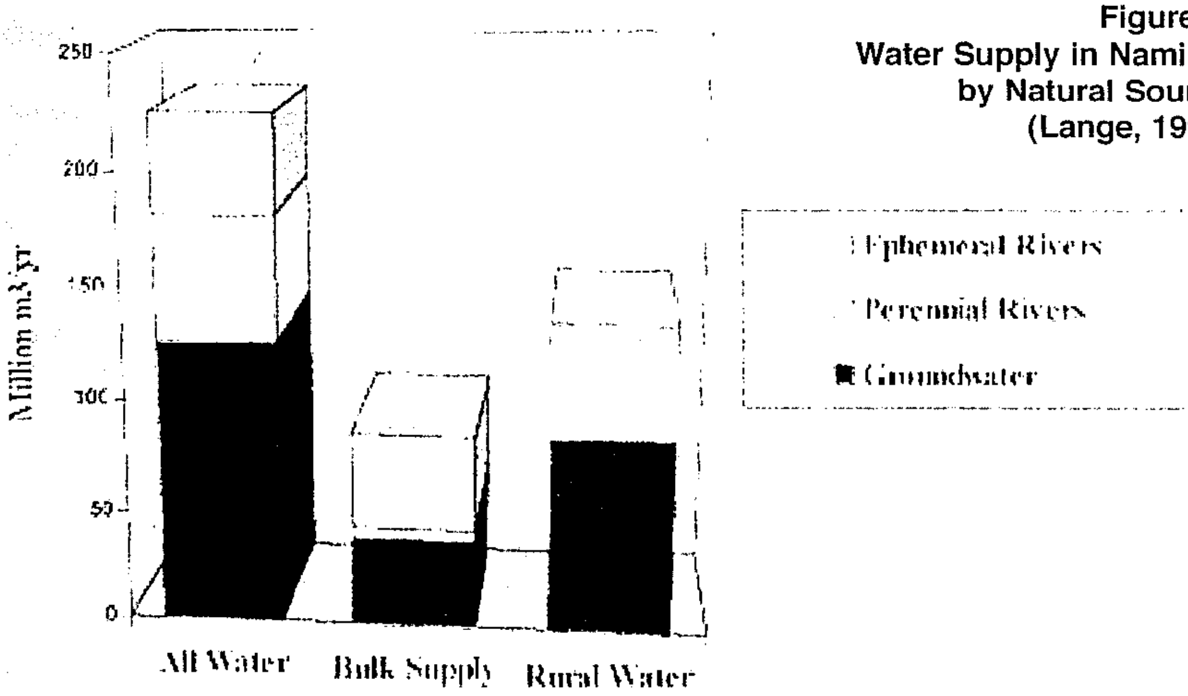

Figure 5.
Water Supply in Namibia
by Natural Source
(Lange, 1997)

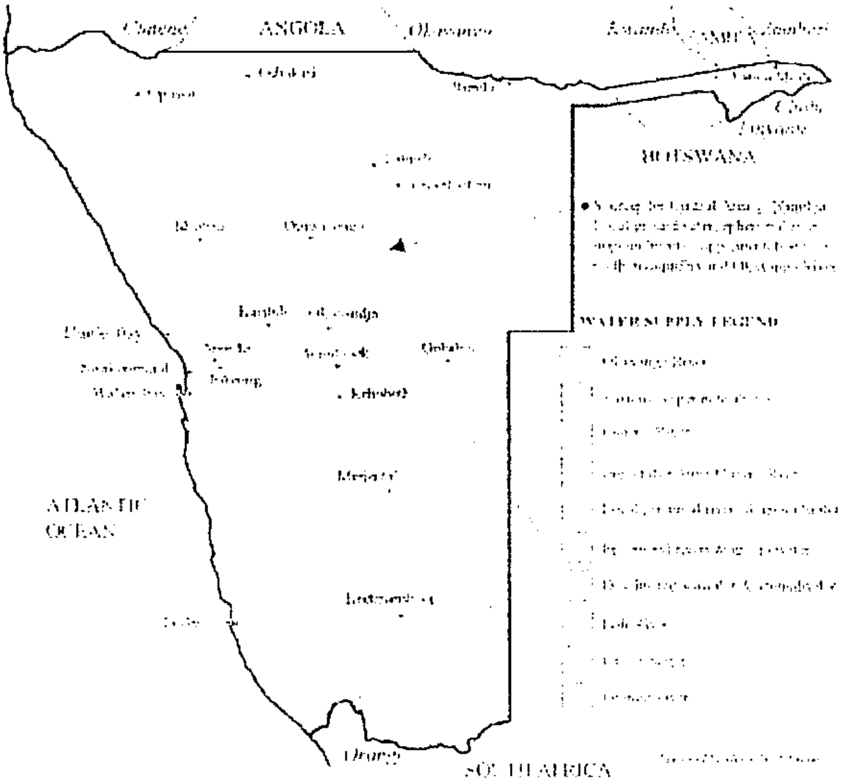

Figure 6.
Water Supply Regions of Namibia (Becker, 1998)

Central Area Water Supply

The ten major dams in Namibia can yield 87 Mm3/yr at 95 percent assurance[7] - which is nearly half of Namibia's estimated total potential assured surface water yield - but only 14.05 Mm3/yr of this volume is currently available to the Central Area through the existing supply system[8]. Approximately 29 Mm3/yr of groundwater compliments surface water supplies, in addition to approximately 3.5 Mm3/yr of reclaimed water from the Windhoek municipal system, totalling 46 Mm3/yr in the Central Area. (Table 2).

Table 2 below lists the various sources of water for the Central Area. From 1996 to 1998, dams supplied approximately 30 percent of total supply, groundwater provided 62 percent and reclamation provided roughly 8 percent.

Making Ends Meet

Namibia's scant and erratic rainfall pattern creates significant challenges for water supply and management. Toward the end of April each year, the Namibian government assesses its current water supply situation, and determines whether current supplies and planned projects could meet demand for the next two years, even if the coming rainy season should fail. In an average year, the Central Area water supply system could comfortably meet growing demand, but average years occur infrequently. In fact, over the past 15 years, rainfall has been 15 percent below the longterm average (Lange, 1997), and since 1990 the three dams supplying Windhoek have experienced fewer than four years of average or better inflows. If it appears that supplies are not sufficient to sustain the country for two years, the government initiates contingency measures, such as in 1996 when the government expanded conservation measures and commenced the feasibility study for the Okavango pipeline (P. Heyns, pers. comm.).

