Water use and demand

Namibia

REPORT INFORMATIONS

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CORBWA – Water Demand in the Namibia Section

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Abbreviations

ANN	Aquaculture in Northern Namibia
CAN	Central Area of Namibia
CBS	Central Bureau of Statistics
CORB	Cubango Okavango River Basin
CORBWA	Cubango Okavango River Basin Water Audit
DWA	Department of Water Affairs
DRWS	Directorate of Rural Water Supply
ENWC	Easter National Water Carrier
EPSMO	Environmental Protection and Sustainable Management of the Okavango
FAO	Food and Agriculture Organisation of the United Nations
GDP	Gross Domestic Product
GTO	Grootfontein-Tsumeb-Otavi Karst
KWMB	Karst Water Management Body
IWRMPJVN	Integrated Water Resources Management (IWRM) Plan for Namibia
LA	Local Authority
MAWF	Ministry of Agriculture, Water and Forestry
MET	Ministry of Environment and Tourism
MFMR	Ministry of Fisheries and Marine Resources
NPC	National Planning Commission
NWRMR	Namibia Water Resources Management Review
N$	Namibia dollar
OKACOM	Permanent Okavango River Water Commission
WAN	Water Accounts of Namibia
WCA	Water Control Area
WCE	Windhoek Consulting Engineers

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1. Introduction

This report summarises the results of the Namibia study of water use and demand in the Namibian part of the Cubango Okavango River Basin (CORB). Similar reports are being prepared for Angola and Botswana. The three country reports will be synthesised into a basin wide report on water use and demand.

The terms of reference for the country study list the following tasks:

1. Assemble national water use data in a common basin-wide database; ensure proper documentation of the water use database;
2. Collect recent literature and (inter)national data sources on domestic water use, industrial water use, irrigation and associated water use in agriculture (in consultation with the agricultural specialist), and water use for environment and tourist industry in the riparian countries;
3. Work out methodologies to distribute national statistical information over the Namibia part of the CORB and to deal with critical data gaps;
4. Prepare data products to present assessment results in tabular, graphical, and geo-referenced form;
5. Prepare a detailed technical documentation of the applied methodology, and a national report with the results of the water use assessment for the Namibia part of the CORB;

The work is part of the OKACOM-FAO CORB Water Audit (CORBWA) project. The CORB has an "active" part and a "non-active" part. The active part constitutes the relatively narrow catchment area along the actual river, with its two principal tributaries, and around its delta, while the non-active part comprises areas in Botswana and Namibia where associated groundwater resources and flows are found, including fossil aquifers (i.e. aquifers no longer being recharged). OKACOM has officially adopted a basin boundary that comprises the active catchment area as well as some, but not all, of the non-active part of the basin. Figure 1 below, shows the officially adopted basin boundary as well as those parts of the non-active basin that are not included within the official basin area (marked as cross-hatched areas).

For Namibia, only relatively small parts in the southeast of its portion of the non-active basin, along the border to Botswana -- essentially the Rietfontein Block area -- have not been included within the official CORB boundary. The main reason for the exclusion of these parts is that the ephemeral Rietfontein and Chapman's rivers draining the Rietfontein Block area and flowing in an eastern direction into Botswana, "discharge" (if and when they flow) into the saltpans of the central Kalahari, downstream of the Okavango Delta, unlike the Omiramba Otjozondju, Eiseb and Epukiro (also ephemeral rivers) further north, which "discharge" (if and when they flow) into the Delta and therefore included in the official CORB area.

Figure 1: Namibia segment of the Cubango Okavango River Basin (CORB)

2. Water supply, use and productivity in Namibia[1]

This section provides a brief overview of water use, supply and productivity at the national level (for Namibia as a whole). Data and information presented here are based on the Draft Technical Summary of the Water Accounts of Namibia (WAN, 2004) and the more recent Draft Integrated Water Resources Management Plan prepared by the IWRM Plan Joint Venture Namibia (IWRMPJVN, 2010), along with several Theme Reports that were prepared to develop the IWRM Plan.

Namibia is the most arid country south of the Sahara, with generally low but highly variable precipitation ranging from a maximum of about 650 mm/a in the northeast to less than 50 mm/a along the coast. It is estimated that country-wide on average only about 2% of the rainfall ends up as surface run-off and as little as 1% of the rainfall effectively recharges groundwater resources. Given the country's very dry and unpredictable climate, water availability, i.e. secure, equitable and universal access to fresh water – tends to be a critical limiting factor for social well-being and economic development. This highlights the need for an efficient use and effective management of scarce water resources and puts a premium on water security.

The national water accounts for Namibia (WAN, 2004), developed for the period 1997/98 – 2001/02, provide a framework for measuring the contribution of water resources to the different sectors of the national economy and the impacts of changes in the economy on water resources. Table 1 below, summarises some of the results of these national water accounts. Overall use of freshwater (including recycled water) increased from 234 Mm^3/a to 282 Mm^3/a during the period, an increase of 20%. Around 14% of the water abstracted nation-wide was lost or unaccounted for during the water supply process from abstraction to use. Freshwater use increased somewhat faster than the national population, so that per capita water use increased by some 8%. The productivity of water (i.e. its direct contribution to national income, in terms of value added per unit amount of water used) was shown to vary greatly between sectors, with agricultural production making much less of an economic contribution per m^3 of water used than non-agricultural economic activity.

[1] The terms "water supply", "water use", and "water productivity" are used in line with the definitions given in the Water Accounts of Namibia (WAN, 2004) establishing a series of physical water flow accounts and monetary water accounts for Namibia. "Water supply" is defined as the amount of water abstracted (or withdrawn) from the source. "Water use" is defined as the amount of water remaining for end users after all water consumed in production and all losses during water transfers (delivery to end users) have been accounted for. "Water productivity" (of an economic sector or of the whole economy) is defined as the value added (to an economic sector or to the whole economy) per unit amount (usually m^3) of water used. The physical water flow accounts presented in the Water Accounts of Namibia are limited to water supply and use accounts. Wastewater accounts are not presented. This means that no data are available from the Water Accounts of Namibia for the proportion of the water used by end users that is "consumed" (i.e. evaporated or transpired) or the quantity (and quality) of return flows (i.e. the wastewater discharged to the environment during end use).

Table 1: **Water supply, use and productivity 1997-2001**

	1997-98	1998-99	1999-2000	2000-01	2001-02
Freshwater supply and use (Mm^3)					
Freshwater supply	274	272	295	311	326
Freshwater use	234	240	254	266	282
Losses & unaccounted for water	40	32	41	45	44
Population (million)	1.6	1.7	1.7	1.8	1.8
Per capita water use (m^3/person)	142	142	146	149	154
Water productivity					
GDP (N$ million)	13,942	14,406	14,896	15,382	15,823
N$ GDP/ m^3 water used (all sectors)	59.5	60.2	58.7	57.9	56.2
N$ Agr GDP/ m^3 agr water used	5.5	5.6	5.5	5.2	4.2
N$ Non-agr GDP/ m^3 non-agr water used	194.2	185.3	207.6	209.5	209.3

Source: WAN, 2004

Table 2 below, provides a more detailed breakdown of water use by economic sector, also based on the national water accounts. The lion's share of water (70% to 75%) was (and is) used in agriculture (crop irrigation and livestock production) – 2/3 thereof in commercial agriculture and 1/3 in communal agriculture. In commercial agriculture, crop irrigation clearly dominates livestock production in the level of water use, while that is not the case for communal agriculture. The strong increase (by 44%) in water use for commercial crop irrigation from 1997/98 to 2001/02 was due to a major expansion (by 48%) of the area under irrigation, from 6,674 ha to 9,847 ha. Other major, but in overall quantities significantly smaller water use sectors are urban households, government institutions, and to a lesser extent rural households, mining and services.

Table 2: **Water use by economic sector 1997-2001**

Sector	Water Use (Mm^3)		Water use (% of total)	
	1997/98	2001/02	1997/98	2001/02
Agriculture	**167.3**	**210.2**	**71.4**	**74.7**
Commercial agriculture	**112.5**	**145.2**	**48.0**	**51.6**
Commercial crop irrigation	88.7	119.8	37.9	42.5
Commercial livestock	23.8	25.5	10.1	9.0
Communal agriculture	**54.9**	**64.9**	**23.4**	**23.1**
Communal crop irrigation	27.5	32.3	11.7	11.5
Communal livestock	27.3	32.7	11.7	11.6
Households	**30.2**	**33.6**	**12.9**	**11.9**
Urban households	21.7	24.5	9.2	8.7
Rural households	8.5	9.2	3.6	3.2
Government	**14.2**	**14.2**	**6.1**	**5.0**
Mining	**8.7**	**7.0**	**3.7**	**2.5**
Services	**7.0**	**7.9**	**3.0**	**2.8**
Manufacturing	**6.5**	**7.5**	**2.8**	**2.7**
Other	0.4	1.6	0.2	0.4
Total	**234.4**	**281.5**	**100.0**	**100.0**

Source: WAN, 2004

Tables 3a and 3b below, present a more detailed breakdown of water productivity by economic sector. The very low economic contribution per m^3 of water used by the agricultural sector, and in particular commercial crop irrigation (the largest water user in the economy), contrasts with much higher water productivities for other sectors like services and manufacturing (small or moderate water users) and impacts on the relatively low water productivity of the overall economy. The aggregate water productivities of sectors presented in Tables 3a and 3b mask considerable variations in water productivities across sub-sectors. For example, within the services sector, communication contribute N$5,000 – N$8,000 in value added per m^3 of water used, while hotels & restaurants contribute only around N$150 N$ in value added per m^3 of water used (WAN, 2004).

Table 3a: **Contribution of freshwater resources to national income by economic sector 2001/02**

Sector	Proportion of water used (%)	GDP (N$ million)	Water productivity (N$/$m^3$)
Agriculture	**73.6**	**918**	**4.5**
Commercial	49.1	623	4.6
Communal	24.4	296	4.4
Fishing	0.3	649	939.0
Mining	**3.3**	**1,162**	**127.2**
Diamond mining		324	39.6
Other mining		838	891.1
Manufacturing	2.4	1,697	260.6
Utilities	0.1	229	998.4
Construction	0.1	510	1,850.7
Services	**2.9**	**4,373**	**551.9**
Trade		1,513	775.5
Hotel and restaurant		298	164.8
Government	5.2	3,313	234.2
Average for all sectors			57.2
Average, excluding agriculture			203.8

Source: WAN, 2006, as cited and presented in the IWRMPJVN, 2010b

Table 3b: **Water productivity by economic sector 1997/98 and 2001/02**

Sector	Value-added per m^3 of water used (in constant 1995 prices)	
	1997-98	**2001-02**
Agriculture	**5.5**	**4.2**
Commercial agriculture	**4.6**	**4.1**
Commercial crops	0.83	0.99
Commercial livestock	18.5	20.9
Communal agriculture	**7.5**	**4.6**
Fishing	**14,352.5**	**991.3**
Mining	**130.3**	**167.0**
Manufacturing	**227.7**	**226.6**
Utilities	**1,077.5**	**1,013.5**
Construction	**1,920.7**	**1774.4**
Services	**547.7**	**575.3**
Government	**211.1**	**234.2**
Economy-wide		
GDP/m3 of water all sectors	59.5	56.2
GDP/m3 of water excluding agriculture	157.3	170.2

Source: WAN, 2004

Nationwide water supply (i.e. water abstraction/withdrawal from natural sources) is projected to approximately double between now and the year 2030, rising from about 335 Mm^3/a in 2008 to an estimated 770 Mm^3/a in 2030 (IWRMPJVN, 2010). Table 4 below, provides a sectoral breakdown of this projection. The dominant role of crop irrigation as the largest water user is projected to become even more dominant in future, as planned major new irrigation projects are implemented as part of the Government's "Green Scheme" along the perennial national border rivers, in particular the Cubango-Okavango River in the northeast and the Orange River in the south. After crop irrigation, the next two largest water users are livestock production and urban areas (local authorities). Here projections are that in coming years, water withdrawals for use in urban areas (which are expected to continue to expand fast due to rapid urbanisation and continuing population growth) will overtake water withdrawals for use by the livestock sector (for which overall stable livestock numbers and no further growth is anticipated).

Table 4: **Current and projected water demand for Namibia by end use sector**

End Use Sector	Water End Use in Mm^3/a					
	1999	2008	2015	2020	2025	2030
Urban Areas[2]	62.6 (21%)	66.0 (20%)	80.0	91.1	103.5	117.2 (15%)
Rural Domestic	5.7 (2%)	10.3 (3%)	10.6	10.9	11.1	11.4 (1%)
Livestock	77.1 (26%)	86.8 (26%)	86.8	86.8	86.8	86.8 (11%)
Crop Irrigation	135.9 (46%)	35.3 (40.5%)	204.6	344.6	379.8	497.2 (65%)
Mining	13.4 (4.5%)	16.1 (5%)	17.2	18.1	19.1	20.3 (3%)
Tourism	2.3 (1%)	19.6 (6%)	27.5	31.9	35.2	38.9 (5%)
Total	**296.9 (100%)**	**334.1 (100%)**	**426.7**	**583.4**	**635.6**	**771.7 (100%)**

Sources: IWRMPJVN, 2010 for 2008-2030 figures; WCE, 2000 for 1999 figures

Water demand is generally driven by major forces such as population increase, urbanisation, standard of living, technological change, economic growth and trade expansion. Realisation of Namibia's long-term development vision (Vision 2030) is expected to translate into an increase in water demand that is shaped by anticipated sectoral trends summarised in the IWRM Plan (IWRMPJVN, 2010), as reproduced in Table 5 below..