Table 2.
Existing Surface and Groundwater Resources in the Central Area

Source	Ave. Annual Supply 1996-98 (Mm3/yr)	Sustainable Yield (Mm3/yr)
Surface water		
Dams	13.9	14.05
Reclamation/Recycling	3.5	5
Groundwater		
Windhoek	2.3	2
Otjiwarongo	2.7	2.7
Platveld	0	5
Tsumeb: Carbonate	11.5	20
Unconfined	0.44	12
Confined Kalahari	2	2
Grootfontein Karst Aquifers		
Area I	4.5	4.5
Area II	5.1	5.5
Area III	0.07	3
Area IV	0.06	1.5
TOTAL	46.07	77.25

Notes: Average Annual Supply figures based on unpublished NamWater data for water use between March 1996 and May 1998. "Sustainable yield" means 95% assured yield in the case of dams. In the case of the Tsumeb Aquifers include undeveloped potential in addition to existing capacity.
Sources: Sustainable Yield figures are taken from WTC, 1997; Becker, 1998; Kirchner, 1997.

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[7] This means that there is a 95% probability each year that precipitation will produce sufficient runoff to provide 87Mm3 of water from dams after accounting for evaporation.

[8] Only four reservoirs service the Central Area: Omatako, Von Bach, Swakoppoort and Goreangab. See Table 1.

Section 3. • Worst Case Scenario: Another Water Supply Crisis in 2001?

In September 1998, NamWater announced that the Central Area had adequate water supplies for the next three years, i.e., until September 2001, even if no rain falls in that time. What if Namibia receives no significant rainfall or runoff in the coming rainy season, and the country is faced with a situation similar to that in 1996 that prompted the acceleration of the Okavango pipeline plan? Would the Okavango River be the best water supply option? It is becoming increasingly clear that the answer is "No". If NamWater and the government continue (and expand) the development of new groundwater sources, demand management strategies, artificial aquifer recharge and other smaller measures, the Okavango pipeline would be rendered unnecessary for the foreseeable future.

It is possible to quantify a hypothetical water supply shortfall in the Central Area if Namibia receives no significant rainfall before September 2001. (See Annex 1 for a detailed accounting of projected water demand and supply in the Central Area supply system in 2001, which is the first year contingency water supply measures would be needed. Demand estimates for 2001 in Annex 1 are based on the "likely" demand increases developed by the Department of Water Affairs (1997), and does not include possible demand management measures.) A key assumption is that Central Area dams have no remaining supply available. Thus, from the planning perspective, the required emergency volume would equal the difference between the Central Area's projected water demand in 2001 and the Central Area's groundwater supply.

The analysis starts with Windhoek demand (21.1 Mm3/yr), taking into account the supply of reclaimed and recycled water, and proceeds upstream through the Central Area supply system to the Grootfontein area, including demands and available groundwater supplies along the way.

This estimate is less than that used for the 1997 pipeline feasibility study for three reasons:
1) the closure of the Tsumeb Mine, reducing total demand by 3.4 Mm3/yr, 2) increasing supply by 4.0 Mm3/yr through the expanded Windhoek water reclamation system, and 3) the addition of 1.5 Mm3/yr from the Berg Aukas mine. No additional water supply sources are assumed to be operational by June 2001 for this exercise.

The total estimated water demand in 2001 for the Central Area is approximately 51 Mm3/yr, which represents approximately a 4 percent annual increase. If the Central Area receives no runoff during the next two rainy seasons, and no steps are taken to expand the supply other than the three listed above, the total supply would be approximately 35.5 Mm3/yr, leaving a deficit of approximately 15 Mm3/yr in 2002. Thus, an additional supply of 15.5 Mm3/yr must be identified or developed by 2001 in order to avoid a hypothetical water supply crisis[9] .

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[9] The 1997 feasibility study estimated that the Central Area could face a shortfall of 18 Mm3/yr by 1998. The possible shortfall in 2002 would be less than this because of the additional supplies listed above and because of the Tsumeb Mines closing down.

Namibia has a window of opportunity to get far enough ahead of the drought cycle that emergency planning is unnecessary. If Namibia continues to expand three water supply measures it is currently pursuing, i.e., water demand management, artificial recharge, reclamation/recycling and new groundwater sources, the water supply system could be resilient enough to meet demand and weather droughts – without going to the Okavango River for the foreseeable future. It is a case where long-term objectives can meet short-term threats. While all those concerned would prefer a longer period of water security with which to plan, if public and private sectors act with urgency, an emergency such as that experienced in 1996 likely will not occur again. The following sections evaluate a number of potential strategies and new sources to supply a possible shortfall in 2002. Schemes such as extracting water from the Kunene and Orange rivers are not considered here because their costs and time to develop are prohibitive.

Demand Management

Despite rapid urban growth rates in the 1990s – more than 5 percent annually in Windhoek – Namibia is still a relatively un-urbanised country. Approximately 32 percent of the population lives in urban centres, which is low compared to 80 percent in many developed countries and an estimated 58 percent in South Africa (Heyns et al., 1998). Because the cities, especially Windhoek, continue to dominate the country's economic, legislative, administrative and financial activities, Namibians will continue to flock to urban areas in coming years. In fact, the rate of urbanisation in Namibia is expected to increase significantly before growth levels off (van der Merwe, 1999).

Because urban services can be provided more efficiently and managed more effectively than rural services, higher urbanisation rates can be beneficial to water demand management efforts. The City of Windhoek initiated a demand management programme in 1992, and by 1996, the city's aggressive conservation and pricing measures succeeded in reducing demand to 1989 levels, despite a 35 percent population increase since that time.

Future water consumption in urban areas could be reduced by at least 30 percent through implementation of effect water demand management programmes (Heyns et al, 1998). As Table 3 shows, managed water demand in Windhoek in 2001would be 30 percent or more lower than unrestricted demand.