Table 5: **Expected sectoral trends shaping future water demand increases**

Urban Areas	The urban population is expected to increase dramatically, from 610 000 (33%) in 2001 to 2.24 million (75%) in 2030. The high rate of urbanization, in combination with rising incomes and industrial development, will increase urban water demand significantly. Rural-urban migration requires major capital investment in infrastructure to provide access to water (and sanitation) services especially to the poor.
Rural Domestic	Given anticipated high rates of urbanization, the rural population is not expected to increase significantly.
Livestock	Due to the limited livestock carrying capacity of the soil, it is foreseen that the water demand by livestock will remain stable, influenced mainly by annual rainfall and availability of grazing. The policy of value addition within the meat industry will require an increase in the number and capacity of abattoirs. This may contaminate water resources if not carefully managed. The biggest threat to water resources as a result of overgrazing is bush encroachment that reduces the recharge of groundwater sources.
Crop Irrigation	According to the Green Scheme, most new irrigation schemes will be concentrated along the perennial rivers, which will increase the water requirements in these areas significantly. Water use efficiency and pollution will be major focus areas for proper water management to prevent international conflicts.
Mining	Large mines can consume vast quantities of water. In the latest developments along the coast, desalination of seawater has been developed to supply uranium mines in the desert. This is a

[2] "Urban areas" comprises all urban-based water users that are located within local authority areas, including households, public-sector institutions and companies, private-sector industrial establishments, tourism establishments and other service facilities.

	welcome initiative. Mines can constitute a serious pollution threat in Karst and other secondary aquifers if not properly managed and controlled
Tourism	The tourism sector is identified as one of the major growth sectors. The development of high quality, low impact consumptive and non-consumptive tourism is encouraged. The large number of lodges established in Namibia (500+) may increase the water requirement in the sector significantly. Care must be taken that abstraction of water for lodges in ecologically sensitive areas does not lead to over abstraction of water. If not properly managed, inadequate wastewater and refuse disposal may cause groundwater pollution.

Source: (IWRMPJVN, 2010)

In order to meet projected water demand, Namibia will have to further expand water supply from conventional water resources (perennial rivers, impounded ephemeral water, and groundwater) and increasingly develop the country's non-conventional water resources. The latter include: desalination of sea water, direct and indirect reuse of water, recycling of industrial waste water, reclamation of domestic sewage water, artificial enhancement of aquifer recharge, water banking in aquifers, inter-basin transfers, integrated use of impounded water (dams), conjunctive use of (surface and ground) water, as well as rainfall and fog harvesting (IWRMPJVN, 2010b).

At the same time, and given the arid conditions in Namibia, water demand management (WDM) will continue to be an essential component of an integrated approach to sustainable management of the water sector for the country. Generally, WDM aims to reduce water requirements for given end uses[3] (or limit water use increases associated with expanding demand for water services) by improving water use efficiency and by altering water use patterns, through a variety of complementary technical, economic and awareness building measures and approaches. The urban water supply sector (including industry) and the irrigation sector offer the greatest scope for WDM measures to be applied and for the same water services to be delivered more cost-effectively and using less water. By comparison, the potential for saving money and water through WDM interventions is generally more limited in the livestock, rural domestic, mining, and tourism sectors (IWRMPJVN, 2010c).

Table 6 below summarises the results of a basin-focused assessment of the water resource potential (both surface water and groundwater) as well as current and projected future water resource utilisation for Namibia's 11 national water basins which are mapped and explained in section 3.1 (see Figure 2). As of 2008, total water abstraction in the Okavango-Omatako and Eiseb-Epukiro national water basins, which approximately, but not precisely, add up (in terms of surface area) to the Namibian part of the CORB, amounts to 67 Mm^3/a or approximately 20% of national water use estimated at 334 Mm^3/a. Most of the water abstracted in these two national water basins, in particular the Okavango-Omatako basin, is surface water from the Okavango River primarily destined for irrigated cultivation (see Sections 3.2.1 and 4.1). Water abstraction from sources in the two national water basins combined (and hence approximately in the Namibian part of the CORB) is projected to increase to 226 Mm^3/a by 2030, which is about 30% of nationwide water abstraction

[3] "Urban areas" comprises all urban-based water users that are located within local authority areas, including households, public-sector institutions and companies, private-sector industrial establishments, tourism establishments and other service facilities.

(estimated at 772 Mm^3/a). The increased national share of water withdrawals from within the two national water basins (and hence approximately from the Namibian part of the CORB) is primarily due to the expected rapid expansion of Green Scheme irrigation schemes along the Namibian section of the Cubango-Okavango River (see Sections 3.2.1 and 4.1).

The assessment of water resource potential and utilisation by national water basin leads the IWRM Plan to the following conclusion: Namibia as a whole, has sufficient water resources to meet the goals set out in Vision 2030 but the abstraction and distribution of water over large areas, coupled with the supply of remote communities and demand centers, remains a major challenge in terms of upgrading, replacement and maintenance of the necessary infrastructure (IWRMPJVN, 2010).

Table 6: **Current and projected water resource potential and abstraction by national water basin**

Basin	Water Resource Potential (Mm^3/a)			Water Abstraction (Mm^3/a)		Surplus (Deficit) (Mm^3/a)		Installed Infrastructure Capacity (Mm^3/a)	
	Surface	Ground	Total	2008	2030	2008	2030	2008	2030
Cuvelai-Etosha	180.0[4]	24.0	204.0	63.7	85.6	140.3	118.4	74.0	13.0
Eiseb-Epukiro	0	20.0	20.0	8.6	11.2	11.4	8.8	0	5.8
Kuiseb	9.8	8.0	16.8	8.4	12.6	8.4	4.2	1.0	13.9
Kunene	31.5	26.2	57.7	10.0	11.2	47.7	46.5	0	7.9
Nossob-Auob	8.0	32.5	40.5	31.1	34.9	9.4	5.6	6.2	2.8
Okavango-Omatako	250.0[5]	29.6	279.6	58.1	215.1	221.5	64.5	36.7	2.2
Omaruru-Swakop	41.0	29.5	70.5	50.6	74.9	19.9	(4.4)	27.5	18.1
Orange-Fish	379.9[6]	160.0	539.9	74.8	119.6	465.1	420.3	91.3	3.8
Tsondab-Koichab	0	1.8	1.8	3.9	5.1	(2.0)	(3.3)	0	5.8
Ugab-Huab	7.5	19.8	27.3	14.7	22.0	12.6	5.3	0	16.6
Zambezi-Kwando-Linyati	4000.0[7]	10.0	4010.0	10.3	179.6	3999.7	3830.4	4.75	5.6
Total				**334.1**	**771.7**				

Source: IWRMPJVN, 2010

Note: The two shaded national water basins (Okavango-Omatako and Eiseb-Epukiro), add up approximately, but not precisely, to the Namibia part of the transboundary CORB (see section 3 for more discussion on this point).

[4] Agreed allocation with Angola from the Kunene River

[5] Based on the irrigation of 16 550 ha @ 15 000 $m^3/ha/a$. Calculated on low flow conditions in the river and an assumed 25% of the flow reserved for environmental flow. See also sections 3.2.1 and 4.1 of the present report.

[6] A recent study into the management of the Lower Orange River considered various options to increase the yield of the entire Orange River System. Should additional measures be implemented to increase the yield of the system an allocation of 224.4 Mm^3/a could be available to Namibia. This figure has been used in this study.

[7] 10% of mean annual rainfall (MAR) at Katima Mulilo.

3. Data sources and methodology

3.1 Overall approach to determine levels of water abstraction to meet sectoral water demand

This report draws heavily on the Draft IWRM Plan (IWRMPJVN, 2010) and several related Theme Reports. It also refers to the Draft Technical Summary of the Water Accounts for Namibia (WAN, 2004) as an important source of water use and supply data in Namibia.

Theme Report 2 'The Assessment of Resources Potential and Development Needs', prepared under the Draft IWRM Plan project (IWRMPJVN, 2010b) provides a comprehensive assessment of water withdrawals for each of the principal water demand sectors in Namibia including projections of water withdrawals up to 2030, for each of the country's 11 national water basins. The assessment:

- Collates available data on levels of water-using economic activity and social needs/demands for the principal water-using socio-economic sectors;
- Organises, aggregates and/or distributes that data by national water basin (rather than political administrative region);
- Translates (current and projected future) levels of economic activity or social need/demand into corresponding (current and projected future) levels of water abstractions by sector and by basin, using quantitative data on precise measured (metered) levels of water withdrawals per sectoral activity or need/demand, where available, or plausible assumptions about likely water withdrawals per sectoral activity or need/demand, where necessary;
- Organises available data on water abstraction (by category of source where available) by national water basin;
- Pinpoints current inter-basin water supply transfers; and
- Estimates the surface water and groundwater resource potential as well as determines the demand-supply balance, for each of the national water basins.

Namibia's IWRM Plan provides comprehensive data, information and analysis about current and projected levels and patterns of water withdrawals by national water basin and economic sector. The main emphasis is on quantities of water abstracted. Relatively little data is provided on aspects of water quality, which reflects the general paucity of information that is available on (groundwater and surface water) water quality. Furthermore, with the exception of some information on irrigation efficiencies for different irrigation technologies, virtually no data and analysis is presented on levels (or proportions) of water "consumed" (i.e. evaporated or transpired) by different sectoral end users or on the quantity (or quality) return flow (wastewater effluent) from different sectoral end uses, again reflecting the general lack of information on these aspects in Namibia.

For these reasons, this report focuses on describing and analysing sectoral levels and patterns of water withdrawals from CORB-Namibia, with some (very limited) discussion, where data is available, on aspects of end users' consumption of water (e.g. for the irrigation sector – see section 3.2.1).

Furthermore, with the possible exception of NamWater bulk water supply operations, hard information on water losses during water production and delivery to end users is virtually non-existent. The Water Accounts of Namibia does present some estimates on nationwide water losses for the years 1997 – 2002, but these are rather dated and not specific to CORB-Namibia. Therefore, analysis in this report is largely limited to levels and patterns, by sector, of water withdrawals from CORB-Namibia, with no little or no distinction between levels of water abstraction and levels of "end use" and little or no discussion of quantitative or qualitative aspects of water "end use" regarding the proportions of water that is consumed by end users (or end use sectors) and levels/quality of return flows.

Figure **2** shows the 11 national water basins, as delimited during the Namibia Water Resources Management Review (NWRMR) in the early 2000s. The water basins do not coincide with the country's surface water catchment areas or groundwater catchment areas, as can be seen from Figure **3**. The reason is that the boundaries of the national water basins have been defined not only on the basis of physiographic parameters (i.e. the country's surface water catchments and groundwater catchments) but also on the basis of various other criteria, such as the location of important water supply infrastructure and water use centres, the boundaries of political administrative regions, the location of population centres, the location of other infrastructure, such as roads (BIWAC, 2004).

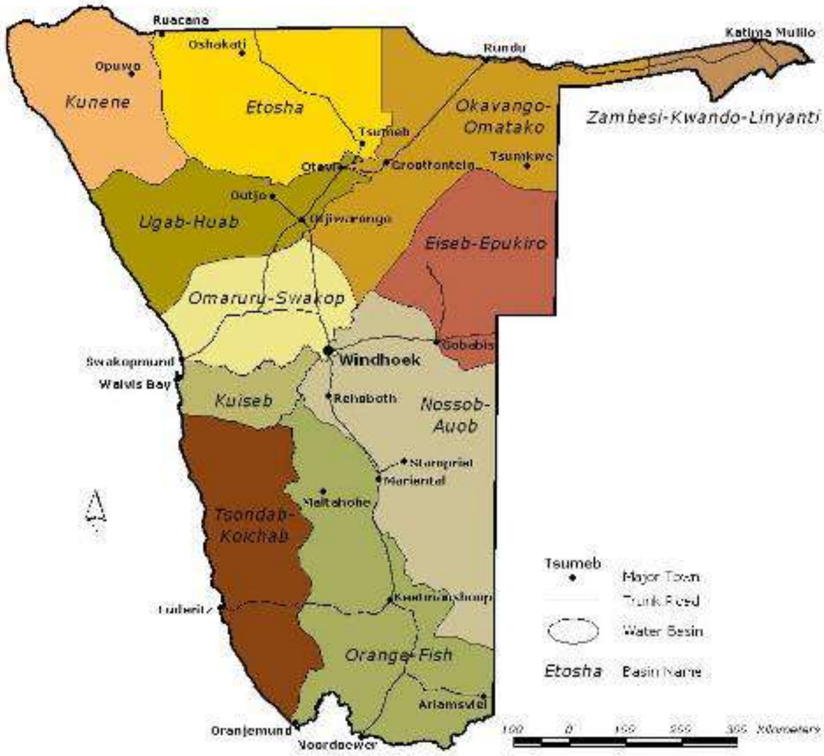

Figure 2: **National water basins of Namibia**

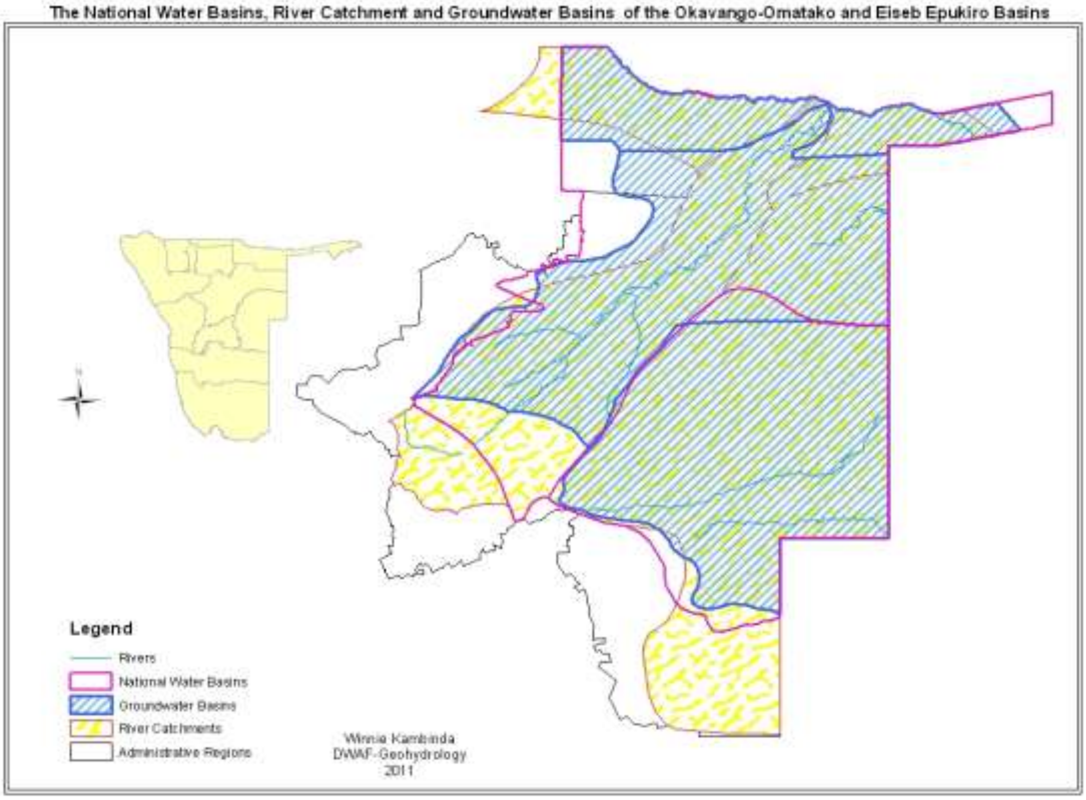

Figure 3: **National water basins versus national river and groundwater catchments**

Figure **4** below, provides an overlay of two national water basins (Okavango-Omatako and Eiseb-Epukiro), three Administrative regions (Kavango, Otjozondjupa, and Omaheke), and the CORB.