Table 3 Unrestricted vs. Managed Water Demand in Windhoek

	1995	2000	2002	2005	2010	2015
Unrestricted	21.1	26.7	29.86	34.6	44.4	57.1
With WDM	17.9	19.74*	20.75*	24.1	27.9	32.3
% Savings	15	26	30	30.4	37.2	43.4

* Data from WTC, 1997.

Adapted from B. van der Merwe, 1999.

In our worst case scenario, Windhoek demand in 2001 was estimated to be 22.6 Mm3/yr. If effective demand management measures are in place by then, demand could be reduced to 20.75 Mm3/yr, a savings of 1.85 Mm3/yr.

Artificial Recharge of the Windhoek Aquifer and Water "Banking"

Namibia experiences tremendously high rates of evaporation. During 1997, for example, the volume of water supplied by Windhoek's three dams totalled 15.7 Mm3, while evaporation losses from the dams exceeded 35 Mm3. As a result, Namibian water planners have historically relied more heavily on surface supplies than groundwater during rainy periods and vice versa[10]. There is incentive to utilise surface supplies quickly before they are evaporated.

Another strategy to minimise evaporation losses is to store surface water underground until its needed at a later date. Windhoek has recently begun exploring the effectiveness of this technique, known as artificial recharge. In August 1998, the city began injecting treated water supplied by NamWater into the Windhoek Aquifer and found that water levels at surrounding boreholes were rising at four times the natural recovery rate.

If the recharge tests continue to prove successful, the large-scale application of this technique has the potential to save significant amounts of water, which could substantially increase the sustainable yield of the Windhoek Aquifer, as well as the aquifer's capacity to sustain the Windhoek during a drought. It is estimated that for every 1 Mm3 of water temporarily stored underground, 0.4 Mm3 is spared from evaporation. Thus, if Windhoek injected 5 Mm3/yr into its aquifers, it would have an extra 2 Mm3/yr for later use that would have been lost to evaporation had it remained in one of its dams (van der Merwe, 1999).

Similarly, water could be injected underground and reserved from normal consumption, thereby "banking" water for use during a drought. The total capacity of the Windhoek aquifer is estimated to be between 15-25 Mm3 (van der Merwe, pers. comm). The annual sustainable yield is considered to be 2 Mm3/yr, and emergency yield is considered 4 Mm3/yr. This means that not even half of the aquifers capacity is being utilised. Therefore, it could be possible to inject and maintain a certain volume of water and set it aside for drought use only. This is in effect what is already done to a limited extent, in that over a two year emergency period 8 Mm3 not 4 Mm3 can be pumped for two years. Assuming the artificial recharge proves feasible on a large scale, Windhoek could inject 6 Mm3, for example, that could supply an additional of 3 Mm3/yr for two years during a drought. If the maximum capacity is found to be 25 Mm3, Windhoek could bank even more water.

Short-term emergency pumping of aquifers

The Central Area has occasionally been forced to pump water from aquifers at rates exceeding their long-term sustainable yield. The general policy of the Department of Water Affairs holds that aquifers should not be pumped at greater than sustainable rates for more than 24 months to avoid causing permanent damage to the resource (Heyns et al, 1998). WTC (1997) compiled DWA's proven or estimated emergency and long-term sustainable pumping rates for the Central Area's aquifers. Table 4 shows that if the Central Area's aquifers are pumped with existing boreholes at emergency rates, an additional 13.4 Mm3/yr would be available for up to two years in a drought situation. The net potential emergency yield would increase to 26.9 if the Abenab and Tsumeb mines were developed.

Development of "New" Ground Water Sources

The abandoned mines in the Grootfontein-Tsumeb area, and the Tsumeb and Platveld aquifers represent important untapped groundwater resources that could play a significant role in meeting growing demand and emergency supply needs (WTC 1997; NamWater , 1998). In addition to the economic and technical issues surrounding these potential sources, water quality is a potential problem that would have to be addressed in some cases, such as the Tsumeb Mines and other areas of the Tsumeb aquifer (E. van der Merwe, pers. comm.).

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[10] For example, in 1996 the Windhoek Aquifer provided the city with more than 3.6 Mm3/yr – almost double it's sustainable yield – because surface supplies were nearly depleted. When the rains fell in 1997, the city reverted to surface supplies and allowed the Windhoek Aquifer to recharge by only using 0.9 Mm3/yr, less than half it's sustainable yield (NamWater unpublished data).

Table 4. Emergency Supply Potential of Central Area Groundwater Resources

Groundwaer Source	Sustainable* Yield Mm^3/yr	Emergency Yield Mm^3/yr	Available Difference** Mm^3/yr	Comments
Windhoek Wellfield	2	4	2	
Extra from "Water Banking"		3	3	Feasibility must be proved.
Otjiwarongo Marble Aquifer	2.7	4.1	1.4	
Platveld Aquifer	5	5	0	
Tsumeb Aquifers: Carbonate	11.5	20	0	2001 availability uncertain.
Unconfined	0.5	12	0	"
Confined	2	2	0	"
Grootfontein Karst Aquifers				
Area I	4.5	6.5	2	
Area II	5.5	8	2.5	
Area III	3	4.5	1.5	
Area IV	1.5	5.5	4	
Abandoned Mines				
Berg Aukas	1.5	5	3.5	Available by end '99.
Abenab	2	5	5	Must be developed.
Tsumeb	2	5	5	"
TOTAL	**38.2**	**89.6**	**29.9**	

Sources: WTC 1997; Becker, 1998; Kirchner, 1997. Yield figures for the Abenab and Tsumeb mines from unpublished NamWater data.
* "Sustainable" figures represent actual or estimated yield figures.
** "Available Difference" means the volume of water over and above the Sustainable Yield that currently is or could be available in time to meet emergency demand by 2001.

Abandoned Mines in Grootfontein - Tsumeb Area

Information from past pumping practices and recent studies suggest the three abandoned mines in the Grootfontein-Tsumeb area, namely the Berg Aukas, Abenab and Tsumeb mines, represent a significant potential contribution to the Central Area water supply. More on-site investigations need to be carried out to confirm estimated sustainable and emergency yield rates, which DWA and NamWater plan to continue in 1999 (M. Harris, pers. comm.). Available information suggests the combined sustainable yield is more than 5 Mm3/yr, while the emergency yield likely exceeds 15 Mm3/yr (WTC, 1997; NamWater, 1998).