It is apparent from the figures that the Namibian part of CORB comprises parts of the three administrative regions and approximately coincides with the two national water basins. In terms of surface area, this can be expressed as follows:

(1) CORB-Namibia = 85% of the Kavango Region + 70% of the Otjozondjupa Region + 40% of the Omaheke Region

(2a) CORB-Namibia ~ Okavango-Omatako basin + Eiseb-Epukiro basin (~ = approximately)

However, the Namibian part of the CORB is not perfectly congruent with the merged two national water basins, since the CORB boundary deviates from that of the merged two national water basins in several respects as outlined below. The Namibian part of CORB:

- Includes the whole catchment area of the ephemeral Omatako river, whereas the Okavango-Omatako national water basin has been delimited in such a way as to exclude the highest part of the catchment area of the Omatako river, upstream from the Omatako dam. This portion of the Omatako catchment area has been added to the Omaruru-Swakop water basin on the grounds that the main purpose of the Omatako dam is to supply the national capital Windhoek by way of water transfer to the Von Bach dam which is located in the Omaruru-Swakop basin;

- Includes parts of the Grootfontein-Tsumeb-Otavi (GTO) Karst area that the Okavango-Omatako basin does not include, and does not include other parts of the GTO Karst area that the Okavango-Omatako basin includes (see Figure 8, section 3.2.1).
- Does not include small parts of the south-western Kavango Region and north-western Otjozondjupa Region, as its boundary is defined by the boundaries of the Okavango and Omatako River catchments, whereas the north-western section of the Okavango-Omatako national water basin boundary follows the boundaries of the administrative Kavango and Otjozondjupa Regions;
- Includes a small part of north-eastern Ohangwena, as its boundary is defined by the boundaries of the Okavango and Omatako River catchments, whereas the extreme north-western section of the Okavango-Omatako national water basin boundary follows the boundary between the administrative Kavango and Ohangwena Regions;
- Does not include the Rietfontein Block area which is located in the south-eastern corner of the Eiseb-Epukiro national water basin, close to the national border to Botswana, and drained by the ephemeral Rietfontein and Chapman's rivers;
- Does not include the eastern part of that portion of the Kavango Region which forms part of the Caprivi strip, again because of a the mismatch between a catchment boundary (that of the Okavango River) representing the boundary of CORB and an administrative boundary (that of the Kavango Region) representing the easternmost section of the Okavango-Omatako national water basin boundary.

In view of these deviations, a more accurate version of the surface-area relationship (2a), expressing CORB-Namibia as a function of <u>all</u> national water basins sharing the CORB in Namibia, would be:

(2b) CORB-Namibia = 85% of Okavango-Omatako basin + 80% of Eiseb-Epukiro basin + 15% of Omaruru-Swakop basin + 5% of Cuvelai-Etosha basin[8]

Surface-area relationships between the four national river basins in (2b) and relevant administrative regions can be estimated from Figure 4 and/or taken from spreadsheets developed by Windhoek Consulting Engineers (WCE) in support of results presented in the IWRM Plan, Thematic Report 2 (IWRMJVN, 2010b), as follows:

(3a) Okavango-Omatako basin = 100% of Kavango Region + 50% of Otjozondjupa Region

(3b) Eiseb-Epukiro basin = 70% Omaheke Region + 10% Otjozondjupa Region

(3c) Omaruru-Swakop basin = 60% of Erongo Region + 20% of Otjozondjupa Region + 10% of Khomas Region

(3d) Cuvelai-Etosha basin = 100% of Oshikoto Region + 100% of Ohangwena Region + 100% of Omusati Region + 100% of Oshana Region + 10% of Kunene Region

[8] Strictly speaking, the Namibian part of CORB also comprises a tiny part (on the order of 1%) of north-eastern Oshikoto Region – which is neglected in this CORBWA report.

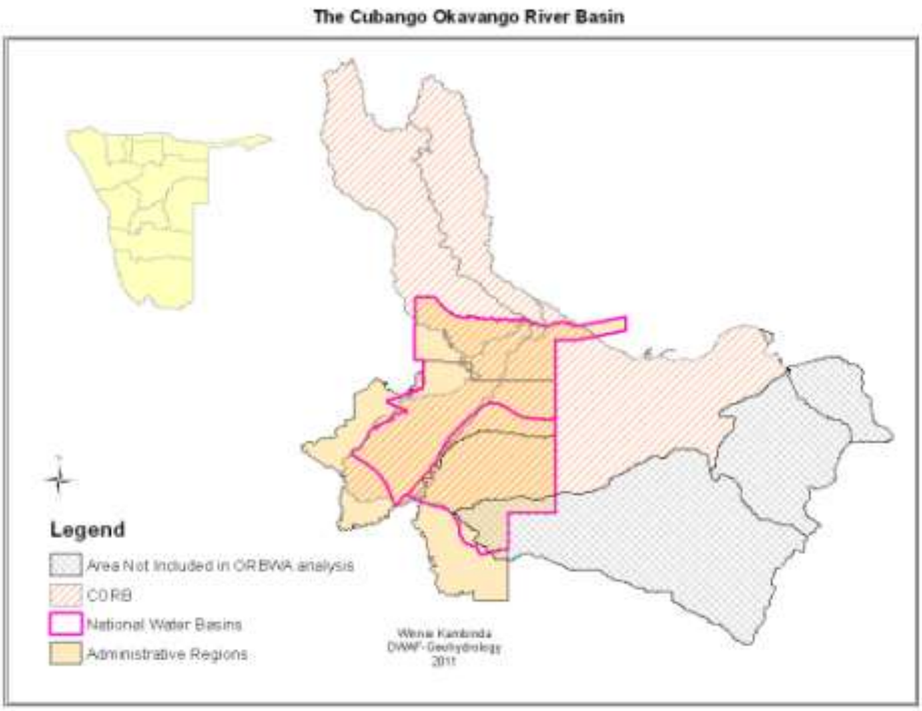

Figure 4: **Administrative regions, national water basins and the CORB - Namibia**

Equation (2b) will be used to determine volumes of water withdrawals from the Namibian part of the CORB, by end use sector, from estimated volumes of water withdrawals, by sector, for the national water basins sharing CORB-Namibia, available from the IWRM Plan for Namibia. But this method for estimating sectoral water withdrawals in CORB-Namibia will only be used for some of the sectors, namely livestock, rural domestic, and tourism (see Sections 3.2.2, 3.2.5, and 3.2.7). Different methods will be used for the other sectors.

If the boundaries of the Okavango-Omatako and Eiseb-Epukiro national water basins were defined in such a way as to coincide exactly with the boundary of the Namibian part of CORB, estimating water withdrawals from CORB-Namibia would simply involve adding up the water withdrawal figures for the two national water basins. Equation (2a) could be used without any adjustment and there would be no need for equation (2b). This would facilitate transboundary data management on water withdrawals and other water use aspects as well as monitoring and planning in the CORB, as it could build directly on national water-related data management, monitoring and planning in the two national water basins. By contrast, leaving the national basin boundaries as defined during the Namibia Water Resources Management Review, and the CORB-Namibia boundary as agreed by OBSC-Namibia and OKACOM, will require corrections and adjustments to national water basin based water data management, monitoring and planning, prior to their application in the transboundary context, to ensure accuracy.

The question arises, therefore, as to whether there might be scope for re-visiting and adjusting the current delimitations of the two national water basins (Okavango-Omatako and Eiseb-Epukiro) and/or of the Namibia part of the CORB, with a view to achieving full congruence between national and transboundary basin boundaries. This issue has been raised with OBSC-OKACOM Namibia.

The following sub-sections will discuss the data, methods and assumptions that the IWRM Plan (Theme Report 2) used to determine water abstraction levels and patterns for the national water basins, so as to clarify the methodological basis for the findings on volumes of water abstraction from the Namibia part of the CORB presented in this report, for sectors where the IWRM Plan figures are used. As well, other options to apportion water abstraction volumes to CORB-Namibia, not based on the IWRM Plan and its analysis by national water basin, will be considered and discussed. This will be relevant, for instance, in the case of the Karst groundwater area through which the CORB boundary cuts (see sections 3.2.1 and section 4.1.2).

Finally, it should be noted that for the purpose of the Namibian part of CORBWA only three categories of water abstraction sources are considered: surface water from perennial rivers, surface water from ephemeral river dams, and groundwater. Other categories (such as rainwater, wastewater, recycled water, grey water, soil water, etc.) are either not relevant or not amenable to analysis because of lack of data or gaps in the available data. Of particular note is that no attempt has been made to estimate water use in rain-fed farming, as this does not involve use of either surface water or groundwater.

In what follows, the following socio-economic sectors are considered:

- ✓ Irrigated cultivation
- ✓ Livestock production
- ✓ Aquaculture
- ✓ Urban households (within local authority areas)
- ✓ Rural households (outside local authority areas)
- ✓ Mines and industrial establishments (outside urban settlements/local authority areas)
- ✓ Tourism facilities and other service establishments
- ✓ Ecological water requirements, including water use by wildlife and natural forests.

Other possible sectors (such as commercial forestry) do not exist or are insignificant water users in the Namibia part of the CORB.

3.2 Water abstraction levels to meet water demand by sector

3.2.1 Irrigated cultivation

This section discusses methodological aspects and addresses issues of data availability and gaps for how current water abstraction for irrigated cultivation in the CORB can be estimated, and how water abstraction levels can be projected .to meet future demand for crop irrigation in the CORB.

For Namibia as a whole, Table 2 above, in section 2, show that crop irrigation is by far the largest water-using sector, accounting for close to half of overall water abstracted in Namibia. Table 4 also shows that major new irrigation developments envisaged under Vision 2030 are projected to further drive up the share of water abstracted for crop irrigation to nearly 2/3 of overall national water withdrawals by the year 2030. This situation specifically holds for the Namibian part of the CORB where irrigated cultivation has come to play a major role, and is projected in future to play an even greater role in agriculture and economic development.

Irrigation areas and schemes

Figure **5** and Figure **6** below, show the geographic distribution of irrigation areas within the three relevant administrative regions and the two most relevant national water basins, respectively, overlain on top of the CORB. The Green Scheme irrigated cultivation activities in the Namibian part of the CORB are concentrated along the perennial Cubango-Okavango River and in the Grootfontein-Tsumeb-Otavi (GTO) Karst area, only part of which falls within CORB, given that the CORB boundary cuts through the Karst area. Other significant irrigation areas are found in the upper Omatako catchment, east of the Omatako dam (around the Hochfeld, Otjozondu, and Imkerhof settlements areas), at the Osire settlement/refugee camp (northeast of the Omatako dam), and further east near Otjinene town in the Eiseb-Epukiro national water basin.

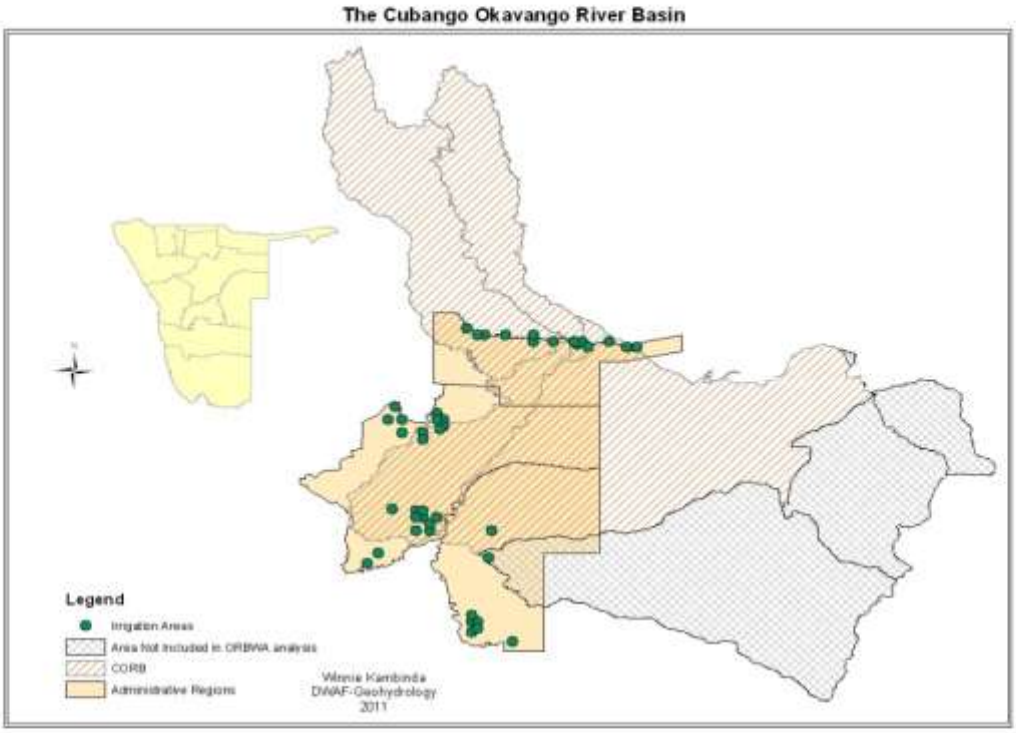

Figure 5: **Irrigation areas, administrative regions and the CORB**

Source: Windhoek Consulting Engineers (WCE) a member of the Joint Venture Namibia consortium who developed the IWRM Plan (original source: Geohydrology Division, DWA, MAWF)

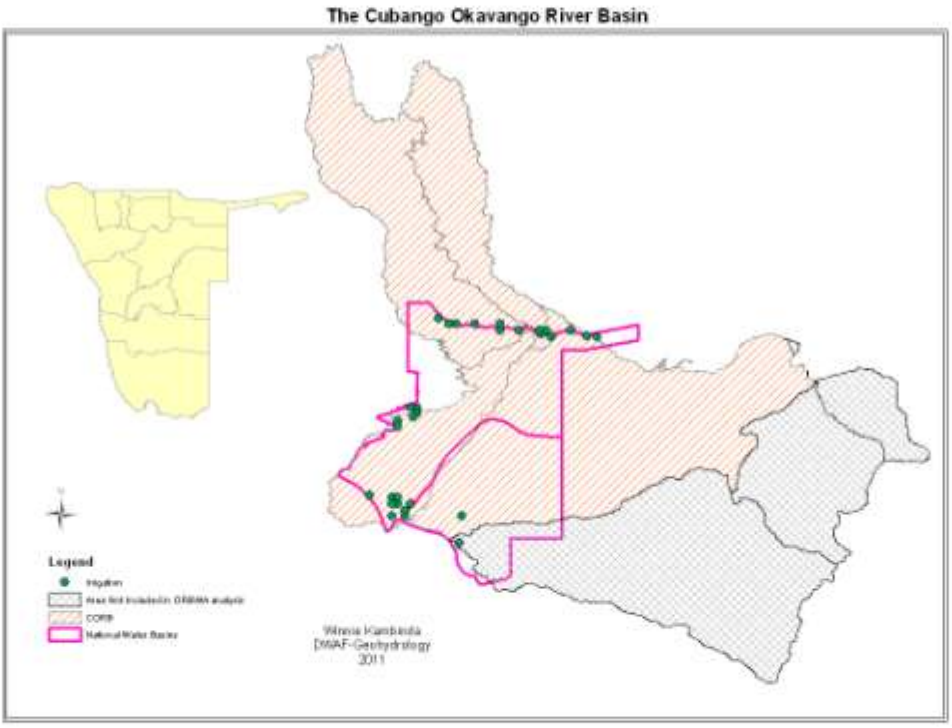

Figure 6: **Irrigation areas, national water basins and the CORB**

Source: Windhoek Consulting Engineers (WCE) a member of the Joint Venture Namibia consortium who developed the IWRM Plan (original source: Geohydrology Division, DWA, MAWF)

Along the Namibian section of the Cubango Okavango River, a number of Green Scheme irrigation projects drawing on surface water from the river, mostly involving out-grower type crop cultivation arrangements, have come on stream. The cumulative number of projects and aggregate irrigated area are projected to further increase substantially in the coming years.

The largest and most significant groundwater-based irrigation areas are found in the larger Grootfontein – Tsumeb – Otavi (GTO) Karst Water Control Area (WCA) that straddles the CORB-Namibia boundary such, that only part of the GTO Karst area falls within the CORB. Different options exist for apportioning water use for irrigation and other purposes in the Karst area to the Namibian part of the CORB. These options are discussed later in this section specifically for irrigated cultivation, on the basis of a map of the Karst sub-catchments.

The extent to which the Karst groundwater area is linked hydrologically to the surface flow of the Okavango River, if at all, is not clear. The water resources/hydrology assessment report prepared under CORBWA for the Namibian part of the CORB is expected to shed some light on this question.

Methodology for determining water use in crop irrigation

There are three principal ways of determining irrigation water abstraction volumes:

- through measurement of actual water abstraction volumes, by means of water meters in areas where water charges are levied and/or water permits are required;
- on the basis of information on crops grown and specific crop water requirements; and

- on the basis of the areas irrigated and typical water allocations per unit area.

The advantages and disadvantages of each of these ways to determine irrigation water use will now be briefly discussed. More details are found in Appendix A4.

Measuring irrigation water abstraction volumes by means of water meters in areas where water charges are levied and/or water permits are required

In principle, the most accurate way of determining the quantity of water abstracted for use by an irrigation scheme is by installing a water meter at the point of water abstraction or intake and measuring the quantity of irrigation water abstracted over time on the basis of periodic readings. In practice, however, very few irrigation schemes/farms have their own installed water meter and measure the water abstracted. One reason for the widespread absence of water meters on irrigation schemes/farms is that few schemes/farmers are charged for the water they abstract – and where they are charged, the charge is not levied on the basis of the water actually abstracted but according to the size of the area (to be) irrigated.

Where water permits are required these can be used in principle to determine quantities of water abstracted for irrigation. But in practice, poor compliance with permit conditions has limited the extent to which licensees have regularly reported actual water use, for which reason it is necessary to resort to data on allocated amounts of water as a proxy for water actually abstracted. However, the stated quantities of water (to be) allocated may not be a good indicator for the quantity of water actually abstracted. The percentages mentioned for actual water withdrawal (relative to permitted water use) in the previous paragraph suggest that by using allocated quotas as a proxy for actual water use tends to yield conservatively high water use estimates. Nevertheless, this seems to be the best method available for providing a rough estimate of irrigation water withdrawals use in areas where irrigation farmers and schemes require permits.

Estimating irrigation water abstraction and consumption on the basis of crops grown and specific crop water requirements

In the absence of meters to accurately measure volumes of water abstracted for irrigation and given generally poor reporting of actual water abstraction where permit conditions require installation of a meter are required and exist, estimates of the actual amounts of water abstracted and consumed by an irrigation scheme can be made on the basis of the following crop irrigation related data and information:

- The total area planted and irrigated;
- The type of crops grown using irrigation;
- Specific water requirements for the crops irrigated – which are influenced by climatic factors (most importantly the evaporation rate, given Namibia's dry climate, but also factors like rainfall patterns and the wind regime) and agro-ecological conditions (e.g. soil type) of the area where the irrigation scheme is located;
- The irrigation technology employed; and
- The irrigation management efficiency, in particular the efficiency of irrigation scheduling.

Table 7 presents specific crop water requirements for different crops and different irrigation systems, for the northern and north-eastern regions of Namibia where evaporation rates are between 2,500 and 2,900 mm/a. With the exception of lucerne (alfalfa), specific crop water requirements are below the widely used irrigation water allocation quota of 15,000 m^3/ha/a – and for some crops (maize, potato, sorghum and vegetables) as little as half (or less) of the allocation quota. Commonly accepted irrigation efficiencies (defined as the proportion of the applied water that is used by the crops) are indicated for the different irrigation technologies (flood irrigation, centre-pivot irrigation, sprinkler irrigation, and drip & micro irrigation, respectively) and reflected in the differences in the figures for crop water requirements across irrigation systems.

Table 7: **Specific crop water requirements for the northern and north-eastern Regions of Namibia**

Crop	**Net Water Requirement (mm/season)**	**Irrigation System Water Requirement** (m^3/ha/a)			
		Flood (Efficiency: 65%)	**Sprinkler** (Efficiency: 75%)	**Centre Pivot** (Efficiency: 85%)	**Drip & Micro** (Efficiency: 95%)
Lucerne	1,630	25,100	21,730	19,180	17,160
Cotton	887	13,100	11,830	10,440	9,340
Citrus	836	12,880	11,150	9,840	8,820
Wheat	659	10,100	8,790	7,750	6,940
Vegetable	507	7,810	6,760	5,970	5,340
Maize	506	7,790	6,750	5,950	5,330
Sorghum	492	7,580	6,560	5,790	5,180
Potato	448	6,900	5,970	5,270	4,720

Source: IWRMPJVN, 2010c

Details on how these specific crop water requirements where determined and on crops grown by Green Scheme projects and in the GTO Karst WCA are found in Appendix A5. The extent to which the crops actually grown correspond to those intended to be grown, as per irrigation permit, is not clear at all. Reasons for permit holders' lack of compliance with permit conditions for crops to be grown are discussed in Appendix A5.

Estimating irrigation water withdrawals on the basis of the areas irrigated and a typical water allocations per unit area

In the absence of accurate irrigation water metering/reporting and given the lack of accurate data on crops grown, it is necessary to resort to a simpler method for estimating irrigation water abstraction by determining the areas (to be) irrigated (in hectares) and applying typical average irrigation water allocations per hectare of irrigated area. This results in the following formula for estimating irrigation water use:

(4) Quantity of water abstracted for crop irrigation per year = irrigated area (ha) x typical water allocation

This relatively crude method follows the approach adopted by the recent IWRM Plan to determine irrigation water withdrawals for each of the national water basins.

Typical permit allocations for irrigation water

We will now first discuss typical irrigation water allocations per hectare and thereafter determine irrigated land areas in the Namibian CORB, with a focus on the principal irrigation areas: the Green Scheme projects along the Namibian section of the Cubango-Okavango River and the Grootfontein-Tsumeb-Otavi (GTO) Karst area.

Typical average irrigation water allocations range from 15,000 m^3/ha/a (as per the Green Scheme criteria - (Liebenberg, 2009) to 10,000 m^3/ha/a (as stipulated by the new water allocation guidelines for irrigation farmers in the GTO Karst area - DWA, 2004[9]). The IWRM Plan applied a so-called "typical" irrigation water allocation of 15,000 m^3/ha/a for both surface water and groundwater irrigation in the Okavango-Omatako national water basin as well as for surface water irrigation in other national water basins, and a "typical" lower allocation of 12,000 m^3/ha/a for groundwater irrigation use in all other national water basins. For the CORBWA-Namibia, we propose a somewhat different combination of typical irrigation water allocation factors, distinguishing between surface water and groundwater irrigation, rather than between basin: 15,000 m^3/ha/a for all surface river water irrigation (such as in the Green Scheme irrigation projects) and 12,000 m^3/ha/a for all groundwater irrigation (e.g. throughout the GTO Karst area).

Methods and data sources for determining irrigable and irrigated areas (as a basis for estimating water withdrawals for irrigation)

Namibian section of the transboundary Cubango-Okavango River

Along the Namibian section of the transboundary perennial Cubango-Okavango River, there are large irrigable areas, i.e. land that in principle lends itself for irrigated crop cultivation (Green Scheme projects). However, the land area that can actually be irrigated on the Namibian side is constrained by the amount of water available from the river for purposes of irrigation. Although a tri-partite Permanent Okavango River Water Basin Commission (OKACOM) formed by the governments of Angola, Botswana and Namibia has been in existence since 1994, a transboundary diagnostic analysis has only recently been completed (TDA, 2009), with the strategic action programme (SAP) still under development. This means that no agreement has yet been reached with regard to how the available river water should be divided among the three riparian countries. The absence of such an agreement and the possibility, if not likelihood, that reaching a transboundary allocation agreement could take a long time, led the Government of Namibia (GRN) to formulate a "reasonable and internationally acceptable" interim policy for utilising and allocating water from the Okavango River (MAWF, 2005).

The interim Policy is based on principles of reserving a sufficiently large proportion of "minimum" flow for "environmental purposes" and sharing the "remaining minimum" flow among the riparian countries. The interim Policy applies these principles separately to the sections upstream and downstream of the confluence of the Cuito river with the Cubango river near Katete town

[9] Until recently, policy guidelines allowed water allocations to irrigation farmers in the Karst up to a maximum of 12,000 m^3/ha/a (DWA, 1992)

separately. The reason for proceeding in this way is that the “minimum” base flow downstream of the confluence is significantly larger than upstream of the confluence, both in absolute terms and relative to the long-term average flow, because the seasonal variability of the stream flow of the Cuito river is considerably less than that of the Cubango river, for which reason.

Based on the resulting upstream and downstream limits for river water abstraction rates and based on assumed limits for short-term and long-term irrigation water application rates, the GRN interim policy determines the land areas that can be irrigated along the Cubango-Okavango River, upstream and downstream of the Cuito confluence. Section 4.1.1 presents figures for the resulting irrigable areas, for the land areas already under irrigation, and for the land areas that can still be irrigated, along the Cubango-Okavango River,upstream and downstream of the Cuito confluence (see Table 14). More details of the Namibian Government’s interim policy and its underpinnings are presented in Appendix A6.

Grootfontein-Tsumeb-Otavi (GTO) Karst area

The Grootfontein-Tsumeb-Otavi (GTO) Karst area is endowed with large-scale high-quality groundwater resources that are extensively used for irrigation purposes. For this reason, the GTO Karst is one of Namibia’s declared “water control areas” (WCAs). In such areas, all major groundwater users[10] require a license.[11] The GTO Karst area is the only WCA in the country where an operational management body (the Karst Water Management Body – or KWMB) has been established to represent the interests of local (irrigation) water users, provide coordination among irrigation farmers in matters relating to licence applications, renewals and report-back, and assist government authorities (the DWA) with the implementation of water use policy guidelines and with handling specific licence applications. Because of the existence of KWMB, significant irrigation water use data are available (IWRMPJVN, 2010a), although they remain far from consistent and complete (Beukes, 2011).