Summary of Water Supplies in Worst Case Scenario

Should the coming rainy seasons fail, surface supplies would be exhausted by 2001, which would result in a potential supply shortfall. The total Central Area demand in 2001 would be approximately 51 Mm3/year. All non-emergency sources excluding surface dams would produce approximately 35.5 Mm3/year, leaving a potential deficit of approximately 15.5 Mm3/year. If the Namibian government continues to develop water demand management, artificial aquifer recharge, and new groundwater resources, sufficient water would be available to meet demand for at least two years at a much lower cost than the Okavango Pipeline (Table 5).

Table 5. Emergency Sources Potentially Available in 2001

Source	Contribution to Deficit Mm^3/yr	Cost to Implement N$/m^3	**Issues for consideration**
Demand Management	1.85	0.40 (1)	Effectiveness not guaranteed.
Artificial Recharge	2 - 4 ?	1.25 (2)	Research required. Subject to surface water available.
Emergency Pumping	13	1.30 (3)	Advisable for two years only.
Abenab Mine	5	2	Research needed; Infrastructure required; Water quality.
Tsumeb Mines	5	3.5	Same as above.
Tsumeb Aquifers	20	5	Same as above.
Total of Alternatives	46 - 48	4.72 (ave)	
Okavango Pipeline	18	7 (4)	High cost; damage to wetland of int'l significance.

(1) Based on van der Merwe, 1999. The figure $N0.40 is derived by dividing the projected cost of WDM in 2001 by the 1.85 Mm3 reduction achieved.

(2) Van der Merwe, 1999.

(3) Based on 1999 costs from van der Merwe (1999) increased by 5% annual inflation.

(4) Based on van der Merwe, 1999, p. 35, in 1998 dollars.

Table 5 shows that if the government implements an effective demand management program, applies artificial recharge on a large scale, and utilises aquifers at emergency rates, these measures would produce between 18-20 Mm3/year for at least two years – enough to satisfy worst case scenario conditions. If the abandoned mines or Tsumeb aquifers were developed as well, the water supply would be even more secure.

Systems modelling conducted for the 1997 Okavango pipeline feasibility study (WTC, 1997) indicates that the amount of "emergency" water that would likely be required during the next 15 years to supplement existing supplies in the ENWC system will vary, but will average between only 2.0 - 2.5 Mm3/yr. Thus, based on this modelling, demand management, artificial recharge and groundwater sources could safely meet the water needs of the Central Area projected growth in demand for many years to come as well as in an emergency situation.

The economics of pursuing these measures is also favourable. As Table 5 shows, demand management, artificial recharge and emergency pumping could supply a potential deficit in 2001 at less than N$ 1.30/ Mm3 (excluding any tariffs). If the abandoned mines and Tsumeb aquifer were required as well, the average cost per cubic metre would increase N$ 4.72. This compares very favourably to the Okavango pipeline's cost of approximately N$ 7 per cubic metre (van der Merwe, 1999).

Comparison of Okavango Pipeline and Alternatives

Planners would likely judge emergency supply alternatives using the three criteria applied in the 1997 feasibility study: adequacy of capacity, required construction time and capital costs. There are certainly other criteria to consider in addition to these, such as environmental impacts and operating costs, which would need to be studied in greater detail. As Table 6 shows, the option of using existing aquifers and the abandoned mines would likely surpass the Okavango pipeline alternative in terms of project capital costs and timing.

Clearly the Okavango River pipeline project is not the only option to meet the emergency water supply needs of the Central Area. Existing aquifers, developing abandoned mines, water demand management and the conjunctive use of the Windhoek aquifer appear to offer more than adequate resources to meet Central Area demand for at least two years in an emergency situation. The lower cost and more rapid time to delivery make alternatives to the pipeline more attractive.

Table 6. Comparison of Okavango Pipeline vs. Alternatives

Criterion	Okavango River Pipeline	Groundwater, WDM, Banking
Supply Capacity		
At least 15.5 Mm^3/a	18 Mm3/yr emergency supply.	More than 40 Mm^3/a for up to two years.
Certainty	Certain capacity.	Further investigations required on Abenab and Tsumeb mine emergency yields.
Timing		
Construction	Eighteen months or more if delay.	Less than 18 months.
Delivery of Water		
Economic		
Capital cost	MN$ 600 total capital cost.	Less than MN$ 300 total capital cost.
Capital cost per m3	N$ 33/m^3	N$ 23-28/m^3
Financing	Financing likely to delay project (WTC).	Lower cost less likely to cause funding delay.

The Okavango River originates on the Benguela Plateau, in the highlands of Angola, where it is called the Cubango River. The water flows down from the highlands, through the Caprivi Strip in Namibia and into Botswana, where it splits into smaller channels and wetlands that comprise the delta. The Okavango Delta itself consista of a main river channel, called the Boro River, several smaller river channels and permanent and seasonal wetlands. At the peak of the annual flood, the delta covers more than 17,000 square kilometres of otherwise dry Kalahari Desert. As a swamp in the middle of the Kalahari, the unique Okavango ecosystem shares characteristics of both desert and wetland.

The Okavango River and Delta is increasingly being recognised as an important resource for the region and the world. Nearly 150,000 people living in Namibia and more than 100,000 in Botswana depend on the Okavango in an otherwise harsh landscape. Over 70 percent of riparian community households collect water directly from the Delta in dry season; 75 percent of households collect fish, edible or medicinal plans from the Delta, and nearly 20 percent of households conduct farming in Delta floodplains. The Delta also supplies materials for building homes and making tourist crafts.

The Okavango River in Namibia.
Photo Dr. Karen Ross, Conservation International

The Delta's network of channels, pools, reedbeds and floodplains is home to innumerable species: 5000 insects, 3000 plants, 540 birds, 164 mammals, 157 reptiles, 80 fish and countless micro-organisms. Because Delta flooding peaks in the heart of dry season, the Delta provides critical resources during the most difficult period of the year. The Delta's rich diversity of wildlife and largely undisturbed condition form the backbone of a tourism industry that has grown 11 percent annually since 1986. Tourists spend an estimated US $230 million per year in the Delta area, dollars that directly benefit 6,000 families in the area, and indirectly 60 percent of the population.

The Okavango Delta in flood.
Photo Dr. Karen Ross, Conservation International

In recognition of the vitally important role the Delta plays in the ecological and social fabric of Botswana, the government acceded to the Ramsar Convention in 1997, making the Okavango Delta the largest wetland on the Ramsar List of Wetlands of International Importance. Moreover, the Namibian government is considering designating the Okavango River habitat upstream of the Botswana border as a Ramsar site as well. The Ramsar Convention obligates signatories to promote the conservation of wetlands included in the list, and to promote the "wise use" of all wetlands (IUCN, 1989). Because

Namibia is also a signatory to the Convention, it is under the same obligations as Botswana to manage the Delta wisely. The primary vehicle for achieving these goals is land use planning. The Government of Botswana is beginning the process of developing a management plan for the Delta pursuant to the convention. Similarly, the Permanent Okavango River Basin Commission (OKACOM) has begun the process of developing a management plan for the entire basin.

There is little dispute that the Okavango Delta is a resource whose vitality should be assured, but the challenge of balancing the water needs of the emerging basin states with the preservation of a unique and important ecosystem remains.

Water resources planning and management in Namibia has until recently concentrated on the technical side of supplying water, rather than managing demand (Ashley, et al., 1995). This approach allowed water demand to increase rapidly, burdening Namibia's economy, infrastructure and aquatic systems. The drought in the early 1990s sent a clear message to water suppliers and consumers across southern Africa that it's time to come to grips with the region's limited and unreliable water resources. Namibia was among the surprisingly few countries that responded affirmatively to that message. Many new ideas and programs emerged that set a course toward the sustainable management of this important resource, but more can still be done.

Economics

Namibia has begun taking important steps toward sending water users a clear signal about the scarcity of water and the importance of efficiency. Several commercial sectors in Namibia provide their own water and pay full capital and operating costs. However, in cases where water is supplied by the state they often do not pay the full cost of water. Almost all other consumers using water supplied by the state are subsidised to some degree (Ashley et al, 1998). The government instituted a new pricing policy in 1995 that aims at recovering the "full cost" of providing water. Full cost recovery for all bulk water schemes is being phased in over five years from 1995 to 2000. As for rural water supply, in 1997 the government initiated a five year programme to recover operations and maintenance costs, which will be followed by a four year programme to recover the full cost of supply (Ashley et al., 1998).

Sector	Value added per m^3 of water N$	Percent of Total Water Use(1)
Agriculture		67
Commercial	5	
Communal	2	
Mining		6
Diamond	45	
Uranium	32	
Industry		12
Fish processing	451	
Services		2
Tourism	113	
Transportation	314	

Source: Lange, 1997

(1) Percentages will not total 100 because domestic use is excluded.

An assessment of costs and benefits associated with all major uses of water would lead to the most efficient use of the resource. A recent study on the economic value added by various sectors of the economy from the use of water indicates that agriculture uses 67 percent of water in Namibia and generates less than N$5 per cubic metre of water used (Lange, 1997). Fish processing and tourism, in contrast, produce N$451 and N$113 per cubic metre, respectively (Table 7). Crop irrigation uses nearly twice as much water as livestock but produces only 2 percent of the economic value of livestock. Moreover, crop farmers are the most heavily subsidised water users, paying only 21 percent of operating costs and only 4 percent of total costs (Lange, 1997). The value added by the various water users cannot be the only consideration for managing water use, but these figures should be recognised and taken into account when decisions are made about water allocation (Heyns et al., 1998).

Food Security vs. Food Self-Sufficiency[11]

Ashley et al (1998) argue that it is more efficient and cheaper for Namibia to import certain foods using revenues earned from its export sector (i.e., "food security"), than for the country to grow all of its food at an unaffordably high cost (i.e., "food self-sufficiency"). Namibian farmers provide between 20 and 50 percent of the country's grain requirements each year, depending on annual rainfall, and the balance is imported . It borders one of the largest producers of white maize (whose costs of production are significantly lower than in Namibia), and has ready access to the world grain markets. Namibia can import grain quickly and efficiently from a variety of sources using foreign currency generated from its strong export sector. The recent shift away from a focus on food self-sufficiency towards food security has been a noticeable feature in the agricultural policies of many countries in the southern Africa region, including Botswana. Poverty reduction forms the core of any effort to achieve food security and the principle way this can be done is through the creation of employment opportunities. The production of food grains has lower labour requirements and generates lower incomes per cubic metre of water than other crops. Thus, pursuing food security rather than food self-sufficiency is a less expensive and more efficient option for Namibia.

Updating and Revising Water Policy and Law

As Bethune et al (1998) argue, Namibia's National Water Act requires updating and extensive revision to achieve sustainable water management. Article 95 of the Namibian Constitution states: "the State shall actively promote and maintain the welfare of the people by adopting ... policies aimed at ... maintenance of ecosystems, essential ecologiecal processes and biological diversity of Namibia and utilisation of living natural resources on a sustainable basis for the benefit of all Namibians, both present and future ...." This articulates the guiding principle and basis for developing suitable legislation to achieve Namibia's goals.

Several policy and legal instruments govern the use of Namibia's water resources. The principle one is the Water Act, No. 54 of 1956, which covers a range of issues relating to the protection of surface and subsurface waters from pollution and misappropriation, and sets out the State's interest in protecting the resource. A major limitation of the act, and one that puts it in conflict with Namibia's Constitution, is that it does not stipulate the sustainable use of water resources in terms of social, economic or environmental sustainability. Moreover, it does not recognise the natural environment as a user of water nor as a provider of essential processes and services. The Water Supply and Sanitation Sector Policy (WASP), has effected wide ranging changes in water management in Namibia, including the establishment of the Directorate of Rural Water Supply, the Namibia Water Corporation (Namwater), and the Water Supply and Sanitation Coordinating Committee. However, WASP has certain limitations that need to be addressed. The shortcomings found in the Water Act, WASP and other laws and policies could be rectified in a White Paper on water sector policy that would become the new water law.