Identified groundwater flow regimes within the GTO Karst area have been used as a basis for distinguishing between different sub-catchment areas. A first attempt at sub-dividing the Karst area was made by Gerhard Seeger who distinguished between four (4) sub-catchments (DWA, 1990). Subsequent studies proposed different delimitations and nomenclature for individual sub-catchments (DWA, 2004a). A sub-division into eight (8) “sub-regions”, depicted in Figure **7** below, has emerged as the current spatial framework for controlling groundwater abstraction for irrigation purposes in the GTO Karst area (DWA, 2006). Two sub-groupings of these sub-regions/sub-catchments are often referred to as distinct sub-entities in connection with characterisations of groundwater resources and allocations in the Karst area:- the “northern parts” or “Tsumeb Aquifer” (sub-regions/sub-catchments A, B1, B2, and C) and the “southern parts” or “Otavi-Grootfontein Aquifer” (sub-regions/sub-catchments D, E, F, and G).

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[10] “Major” water users are understood to include farmers irrigating more than 1 hectare of land for crop cultivation as well as any public entities or private-sector organisations abstracting water in excess of 10,000 m^3/a.

[11] Updated water legislation (the New Water Act of 2004) has extended license requirements to <u>all</u> major users of (ground or surface) water for economic activities such as irrigation and mining, including major users in areas other than the traditional water control areas.

The sub-division of the Karst area into 8 irrigation sub-regions was done as part of a process during which criteria for the allocation of permits for the abstraction of Karst groundwater for irrigation purposes were formulated (DWA, 2004). The process resulted in the allocation of a specific amount of groundwater for each irrigation sub-region. As a result of strong rains and substantial groundwater recharge in the Karst area during the rainy season 2005-2006, these criteria (which reflected an all-time low in Karst groundwater levels during 2004-2005), were revised to take into account higher groundwater levels and enhanced groundwater availability (DWA, 2006).

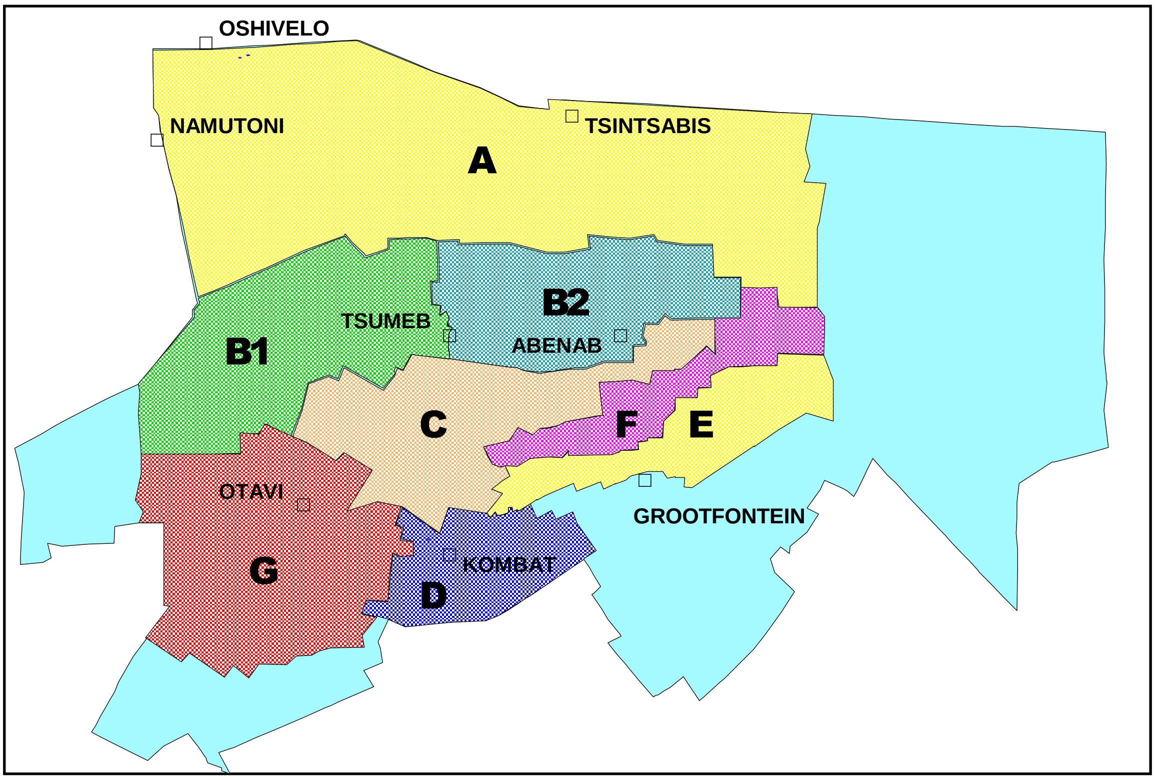

Figure 7: **The irrigation sub-regions of the Grootfontein-Tsumeb-Otavi (GTO) Karst area**

Source: (DWA, 2006)

Based on studies of Karst groundwater resources and recharge rates, (sustainable) allocations of groundwater to different water use sectors have all along been capped at sub-totals of 18 Mm^3/a for both the northern sub-regions (A, B1, B2, and C) and the southern Karst sub-regions (D, E, F, and G), for a total allocation of groundwater of 36 Mm^3/a for the Karst area as a whole. Of the allocation sub-totals, 9.6 Mm^3/a (or 53%) in the northern sub-regions and 2.2 Mm^3/a (or 12%) in the southern sub-region have been allocated to irrigation activities during the years 2005 - 2008 (DWA, 2008). Other major groundwater use sectors have been mining & industrial, urban domestic, and rural domestic & stock watering (see Table **8** below).

Overall sustainable allocations of Karst groundwater resources have been fully utilised and cannot be expanded, unless the rainfall and subsequently groundwater recharge increase. On the other hand, in the event of decreases in rainfall and groundwater recharge, overall Karst groundwater allocations may have to be curtailed (DWA, 2006). Groundwater allocations to irrigation farms/schemes in future may increase (or decrease) to the extent the recharge rates increase (or decrease) and groundwater levels fall and/or groundwater is re-allocated from (to) other water use sectors (mining & industrial, urban domestic, and rural domestic & stock watering).

Table 8: **Groundwater appropriation (in Mm^3/a) for the Northern and Southern Karst sub-regions**

Sub-Region/ Sub-Aquifer	Surface Area (km^2)	Irrigation	Mining & Industrial	Urban Domestic	Rural Domestic & Stock	Total
Northern (Tsumeb Aquifer) A, B1, B2, C	10,980	9.6 (53%)	2.0 (11%)	3.4 (19%)	3.0 (17%)	18.0
Southern (Otavi-Grootfontein Aquifer) D, E, F, G	5,020	2.2 (12%)	9.0 (50%)	4.8 (27%)	2.0 (11%)	18.0
Total	16,000	11.8 (33%)	11.0 (30%)	8.2 (23%)	5.0 (14%)	36.0

Source: (DWA, 2008)
Note: “urban domestic” appropriations only include abstractions by the municipalities of Tsumeb (northern sub-region) as well as Grootfontein and Otavi (southern sub-region).

Figure **8** and Figure **9** below show this Karst area sub-division, with the boundaries of the Namibia part of the CORB and the relevant national water basins (Okavango-Omatako, Ugab-Huab, and Cuvelai-Etosha) superimposed, at a small scale (for the Karst area only) and at a large scale for the CORB as a whole. It is apparent that the boundaries of the CORB and of the Okavango-Omatako basin both cut through the Karst area and across some of the Karst irrigation sub-regions (sub-catchments) -- but in different ways, such that the Okavango-Omatako basin includes parts of the Karst area that CORB excludes and the CORB includes other parts of the Karst area that the Okavango-Omatako basin excludes. Figure 8 and Table 18 (Section 4.1.2) can be used to estimate the surface-area proportions of the different Karst sub-regions (KSRs), of the Karst sub-region groupings (Northern KSRs and Southern KSRs), and of the overall Karst region (KR) that fall within the Okavango-Omatako (O-O) basin and the Namibian part of the CORB, respectively. These can be expressed in terms of the following relationships:

(5) KR portion of O-O basin = 25% of KSR A + 20% of KSR B2 + 35% of KSR C + 65% of KSR D +

100% of KSR E + 100% of KSR F + 10% of KSR G =
20% of Northern KSRs + 50% of Southern KSRs =
30% of overall Karst region

(6) KR portion of CORB-Namibia = 5% of KSR C + 80% of KSR D + 30% of KSR E =
1% of Northern KSRs + 20% of Southern KSRs =
7% of overall Karst region

Two approaches and seven options exist to apportion irrigation water use in the Karst area to the Namibian part of the CORB. One approach uses the sub-division of the Karst area into sub-catchments (irrigation sub-areas), while the other is based on the way the Karst area is shared by the relevant national water basins. The two approaches and seven options (four options for the first approach and three options for the second approach) are outlined in Appendix 8.

The above surface-area relationships (5) and (6) are used in section 4.1.2 as the basis for calculating the irrigation areas and volumes of irrigation water use for some of the options of apportioning the Karst area to the Namibian part of the CORB that are outlined in Appendix 8, using available irrigation data organised either by Karst irrigation sub-area or by national water basin.

It is not clear, *a priori*, which of the two approaches and seven options on how to allocate Karst irrigation water use to the Namibian part of the CORB should be selected for the purpose of CORBWA-Namibia. This needs to be decided by the relevant stakeholders, on the basis of data availability and other criteria. For this reason, both approaches and all seven options are used in section 4.1.2 to calculate estimated irrigated areas and volumes of irrigation water abstracted from within the Karst area, which should be apportioned to the Namibian part of the CORB.

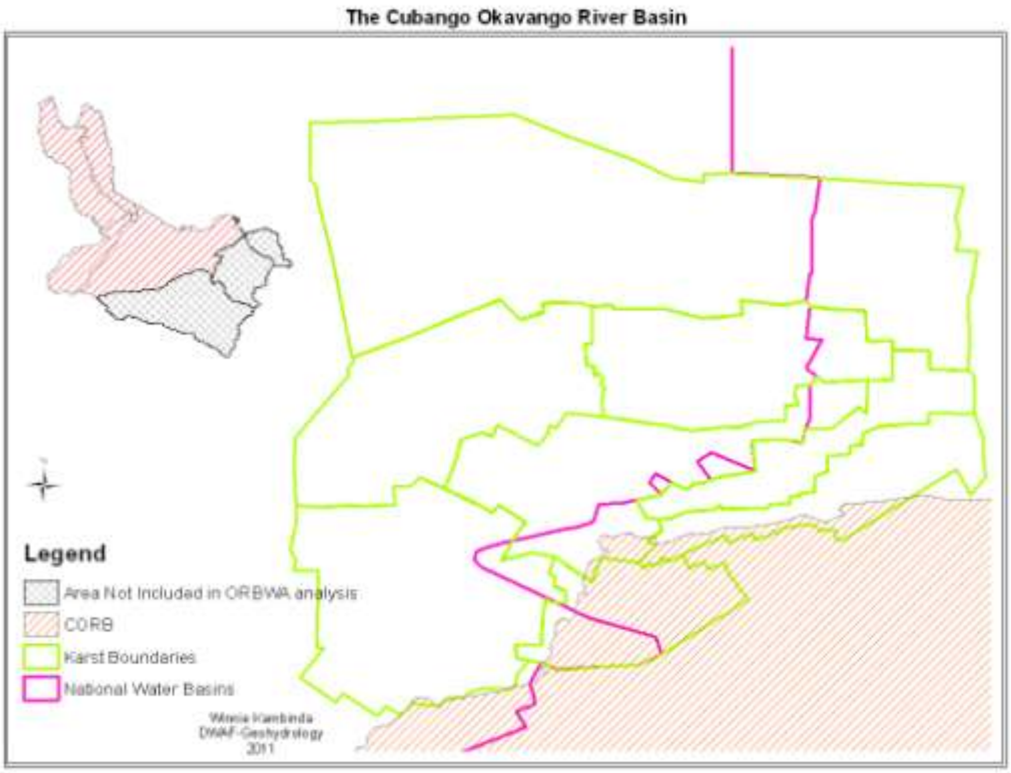

Figure 8: **Boundaries of the CORB and relevant national water basins in relation to the Irrigation sub-regions of the GTO Karst area (small scale)**

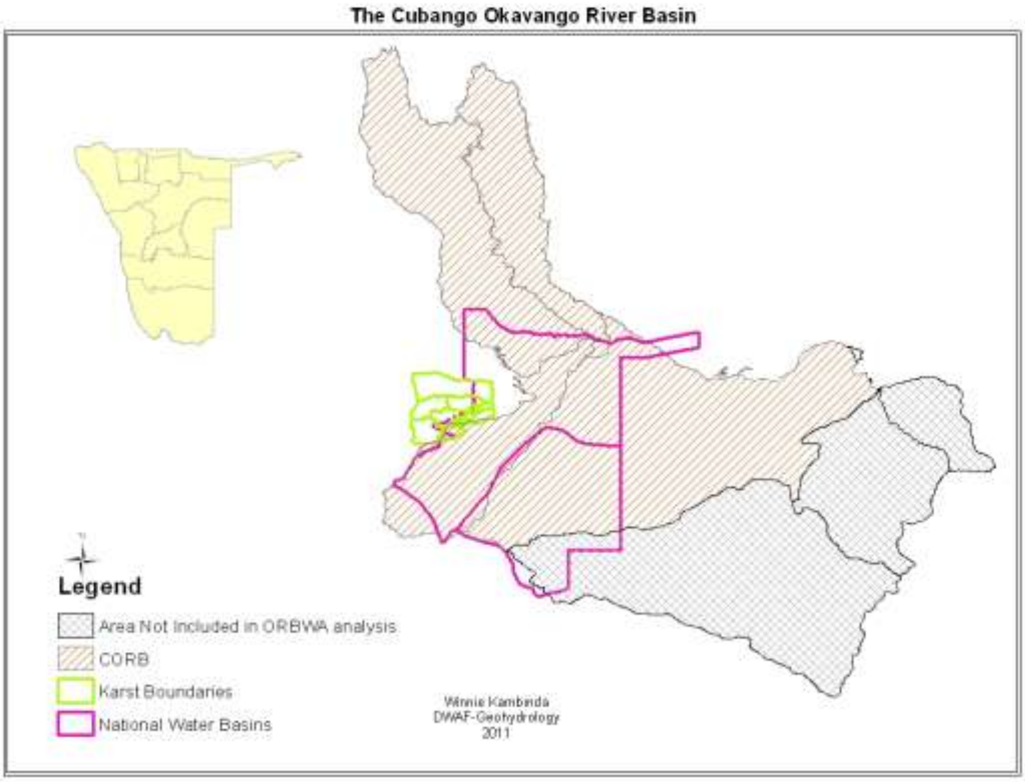

Figure 9: **Boundaries of the CORB and relevant national water basins in relation to the irrigation sub-regions of the GTO Karst area (large scale)**

3.2.2 Livestock production

The Department of Agriculture (Veterinary Services Division) has carried out nation-wide livestock censuses on a fairly regular basis. The latest stock census data are available for the year 2006. In the years before 2006, the stock census was conducted on an annual basis. No stock census was undertaken for the years 2007-2009. A stock census for 2010 has been carried out but its results are not yet available.

For purposes of planning and providing veterinary services, the Department of Agriculture divides Namibia into 12 veterinary regions, each of which is sub-divided into two or more veterinary areas, for a total of 52 veterinary areas. This geographic division has also been used for the planning and implementation of livestock censuses and as a spatial framework for presenting their results. While the results of a livestock census are presented as a database spreadsheet showing livestock numbers (by type of livestock) broken down for the 52 veterinary areas, these numbers are normally aggregated into the livestock numbers for 19 larger "veterinary districts" into which the 52 veterinary areas are merged. The 19 larger livestock districts are shown in Figure **10** below.

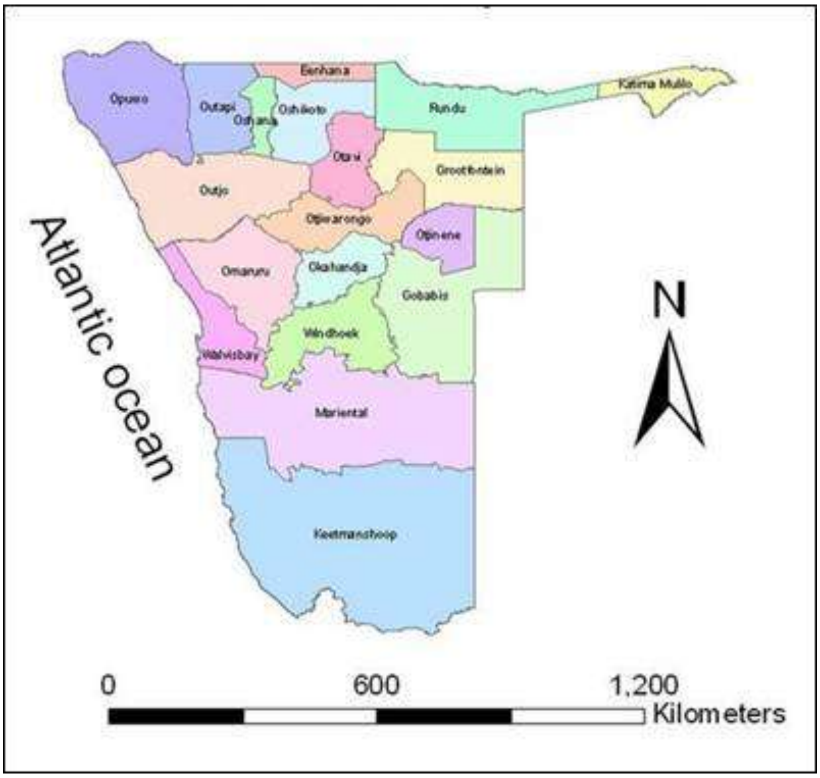

Figure 10: **Veterinary districts in Namibia**

Source: Directorate of Veterinary Services, Department of Agriculture, MAWF

The main purpose of a livestock census is to carry out livestock surveys in order to determine the numbers of different types of livestock for each veterinary areas, district and region, for a given year. The results are published as a database of livestock numbers broken down by type of livestock and veterinary area, for the year in question. Section 4.2 presents livestock data, aggregated by veterinary district, for the latest year for which statistics are available (2006). Annex A2 provides the disaggregate spreadsheet of livestock census data,(livestock numbers by type of livestock and by veterinary area) for the year 2006.

Determining water withdrawals to meet livestock water demand within the Namibian of the CORB requires estimating the numbers of different types of livestock found in the Namibian CORB, on the basis of the available livestock census statistics and assumptions about typical average daily water needs per animal for each type of livestock. Aggregate water withdrawals to meet livestock water demand in the Namibian CORB can then be calculated according to the following formula:

(7) Aggregate water withdrawals to water livestock in the Namibian CORB = sum over "animal numbers x typical averagedaily water needs per animal" for all existing livestock types in the CORB

The following alternative methods can be used to determine existing animal numbers for each livestock type in the Namibian CORB:

a) Identify those livestock veterinary areas that fall within the Namibian CORB, wholly or partly, determine for each of these veterinary areas that portion which is located within the Namibian CORB and the proportion of this portion's surface area relative to that of the whole veterinary area, and calculate animal numbers per livestock type in this portion from the available animal numbers for the whole veterinary area;

b) Proceed as outlined under a) above, but at the level of the larger, more aggregate veterinary districts; or

c) Use the livestock numbers that were calculated or estimated by the IWRM Plan for national water basins from the disaggregate livestock census data at the veterinary area level, using methods similar to a) and b) above to apportion veterinary areas (or parts thereof) to the national water basins and calculate the livestock numbers for the Namibian part of the CORB from those of the relevant four national water basins, on the basis of the surface-area size relationship (2b) in section 3.1 which is reproduced below for convenience. This relationship is applied to the basins' respective livestock numbers, under the assumption that livestock numbers are distributed uniformly within the relevant national water basins

(2b) Namibian CORB = 85% of the Okavango-Omatako basin + 80% of the Eiseb-Epukiro basin + 15% of the Omaruru-Swakop basin + 5% of Cuvelai-Etosha Basin

In order to use methods a) or b) above, it is necessary to be able to overlay the boundary of the Namibian CORB on a map of the veterinary areas or districts. However, it has not been possible to obtain the shape files for the veterinary areas or districts, respectively, for this overlay to be effected. For this reason, it has been decided to use method c).

Finally, aggregate water withdrawals to meet livestock water demand in the CORB is calculated, using typical average daily water needs per animal for different types of livestock that were adopted by the IWRM Plan, as summarised in Table 9 below.[12] It is further assumed, in line with the IWRM Plan (IWRMPJVN, 2010b), that wastage of stock water (due to factors like reservoir overflow, leaking ball valves at stock drinking troughs, evaporation, leaking pipes, etc.) which is significant, will effectively increase the water withdrawals necessary to meet unit livestock water demand by an assumed conservative 50% over what it would be without any water losses. The resulting unit daily water needs are indicated in the lower row of Table 9, both in (l/unit/day) and converted into (m^3/unit/a) (figures in brackets).

Table 9: **Typical average unit daily water needs for different livestock types**

Livestock type	Cattle	Sheep	Goats	Pigs	Donkeys	Horses	Poultry	Camels	Ostriches
Unit Daily Water Needs (l/unit/day)	45	10	10	10	15	25	1	40	4
Effective Unit Daily Water Needs (incl. 50% Water Wastage) (l/unit/day) (m^3/unit/a))	67.5 (24.6)	15 (5.48)	15 (5.48)	15 (5.48)	22.5 (8.21)	37.5 (13.7)	1.5 (0.548)	60 (21.9)	6 (2.19)

Source: (IWRMPJVN, 2010b)

[12] The assumed livestock unit water consumption rates generally are consistent with figures assumed in the Water Accounts for Namibia (WAN, 2004), except for pigs (WAN = 7), poultry (WAN = 0.23), and ostriches (WAN = 11). The Water Accounts for Namibia also include dogs in their livestock water use calculations (WAN = 3).

3.2.3 Freshwater aquaculture

There is a scarcity of data on the freshwater aquaculture sector in the Namibia part of the CORB. Table **10** below, shows a list of freshwater aquaculture projects in the Kavango and Omaheke regions (MFMR, 2005), it is, however, likely that further developments have taken place in the area since 2005. The Government of Namibia foresees the role of aquaculture of freshwater species to enhance food security, to generate income and to improve rural livelihoods.

Table 10: **Freshwater aquaculture projects in the Kavango and Omaheke regions**

PROJECT	TYPE OF FACILITY	LOCATION
Mpungu Fish Farm	Community based fish production farm	Nkurenkuru, Kavango Region
Karovo Fish Farm	Community based fish production farm	Rundu, Kavango Region
Kamutjonga Inland Fisheries Institute (KIFI)	Fingerling & fish production, Research, Training, Information centre	Divundu, Kavango Region
Shipapo Wabambangandu Fish Farm	Community based fish production farm	Kavango Region
Leonardville IAC (new)	Under construction: fingerling & fish production, training	Leonardville, Omaheke Region

Source: http://MFMR/Aquaculture/projection.pdf, 2005.

Fish farming in the Otjozondjupa region is dominated by subsistence farmers who are stocking existing dams with fish. There are approximately 30 subsistence freshwater fish farmers in the Otjozondjupa Region and harvesting in that region amounted to 1 tonne (1,000 kg) of fish in total (MFMR, 2007).

Methodology

In a study conducted by Boyd, E. and Li, L. (1998) to determine the intensity with which 172 countries use freshwater for aquaculture was estimated by dividing annual, freshwater aquaculture production (tonne/a) by annual total natural renewable freshwater (km^3/a). The freshwater aquaculture "production - to - renewable freshwater" ratio (AFR) varied among countries from 0 to 15,000 tonne/km^3. Country-level AFRs were assigned to AFR classes as follows: no freshwater aquaculture, 0 tonne/km^3; low, < 100 tonne/km^3; medium, 100-1,000 tonne/km^3; high, > 1,000 tonne/km^3. The number of countries in each AFR class follows: no freshwater aquaculture, 35; low, 80; medium, 45; high, 12.

The scrutiny of the literature revealed no data on water withdrawals by the freshwater aquaculture sector in Namibia. It is recommended to estimate freshwater withdrawals and determine the "freshwater use intensity" of the aquaculture sector in Namibia.

3.2.4 Urban settlements (local authority areas)

This section and the following one deal with water use and projected future water demand within human settlements. The present section discusses water use/demand for urban settlements (managed by local authorities), while domestic water use in rural areas is addressed in section 3.2.5.

Water abstraction for use in urban settlements

The urban settlement "sector" (i.e. urban local authority areas) includes the following main water user groups (IWRMPJVN, 2010b):

- Households/residences –
  - levels of residential water demand strongly increase with household income, such that for purposes of projecting future residential water demand, it makes sense to distinguish between high, medium and low income households;
  - the income elasticity of urban water demand in Namibia tends to increase with higher income, such that a disproportionate share of residential water goes to high-income households;
  - since the proportion of urban residents that are in the lower income bracket tends to increase over time, linear residential water demand projections (based on fixed proportions of consumers in different income brackets) tend to overestimate future residential water demand.
- Institutions – this water user category includes social service institutions (that are mainly public) such as schools, hospitals, police stations, prisons, churches, and government offices; these institutions can be profligate water users, and often are, especially in cases where they do not have to pay for water supplied from their own budgets and hence do not have an incentive to properly maintain water supply pipes and plumbing infrastructure; in smaller urban settlements, institutions' water demand may account for more than 50% of all water supplied.
- Industries – this includes manufacturing industries and service establishments (using water mainly in workers' facilities), as well as "wet" industries, such as breweries, abattoirs, textile dying establishments, fishing factories, and tanneries (using relatively large amounts of industrial process water in their industrial processes and producing large volumes of polluting/ toxic effluent); industries' water demand usually accounts for less than 10% of the water supplied to urban settlements (with the exception of the more industrial cities/towns like Walvis Bay or Lüderitz that are home to larger numbers of water-using factories.
- Businesses – this includes shops, offices, banks, transportation and communication facilities; collective water demand by such businesses is typically below 5% of the water supplied within urban settlements.
- Tourism establishments and facilities – this includes hotels, guesthouses and restaurants, whose collective share of water demand is normally very small (less than 2%), unless some of these tourism facilities maintain large landscaping areas (which require large amounts of water for irrigation).

Estimating current and project urban populations for the national water basins

Among the many factors influencing water demand in an urban settlement, the size of local resident populations is perhaps the most critical one. The number of people living in the settlement (and their income) not only directly determines the overall level of residential water use, but also influences the extent to which other water user categories are present. The larger the settlement, the greater its need for institutions that provide social services and the more attractive it tends to become as a market and location for businesses, tourism establishments/facilities and industries. It is therefore important to know the numbers of people living in urban settlements or provide accurate estimates of the population size of settlements.