Demand Management and System Efficiency Strategies

The population of Namibia is doubling every 23 years, and as the country continues to develop, a greater percentage of the population will expect to have water continuously available for their various needs. Effective demand management will be the only way to assure that water continues to be available for at least basic needs. For example, if water demand grows at four percent annually, by the time the population has doubled in 2023, the countrywide demand will grow from approxi-

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[11] Food security refers to a nation whose residents are sufficiently well fed to lead a healthy and active life. Food self-sufficiency refers to a nation that produces enough food to feed its members and does not need to import any. No country is self-sufficient in all foods and each country imports food to some degree (Ashley et al, 1998).

mately 240 Mm3/yr to 591 Mm3/yr .

If, on the other hand, demand is limited to only three percent annually, by 2023 countrywide demand will be 473 Mm3/yr, a reduction of 118 Mm3/yr – which is more than six times Windhoek's current demand. The City of Windhoek has already demonstrated the effectiveness water demand management can achieve. The challenge lies with government now to continue to expand the demand management programme without the incentive provided by a countrywide drought.

On a system-wide basis, opportunities exist to increase the assured safe yield through operational innovations. Windhoek's supply comes from numerous sources such as local boreholes, a dam nearby town, a water reclamation plant, re-use of purified effluent, three major dams a distance from town and links to groundwater some 300 km north of the city. By linking the dams to Windhoek's groundwater through artificial recharge as discussed above for example, the city could make significant gains in its safe yield.

Emerging Technologies

Several water supply strategies have been proposed that utilise non-traditional technologies, most notably desalination coupled with solar powered pumping stations to transfer water from the coast. Supplying the Central Area with desalinated water from the coast has been considered in two studies, and found to be currently more expensive than other sources of water (WTC, 1997; Joint Venture Consultants, 1993). Similarly, solar power has been investigated recently and found to be more expensive than other power sources at this time (Nampower, 1997). However, considerable resources are being committed to developing these types of renewable technologies that could yield significant advances that would make them competitive with traditional sources of water and power.

Another technology that has been proposed as a partial solution is wave-powered desalination. Wave-powered desalination involves a series of buoys connected to pumps, which are in turn connected by high-pressure sub-sea piping to the shore. On shore, the pipes would lead to a desalination plant equipped with reverse osmosis membranes and turbine generators. As the buoys rise and fall with wave action, seawater is pumped through the membranes and generators, producing both fresh water and electricity for pumping the water inland. It is estimated that a system consisting of 400 buoys along four kilometres of coastline would have a fresh water production capacity of 21,800 cubic metres per day (8 million per year), and an electrical output of 4 megawatts. The estimated cost of water produced by this system is US \$2.00/m^3, whereas Okavango River water is estimated to cost US \$1.80/m^3 (Hagerman, 1997).

Moreover, there could be funding or subsidisation strategies to reduce the cost of sustainable approaches enough to competitive levels. For example, multi-lateral donors such as the World Bank have expressed goals of supporting sustainable water and energy projects. In addition, some have proposed a cost-sharing arrangement with Botswana, levying a tax on tourists visiting the Okavango Delta, or establishing a regional environmental mitigation bank. While sustainable technologies and creative financing strategies are definitely for the future, opportunities available today should not be overlooked.

Okavango River Basin Management

On the regional level, Okavango River Basin management activities provide another opportunity to promote sustainable water resources management in Namibia. Namibia can be largely credited for stimulating the creation of the Permanent Okavango River Basin Commission (OKACOM), established in 1994 for the sustainable development of the Okavango Basin. The multi-year OKACOM planning process will result in a more thorough understanding of the complex dynamics underpinning the river basin and a comprehensive management plan aimed at promoting sustainable development and protection of Okavango resources.

The OKACOM process provides an opportunity for basin states to define Okavango River instream flow requirements and environmental water demand, complex questions that river planners the world over have recently begun to tackle. Another issue that OKACOM might address is that of compensation: to downstream riparian states for the impacts of upstream use of the resource, or compensation to upstream states for forfeiting the use of resources in order to protect downstream users.

Section 7. • Conclusion

Securing an adequate and reliable water supply is among the most important issues facing Namibia today. Managing the Okavango Delta is of utmost importance to the people, wildlife and economic activities that depend on it. Many people have considered these two goals mutually exclusive, even though the impact on the delta of an emergency water supply for Namibia's Central Area is uncertain. This paper shows that the perceived tradeoff between water security for Namibia and an untapped Okavango River could be a non-issue for the foreseeable future.

While Namibia's water situation today looks fairly secure, drought is a recurring feature of the lansdscape and must be planned for. Even in the worst case scenario, i.e., that it stops raining in Namibia today and surface supplies are exhausted by 2001, Namibia has the infrastructure and technology to withstand another drought without taking the momentous and costly step of building the Okavango pipeline. With effective demand management, large-scale artificial recharge, emergency pumping of aquifers, an expanded reclamation system, a connection to the Berg Aukas mine, and possibly new aquifers developed by that time, a possible supply deficit as a result of drought could be managed without too much upset to people or the economy.

Given the country's existing ability to handle a possible crisis, the country has an opportunity to focus on the long-term planning goal of sustainable water resources management. Relative to many of its neighbours, Namibia has already made significant advances toward this goal; e.g., an exemplary water conservation program in Windhoek, a comprehensive water sector review nearly complete, and a national demand management assessment completed. More needs to be done, however. The Water Act and water policies need to be updated and revised, artificial recharge should be further explored, demand management should be instituted nation-wide, economics should be applied more effectively, and emerging technologies need to be monitored for eventual inclusion in the central supply system.

With effective planning and continued commitment to sustainable water management by all Namibians, the country can continue to grow and prosper without having to consider building an expensive pipeline to the Okavango River for a very long time.

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Annex 1. • Likely Water Demand and Supply and Possible Deficit in 2001 (Mm 3/yr)

Water Demand 2001			Water Supply 2001				Cumul.
Consumer	**Demand**	**Subtotal**	**Source**	**Quantity**	**Subtotal**	**Total**	**Total**
			Windhoek Aquifer	2.00			
			Reclamation & Reuse	10.30	12.30	12.30	12.3
Windhoek	20.88						
Sports Fields	1.43	22.31				-22.31	-10.0
Otjihase Mine	0.40						
Otjihase Abstr.	0.01						
Von Bach-Wnl Abstr	0.16						
Osana Military Base	0.15						
Ovitoto Abstr.	0.01						
Von Bach Resort	0.01	0.75				-0.75	-10.7
Losses	0.22						
Okahandja	1.61						
Gross Barmen Resort	0.07						
Gross Barmen Abstr.	0.01						
Losses	0.01	1.90				-1.90	-12.6
Von Bach Purif. Loss	0.65						
Von Bach Dam			Von Bach Dam	0.00	0.00	0.00	-12.6
Evapor. Losses	1.16	1.81				-1.81	-14.4
Swakoppoort Dam			Swakoppoort Dam	0.00	0.00	0.00	-14.4
Evapor. Losses	1.09						
S.Poort-Okaongava Ab.	0.05						
Okongava-Karibib	0.02						
Navachab Mine	1.15	2.31				-2.31	-16.7
Losses	0.01						
Karibib	0.32						
Karibib Abstr.	0.09	0.42				-0.42	-17.2
Losses	0.02						
Omatakoo Dam			Okatako Dam	0.00	0.00	0.00	-17.2
Evapor. Losses	?						
Line Losses	0.34						
Okakarara	0.46						
Okahitwa	0.01						
Okamatapati	0.11						
Okonkjatu	0.04						
ENWC	0.10						
Goblenz	0.34						
Okakarara Abstr.	1.55						
Ombinca	0.22						
Waterberg Pl. Park	0.10	3.30				-3.30	-20.5
Losses	0.41						
Ditto Fixed	1.00						
Tsumeb	3.02						
Grootfontein	3.29						
Tsumeb Mine	0.00						
Kombat Mine	1.92						
Kombat Irrigaion	0.32						
Permit Holders	1.96						
Commercial Farming	1.33						
Otjikotto & Guinas	3.24						
Berg Aukas Abstr.	0.04						
Berg Aukas Irr	0.00	16.54				-16.54	-37.0
			Tsumeb Carbonate	11.51			
			Tsumeb Unconfined	0.44	11.95	11.95	-25.0
			Berg Aukus Mine	1.50			
			Kaarst Aquifer I	4.50			
			Kaarst Aquifer II	5.11			
			Kaarst Aquifer III	0.07			
			Kaarst Aquifer IV	0.06	11.24	11.24	-13.8
TOTAL DEMAND	49.34	49.34	TOTAL SUPPLY	35.50	35.50	BALANCE	-13.8

Table is based on Table E.9.1-3 in WTC, 1997.

2001 demand estimates are based on a 2.6% annual increase from 1998 figures.

Annex 1. • Likely Water Demand and Supply and Possible Deficit in 2001 (Mm 3/yr)

To use the table in Annex 1:

Column 1:
"Consumer" lists Central Area water consumers only, including evaporative and other losses.

Column 2:
"Demand" lists the expected demand of each consumer in Column 1.

Column 3:
"Subtotal" provides subtotals for each broad consumer area, such as the Von Bach-Windhoek area.

Column 4:
"Source" lists all sources of water for the Central Area supply system.

Column 5:
"Quantity" lists the volumes each source would supply to the system.

Column 6:
"Subtotal" provides subtotals for each source or group of sources.

Column 7:
"Total" lists the volumes of supply or consumption, including losses, for each component of the system. These are the values added to the cumulative total figures in the next column.

Column 8:
"Cumulative Total" provides a running balance of supply minus consumption through the system.

The figure in the bottom right corner, "**BALANCE**", is the final water balance for the entire system. In the case of a hypothetical drought scenario as described above, the balance indicates a deficit of 13.8 Mm3.

Annex 2. • Water Supply Balance Sheet for 2001 Emergency Scenario (Mm 3/yr)

Water Demand 2001			Emergency Water Supply 2001				Cumul.
Consumer	Demand	Subtotal	Source	Quantity	Subtotal	Total	Total
			Windhoek Aquifer	4.00			
			Reclamation & Reuse	10.30	14.30	14.30	14.3
Windhoek	20.88						
Sports Fields	1.43						
Otjihase Mine	0.40						
Otjihase Abstr.	0.01						
Von Bach-Wnl Abstr	0.16						
Osana Military Base	0.15						
Ovitoto Abstr.	0.01						
Von Bach Resort	0.01						
Losses	0.22	23.27				-23.27	-8.9
Okahandja	1.61						
Gross Barmen Resort	0.07						
Gross Barmen Abstr	0.01	1.68				-1.68	-10.6
Losses	0.01						
Von Bach Purif. Loss	0.65						
Von Bach Dam			Von Bach Dam	0.00	0.00		
Evapor. Losses	1.10	1.82				-1.82	-12.4
Swakoppoort Dam			Swakoppoort Dam	0.00	0.00		-12.4
Evapor. Losses	1.09						
S.Poort-Okaongava A	0.05						
Okongava-Karibib	0.02						
Navachab Mine	1.15						
Losses	0.01	2.32				-2.32	-14.7
Karibib	0.32						
Karibib Abstr.	0.09						
Losses	0.02	0.43				-0.43	-15.2
Omatakoo Dam			Okatako Dam	0.00			
Evapor. Losses	?						
Line Losses	0.34						
Okakarara	0.46						
Okahitwa	0.01						
Okamatapati	0.11						
Okonkjatu	0.04	0.97				-0.97	-16.1
ENWC	0.10						
Goblenz	0.34						
Okakarara Abstr.	1.55						
Ombinca	0.22						
Waterberg Pl. Park	0.10						
Losses	0.41						
Ditto Fixed	1.00	3.72				-3.72	-19.9
Tsumeb	3.02						
Grootfontein	3.29						
Tsumeb Mine	0.00						
Kombat Mine	1.92						
Kombat Irrigaion	0.32						
Permit Holders	1.96						
Commercial Farming	1.33						
Otjikotto & Guinas	3.24						
Berg Aukas Abstr.	0.04						
Berg Aukas Irr	0.00	15.13				-15.13	-35.0
			Tsumeb Carbonate	11.51			
			Tsumeb Unconfined	0.44	11.95	11.95	-23.0
			Kaarst Aquifer I	6.50			
			Kaarst Aquifer II	8.00			
			Kaarst Aquifer III	4.50			
			Kaarst Aquifer IV	5.50			
			Berg Aukas Mine	5.00			
			Abenab Mine	5.00			
			Tsumeb Mine	5.00	39.50	39.50	16.4
TOTAL DEMAND	49.34	49.34	TOTAL SUPPLY	65.75		BALANCE	16.4

This table is based on Table E.9 of the Feasibility Study on the Okavango River to Grootfontein link (WTC). Water demand figures are 1998 demand estimates contained in the WTC report increased by 2.6% per annum. Emergency water supply volumes are also from WTC (1997), DWA (1997) and NamWater (1998).