The IWRM Plan (IWRMPJVN, 2010b) estimated the "current" urban populations (for the year 2008) for all 11 national water basins and calculated projected future urban water basin populations, using the following approach, methods and data sources:

- The starting point was a complete list of local authorities (LAs), which was provided by the Ministry of Regional and Local Government and Housing & Rural Development (MRLGH&RD); the list breaks down urban areas into the following LA categories: municipality, town, village, and settlement.
- Each LA urban area on the MRLGH&RD was assigned to one (and only one) of the 11 national water basins, on the basis of the LA's geographic location (coordinates) relative to the geographic boundaries of the national water basins.
- For each LA urban area, the population size was determined for the year 2001, on the basis of 2001 Population and Housing Census data (PHC, 2004), by assigning to the LA those of the 2165 Census enumeration areas (or proportions thereof) that fall wholly (or partly) within the LA area.
- Urban-area specific population growth rates were estimated, to be able to project 2001 urban-area population sizes to the year 2008 ("current situation") and to later years ("projected future situations"), as follows:
    - Use was made of the population projections (and underlying population growth rates) generated by the Central Bureau of Statistics, National Planning Commission by administrative region for the period 2001-2031, using the UN software package MORTPAK (which requires data inputs for a range of 12 influencing factors)[13] and by applying suitable adjustment factors to the calculated populations of the regions to achieve consistency between the regional population projections and national population projections (CBS, 2006);[14]
    - In order to account for rural-urban migration, the CBS-generated region-specific population growth rate projections were adjusted upwards by assuming that population growth rates in larger urban agglomerations are at least 1% higher, and those in smaller urban settlements 0.5% higher, than projected regional growth rates; and

[13] Influencing factors include: access to health facilities, fertility rates/patterns, mortality rates, migration rates/patterns, and life expectancy, which reflect other factors like HIV/AIDS prevalence and access to anti-retroviral medication.

[14] The resulting regional projections come up with the following 2011 population figures and 2001-2011 population growth figures, respectively, for the relevant Kavango, Otjozondjupa, and Omaheke Regions: increase from 202,690 people (2011) to 273,659 people (2011), i.e. a population growth of 35.0% for the Kavango Region; increase from 135,385 people (2001) to 167,051 people (2011), i.e. a population increase of 23.4% for the Otjozondjupa Region; and increase of 68,041 people (2001) to 81,473 people (2011), i.e. a population growth of 19.7% for Omaheke Region.

    - For large urban centres where more accurate population growth rates are available, these were used. For each LA urban area, the population size for the years 2008 ("current situation") as well as for the years 2015, 2020, 2025, and 2030 (projected future situations) was calculated on the basis the estimated LA urban-area specific population growth rates, as per previous bullet; and
- For each national water basin, the urban basin populations was calculated for the year 2008 ("current situation") as well as 2015, 2020, 2025, and 2030 ("projected future situations") by adding up for these years the urban-area populations of all LAs (municipalities, towns, villages, and settlements) falling within the basin.

It should be noted that as soon as the results of the new 2011 Population and Housing Census currently being conducted are available (perhaps around 2014), it will be possible to establish an exact baseline for urban populations for the year 2011 and to cross-check the validity of the urban population growth rates assumed to project urban populations beyond the year the last Census was carried out (2001). It should also be noted that the current 2011 Population and Housing census no longer works with enumeration areas, but captures each domicile individually using GIS tools – which will make it possible to more precisely determine urban populations within each LA area, each administrative region, each national water basin, as well as the Namibian section of the CORB.

Determining the "current" (year-2008) water demand of urban settlements (LA urban areas) by national water basin

NamWater supplies almost all the urban centres (municipalities, towns, villages, and settlements) with bulk water. In the absence of data to determine actual water withdrawals to meet water demand from these urban centres, the IWRM Plan used NamWater figures for water sales to the LA structures of these urban centres to determine their current (year-2008) water withdrawals. A few LAs (mainly municipalities), such as Grootfontein (inside the CORB) and Tsumeb (outside the CORB), but both in the Karst area (see section 3.2.1 and section 4.1.2), supply their own water. Water abstraction figures for these urban centres (usually rather patchy) were provided by the respective LAs – again, very likely not based on actual metered water use, but based on government water permit allocations to the LAs or rough estimates.

Water service providers such as NamWater or the LAs do not keep records of actual water demand in different socio-economic sectors. It is difficult, if not impossible, to obtain disaggregate water demand data from these service providers, as the development of the Water Accounts for Namibia demonstrated (WAN, 2006). It has been suggested that regulations still to be drafted for the new Water Act of 2004 should oblige water service providers to standardise their costing systems and tariff codes in accordance with the categories stipulated in the UN International Standard Industrial Classification of Economic Activities, which are required for National Resource Accounting for Water and used by the Social Accounting Matrix Namibia Water Accounts (IWRMPJVN, 2010b).

Projecting future water demand from urban settlements

The IWRM Plan estimated projected future water demand from urban centres, on the basis of growth rates used by NamWater's Master Plans[15] for their projections of future bulk water demand or LA-specific population growth rates for areas not covered by NamWater's Master Plans.

In some urban areas, there have been huge annual variations (up to 40%) in water demand due to dysfunctional water meters, maintenance of water infrastructure in government buildings or lack thereof, broken pipelines and other reasons. For the purpose of water demand projections, the IWRM Plan (IWRMPJVN, 2010b) generally used the higher water demand figures, in order to be on the conservative side as far as the supply potential of available water resources is concerned.

Estimating current and projected future urban populations in the CORB - Namibia and the levels of water abstraction to meet demand

Current and projected future water demand from urban settlements in the Namibian part of the CORB can be estimated by determining which of the urban LAs (municipalities, towns, villages and settlements) that are assigned by the IWRM Plan to one of the four national water basins sharing the Namibian part of the CORB (Okavango-Omatako, Eiseb-Epukiro, Omaruru-Swakop, and Cuvelai-Etosha), fall within the Namibian part of the CORB and which ones are located outside the CORB boundary. This determination can be made on the basis of the locations (coordinates) of the LAs relative to the geographic locus of the CORB boundary.

[15] To date, most but not all NamWater Master Plans have been finalized. Of the Master Plans that are relevant to the Namibian part of the CORB, the ones for the North-East Water Supply Area (NEWSA, 2010) and the Central East and West Water Supply Area (CEWWSA, 2011) are available, while the one for the Central Area of Namibia (CAN) has not yet been finalised.

Table **11** below, indicates which LAs within the above four national water basins fall within the CORB and which are located outside the CORB, along with their populations in 2001, assumed population growth rate, and calculated “current” population (year 2008). The entire urban population of the Okavango-Omatako basin lives within the CORB, whereas more than 80% of the urban population of the Eiseb-Epukiro basin lives outside the CORB, primarily because the municipality of Gobabis, the capital of Omaheke Region, is located outside of the CORB. The other two national water basins (Omaruru-Swakop and Cuvelai-Etosha), whose respective shares of the CORB are quite small, do not have any urban centres falling within the CORB.

Table 11: **Urban centres (Local Authorities) that fall within CORB - Namibia**

National Water Basin	Administrative Region	Name of urban LA	Type of urban LA	Urban Population 2001	Assumed Pop. Growth Rate (%/year)	Urban Population 2008
Okavango-Omatako	Kavango	***Within CORB***				
		Rundu	Town	36,964	6.0	55,646
		Kapako	Settlement	366	4.0	482
		Kayengona	Settlement	826	4.0	1,088
		Mabushe	Settlement	1,290	4.0	1,700
		Mukwe	Settlement	657	4.0	866
		Muroro-Mashari	Settlement	639	4.0	842
		Ndiyona	Settlement	533	4.0	702
		Nkamagoro	Settlement	1,316	4.0	1,734
		Nkurenkuru (Kahenge)	Settlement	1,629	4.0	2,146
		Divundu	Settlement	1,082	4.0	1,426
		Mururani-Gate	Settlement	388	4.0	511
		Omega	Settlement	838	4.0	1,104
	Sub-total (within CORB)			**46,528**		**68,247**
		Outside CORB				
		None				
	Otjozondjupa	***Within CORB***				
		Grootfontein	Municipality	14,249	3.6	18,245
		Okakarara	Town	3,296	3.6	4,220
		Okamatapati	Settlement	464	2.1	536
		Okatjoruu	Settlement	652	2.1	754
		Okondjatu	Settlement	861	2.1	995
		Coblenz	Settlement	1,279	2.1	1,479
		Tsumkwe	Settlement	871	2.1	1,007
	Sub-total (within CORB)			**21,672**		**27,236**
		Outside CORB				
Total (within CORB)		None		**68,200**		**95,483**
Eiseb-Epukiro	Omaheke	***Within CORB***				
		Eiseb	Settlement	597	1.8	676
		Epukiro Post 3	Settlement	677	1.8	766
		Otjinene	Settlement	1,511	2.8	1,832
		Summerdown	Settlement	442	1.8	500
	Sub-total (within CORB)			**3,227**		**3,774**
		Outside CORB				
		Gobabis	Municipality	13,856	4.8	19,223
		Buitepos	Settlement	777	1.8	880
		Talismanus	Settlement	455	1.8	515
	Sub-total (outside CORB)			**15,088**		**20,618**
	Otjozondjupa	***Within CORB***				
		Gam	Settlement	379	2.1	438
Total (within CORB)	**Sub-total**			**379**		**438**
		Outside CORB				
		None				
				3,606		**4,212**

National Water Basin	Administrative Region	Name of urban LA	Type of urban LA	Urban Population 2001	Assumed Pop. Growth Rate (%/year)	Urban Population 2008
Omaruru-Swakop	Otjozondjupa	***Within CORB*** None				
Cuvelai-Etosha	Ohangwena	***Within CORB*** None				
Grand Total (within CORB)				**71,806**		**99,695**
Grand Total (outside CORB)				**15,088**		**20,618**
GRAND TOTAL (within Okavango-Omatako and Eiseb-Epukiro basins)				**86,894**		**120,313**

Source: IWRMPJVN, 2010b

The current (year-2008) level of water demand from urban settlements within the CORB can be determined by adding determined by adding up the water demand figures presented by the IWRM Plan for all individual LAs within the LAs within the Okavango-Omatako and Eiseb-Epukiro basins that also fall within the CORB, as shown in

in

Table **11**.

The results are presented in (section 4.4). Table 23 below, summarises current (year-2008) urban populations and their water demand levels for the relevant national water basins as well as the Namibian part of the CORB, while Table 24 shows the respective projected future water demand levels.

Annex A3 reproduces complete sub-lists of local authorities (LAs) with their population figures from the IWRM Plan for the relevant four (out of a total of 11) national water basins (Okavango-Omatako, Eiseb-Epukiro, Omaruru-Swakop, and Cuvelai-Etosha) (IWRMPJVN, 2010b).

3.2.5 Rural households (outside local authority areas)

The most important factors influencing water demand in rural areas are (IWRMPJVN, 2010b):

- The size (or density) of the rural population
- Average per capita water demand
- Average distance from homesteads to the nearest water point

Of these factors, the rural population size/density is considered the most important factor for estimating current water demand and projecting future water demand in rural areas.

As outlined in section 3.2.4, the IWRM Plan determined the populations of the 11 national water basins for the year 2001 by drawing on the results of the 2001 Population and Housing Census (PHC, 2004). Each of the 2165 enumeration areas was assigned to one (and only one) of the 11 basins. Those enumeration areas straddling the boundaries of two or more basins were assigned to one (and only one) of these basins, on the basis of the population distributions within these enumeration areas.

Current (year-2008) national water basin populations were calculated by the IWRM Plan (IWRMPJVN, 2010b) based on 2001 basin populations by making use of the population projections (and underlying population growth rates) generated by the Central Bureau of Statistics, National Planning Commission by administrative region for the period 2001-2031 using the UN MORTPAK software (CBS, 2006), as outlined in section 3.2.4. The current (year-2008) rural basin populations were determined by deducting the urban populations in the basin (estimated from local authority (LA) population figures, as outlined in section 3.2.4) from the (overall) basin populations.

Based on a review of existing studies of rural water use in Namibia, the IWRM Plan settled on a "representative" water use figure of 25 litres/capita/day for purposes of estimating rural water use and projecting future rural water demand. While acknowledging arguments in favour of using a higher figure than that, the IWRM Plan notes that the 25 litres/capita/day figure has also been used by the Directorate of Rural Water Supply for planning purposes.[16]

[16] The environmental flow assessment (model and data) assumes average rural domestic water consumption of 50 litres/capita/day (Beuster, 2010), i.e. double the figure assumed in the IWRM Plan and in this CORBWA report.

Due to substantial rural-urban migration in Namibia, urban and rural populations in the country have grown at markedly different rates, and such differential population growth in urban and rural areas is likely to persist in the years to come. Considering, on the basis of available evidence, that rural populations in Namibia will (on average) not increase significantly but remain fairly constant over time, the IWRM Plan estimates that rural water demand will grow at a rate of 0.45% per year. This rural water demand growth rate will also be adopted here.

Current (year-2008) and projected future rural water demand in the Namibian part of the CORB will be estimated from the current (year-2008) and projected future rural water demand in the four national water basins sharing the Namibian part of the CORB, on the basis of the formula (2b) in Section 3.1, reproduced here again:

(2b) Namibian CORB = 85% of the Okavango-Omatako basin + 80% of the Eiseb-Epukiro basin + 15% of the Omaruru-Swakop basin + 5% of Cuvelai-Etosha Basin

3.2.6 Mines and industrial establishments

For the mines operating in the Karst area, a similar issue of how to apportion mining activity and related groundwater abstraction to the CORB-Namibia arises as for irrigation activity. In principle, several of the options that were applied to estimate Karst groundwater withdrawals that could be apportioned to CORB-Namibia could also be applied to mining activity in the Karst. However, only one option is pursued here: only those mines are taken into account which strictly fall within the CORB-Namibia boundaries. Other options might be chosen in follow-up phases to the CORBWA initiative, depending on stakeholder preferences and taking into account the results of the CORBWA-Namibia water resources/hydrology study.