Annex 2. • Water Supply Balance Sheet for 2001
Emergency Scenario (Mm 3/yr)

To use the table in Annex 2:

Column 1:
"Consumer" lists Central Area water consumers only, including evaporative and other losses.

Column 2:
"Demand" lists the expected demand of each consumer in Column 1.

Column 3:
"Subtotal" provides subtotals for each broad consumer area, such as the Von Bach-Windhoek area.

Column 4:
"Source" lists all sources of water for the Central Area supply system.

Column 5:
"Quantity" lists the volumes each source would supply to the system.

Column 6:
"Subtotal" provides subtotals for each source or group of sources.

Column 7:
"Total" lists the volumes of supply or consumption, including losses, for each component of the system. These are the values added to the cumulative total figures in the next column.

Column 8:
"Cumulative Total" provides a running balance of supply minus consumption through the system.

The figure in the bottom right corner, **"BALANCE"**, is the final water balance for the entire system. In the case of a hypothetical drought scenario as described above, the balance indicates a surplus of 16.4 Mm3/yr.

Cost of Utilising Abandoned Mines for 2001Emergency Supply (N$ Million)

Component	Total Capital Cost MN$	Subtotal
Tsumeb		
Base Pump Station	16	
Security and Telemetry	3	
Pipeline Installation (50 km @ 1.3/km)	66	85
Abenab		
Base Pump Station	16	
Security and Telemetry	3	
Pipeline Installation (40 km @ 1.3/km)	53	72
Contingencies (15%)	24	
Preliminary and General Items - 15% for Pump Stations	5	
Preliminary and General Items - 10% for Pipeline	12	41
Professional Fees - Fees	20	
Professional Fees - Site Supervision and Quality Ass.	7	
Detailed Geometric and Aerial Surveys	1	
Detailed Geotechnical Surveys	2	
Bulk Power Supply - High Voltage Transmission	15	45
Allowance for Accelerated Programme (7.5%)	18	
TOTAL CAPITAL COST ESTIMATE	**260**	

Source: Based figures in Table E.22.1 of WTC (1997).

Note: Several cost estimates in Table 5 were taken directly from the WTC feasibility study, including: Base Pump Stations, Security and Telemetry, Pipeline Installation cost per km, fees, surveys, and Bulk Power Supplies. These direct translations of cost figures will over-estimate the cost of the mine schemes somewhat given the smaller scale and shorter distance of the connections to the abandoned mines.

Annex 3. • Utilising Abandoned Mines

Abenab Mines

When the Abenab Mines were in operation until 1959, between 3 - 4 Mm3/yr were pumped from the underlying aquifer (Kirchner, 1997). According to recent hydrogeological testing of the mine, estimates of the long-term sustainable yield range between 1 - 2 Mm3/yr, while the estimated 24-month emergency pumping rate is estimated at 5 Mm3/yr (NamWater, 1998).

Connecting the mine's potential emergency yield of 5 Mm3/yr to the ENWC would require the installation of equipment capable of extracting 684 m3/hr over 20 hours per day, and 40 km of pipeline between the mine and the ENWC. A conservatve estimate of the capital cost of developing this resource is N$ 113 Million (Table 3), which is only two-thirds the capital cost per unit volume of water from the Okavango pipeline.

Tsumeb Mines

As WTC (1997) reports, the Tsumeb Mine shaft was pumped for dewatering purposes an average of 6 Mm3/yr for many years. It is believed that this mine would be able to sustainably yield in excess of 2 Mm3/yr, and for a 24-month emergency period could produce 5 Mm3/yr safely (Kirchner, 1997). Similar to the Abenab and Berg Aukas Mines, the Tsumeb Mine seems a logical addition to the Central Area water supply.

Linking up the Tsumeb Mine to the central supply system could be co-ordinated with connecting the Abenab Mine supply. This would require installing equipment capable of extracting 684 m3/hr over 20 hours per day, and a 45-km pipeline between Tsumeb and the Abenab Mine, where it could join a pipeline to the ENWC. A conservative estimate of the cost of Tsumeb Mine extension (in conjunction with the Abenab connection) is N$147 Million. The combined cost of the Abenab and Tsumeb Mine extensions to the ENWC would be roughly N$250 Million (See Annex 3 for estimates of the cost of connecting the mines to the central supply system).

Tsumeb Aquifers

Three groundwater areas comprise the Tsumeb Aquifers, namely the Carbonate Aquifer, the Unconfined and the Confined Kalahari Aquifer. The estimated combined yield of these aquifers is 34 Mm3/yr, which must be verified by on site investigation (WTC, 1997). Current consumption from these aquifers is approximately 14 Mm3/yr, leaving a potential balance for development of 20 Mm3/yr from the Carbonate Aquifer and the Unconfined Kalahari Aquifer.

In order to develop fully the remaining potential yield of the Tsumeb Aquifers, 200 boreholes, connected to the ENWC by over 700 kilometres pipes of varying diameter, would have to be installed, requiring approximately five years to complete (WTC 1997). Although it would not be possible to develop the Tsumeb aquifer fully by 2002, there would be enough time to develop enough boreholes to make a significant contribution to the water supply.

Platveld Aquifer

The Platveld Aquifer is estimated to have a long-term sustainable yield of approximately 5 Mm3/year. The aquifer has not been developed beyond small-scale local use. In order to develop this resource, over 70 production boreholes, connected to the ENWC by at least 250 km of pipes, would need to be installed. The estimated six years required to develop this aquifer (WTC, 1997) would not meet the requirements of an imminent emergency situation.