It appears that the Otjozondu Holdings Ltd. (Manganese Project) is the only active mine located in the CORB-Namibia at present but there is the likelihood of a reactivation of the Kombat and Berg Aukas mines in the near future. The mining industry was considered fairly diligent when it comes to the management of water for industrial purposes (IWRMPJVN, 2010b). This diligence arises for a number of reasons such as large amounts of water required by the individual mines, high expenditure on fresh water supply, the need for precise inputs of water in the mining processes, proven financial benefits of alternatives such as recycling from the slimes dams and environmental obligations (e.g. ISO 14000/1, mining and water laws and laws in the country of origin of the parent company). Irrespective of this, it was also pointed out that water demand from mines high if not properly controlled. The pollution threat from slime dams also requires special care especially in karst and other secondary aquifers.

Determining water withdrawals to meet demand by industries is not straightforward. Water sources can include self-extracted water, distributed water, or reuse water, and sometimes water is abstracted from a combination of all three sources. In copper mining for example, water is fundamentally used as an input in the traditional flotation beneficiation process, in smelting and electro refining and in the hydro-metallurgical process. However, every joint process or operation in mining requires a greater or lesser volume of water to contribute towards process efficiency.

Methodology

The literature review revealed that there is a lack of data on the water demand from the mining sector in Namibia. This report therefore draws on results of the IWRM Plan to show the estimated water demand by the mining sector as depicted and discussed in Section 4.6.

The projections of the water demand in the Okavango-Omatako water basin were based on an industry growth rate of 2%. It was assumed that the future of the copper mines near Tsumeb in the Cuvelai-Etosha water basin is in doubt and therefore no growth in water demand by the mining sector is expected. It remains to be seen how realistic this assumption is, given steadily rising international prices for most minerals.

Groundwater demand by the mining sector

The Karst Aquifer sub-catchments in the vicinity of Grootfontein and Tsumeb in the north of Namibia have been thoroughly investigated to determine their sustainable safe yield. It was found that the Tsumeb sub-catchments have a long-term sustainable safe yield of 18 million cubic metres per annum and the stored water in the aquifer is more than 800 million cubic metres (see Table 8, Section 3.2.1). A study was done to determine the possibility of mining a certain quantity of the water over a short period of time to serve as a back-up for the surface water resources in the three dams in the central area of Namibia. It was subsequently confirmed that 12 million cubic metres of water per annum can be abstracted over a period of three years if such a contingency should occur, but then the aquifer should be allowed to recover over the next 15 years to replenish the 12 Mm^3 abstracted during that period (IWRMPJVN, 2010b).

Background on the active and inactive mines

Error! Reference source not found. below, shows the location of the active mine (Otjozondu mine) and the two inactive mines (Berg Aukas and Kombat mines) inside the CORB-Namibia boundary.

Otjozondo Holdings Ltd. (manganese) **–** This mining project is currently undergoing a feasibility study which involves an extensive drilling campaign, a detailed environmental assessment study, a detailed metallurgical testing programme, etc. and is expected to be completed by the end of 2011. It is planned to produce approximately 250 000 to 500 000 tonnes of manganese per year over the economic life span of the mine which is expected to be at least 10 years (The Economist, 21 April 2011). It is not clearly stated in the IWRM Plan whether the estimated 5000 m^3/a water demand by the Otjozondu Mining Project is based on the current drilling operations or referring to the future operation process after completion of the feasibility study.

Berg Aukas mine (lead and zinc) – this mine was closed in 1978 because of the then low metal prices on the global markets. The exploration company, Weatherly International, recently signed a formal agreement with Jiangsu Eastern China Nonferrous Metals Investment Company (ECE) to set up a new joint company China Africa Mining (CAM) with a majority shareholding by ECE, which should lead to the re-development and re-opening of the mine (The Namibian, 18 July 2011, p.13). More recently, China Africa Resources Namibia (Pty), the holder of the mining license, commissioned Synergistics Environmental Services to undertake an environmental impact assessment (EIA) in connection with an application for environmental clearance of reactivating the mine (The Namibian, 26 January 2012, p. 20).

The Berg Aukas deposit was originally discovered in 1913 and was worked for a short period between 1920 and 1928. In more recent times, the deposit was worked from 1959 until closure in 1978 when annual production reached a rate of around 130,000 metric tonne per annum of ore, producing an array of lead, zinc and vanadium concentrates. The mine has a large stored volume of water in the excavated mine tunnels, from which 4 million cubic metres of water can be abstracted per annum on a sustainable basis when required for augmenting the water supply to the Central Area of Namibia (CAN). By having the groundwater from the Karst Aquifer accumulating in the Berg Aukas mine available to be used on a conjunctive basis as a back-up for the Von Bach, Swakoppoort and Omatako dams, the 95% assured safe yield from the integrated use of the three dams can be increased from 20 to 30 Mm^3/a, without actually having to use the groundwater, unless the dams have dried up. (IWRMPJVN, 2010b)

Kombat mine (copper) – operations at this mine were suspended in 2008 because of the global recession and related mineral price drops at that time and also because the mine was flooded in 2007. The water pumped from the Kombat Mine Shaft has been mainly used for irrigated crop production in the vicinity of the mine and to a lesser extent by NamWater for bulk water supply to Okakarara, and other consumers along the Eastern National Water Carrier (ENWC) canal as well as to the Central Area of Namibia (CAN) The volumes of groundwater self-supplied by mines in the Karst area decreased significantly when the Weatherly mining group closed operations at its Tsumeb, Tschudi and Kombat copper mines and the company currently does not abstract any groundwater for mining purposes (pers. comms. Mr. Andrew Thompson).

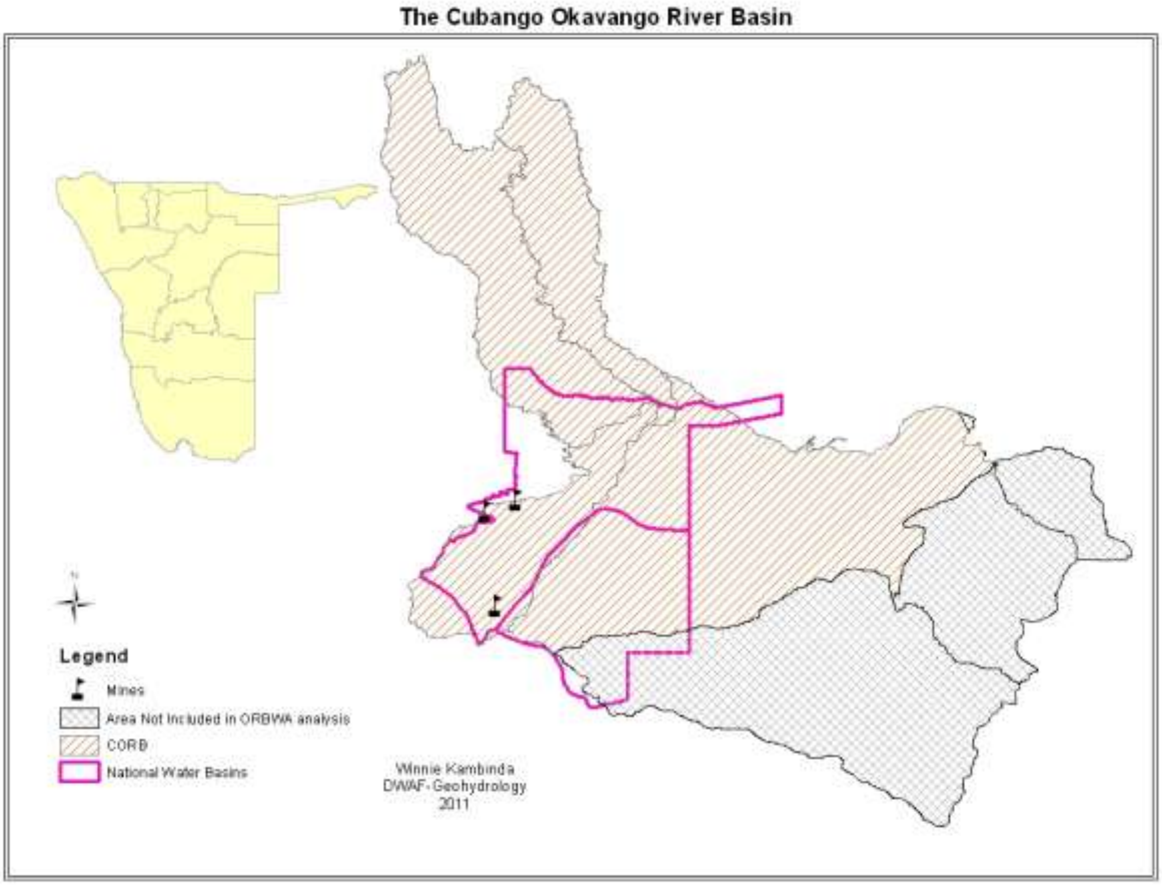

Figure 11: **Location of the Otjozondo, Berg Aukas and Kombat mines in the CORB - Namibia**

Economic contribution of the mining sector

Namibia's national accounts statistics are made available with a significant lag but the figures produced by the Central Bureau of Statistics (CBS) demonstrate that 2009 was an exceptionally difficult year for Namibia's mining industry and its economy as a whole. Significantly, the sector as a whole contracted by an incredible 45 percent while its contribution to Gross Domestic Product (GDP) dropped from 15.9 percent in 2008 to just 10.0 percent in 2009. For the second year in a row the contribution of non-diamond mining to the nation's GDP exceeded the contribution by diamond mining. Total value added by the mining sector fell to N$7.7 billion while mining exports made up 44 percent of the country's merchandise exports. Despite the downturn, the mining sector again spent more on fixed investment than any other sector of the economy with the exception of Government accounting for over one sixth of all fixed investment in the country (Chamber of Commerce, 2010).

Namibia's mineral resources are strategically exploited and optimally beneficiated. This serves to provide equitable opportunities for all Namibians to participate in the industry, while ensuring that environmental impacts are minimised. Investments resulting from mining are made to develop other sustainable industries and human capital for long-term national development. Despite possible rising costs, uncertain prices and variable labour relations, mining continues to maintain its significant contribution towards Namibia's socio-economic development.

3.2.7 Tourism facilities and other service establishments

Error! Reference source not found. and Figure 13 below show the geographic locations, i.e. concentration of the private and community-based tourism facilities within the relevant national water basins. The water demand estimations in the IWRM Plan (IWRMPJVN, 2010b) were based on NTB statistics, however, a review of the Namibia Tourism Board (NTB) statistics for the period 2008-2010 (www.namibiatourism.com.na/research, last accessed July 2011), revealed a strong fluctuation in the number of bed-nights AVAILABLE per month and per year of operation.

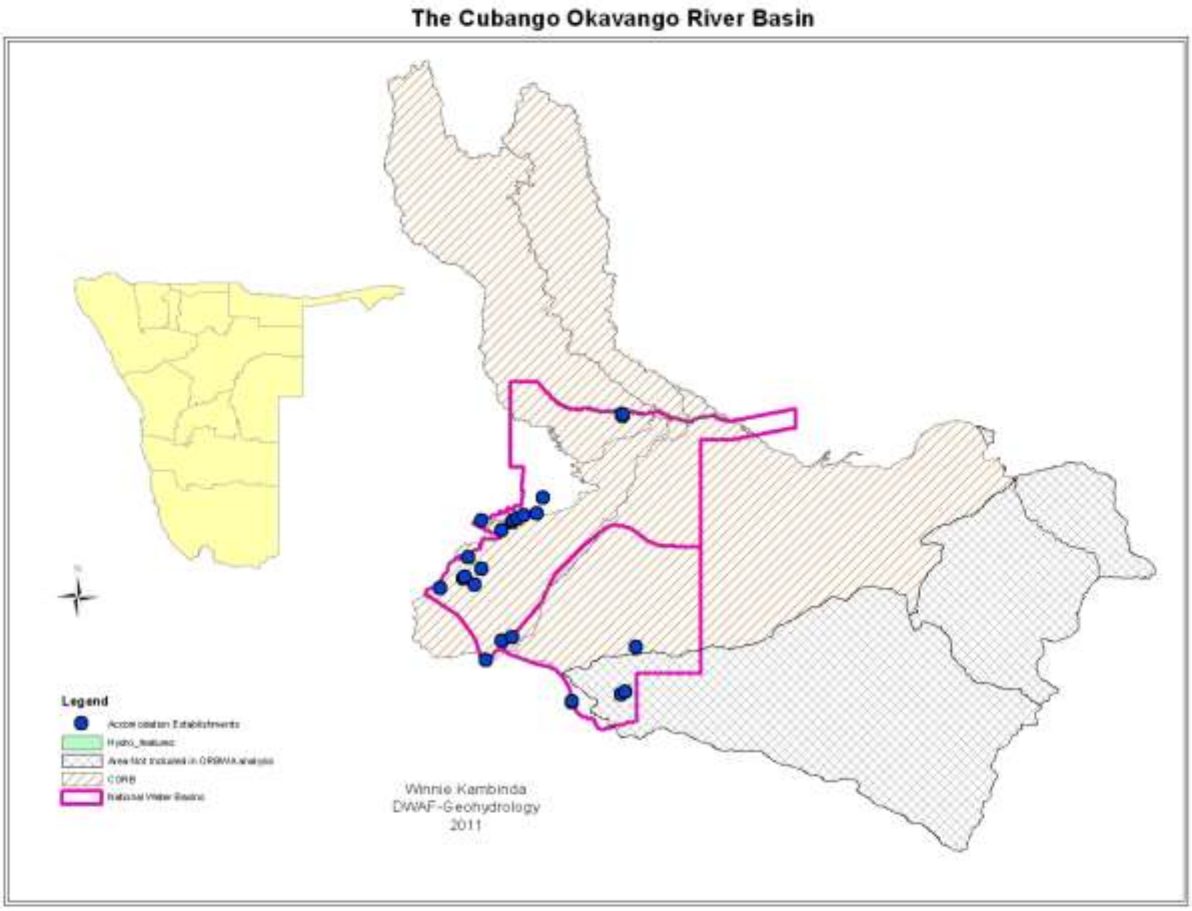

Figure 12: **Location of the tourism facilities in the CORB – Namibia**

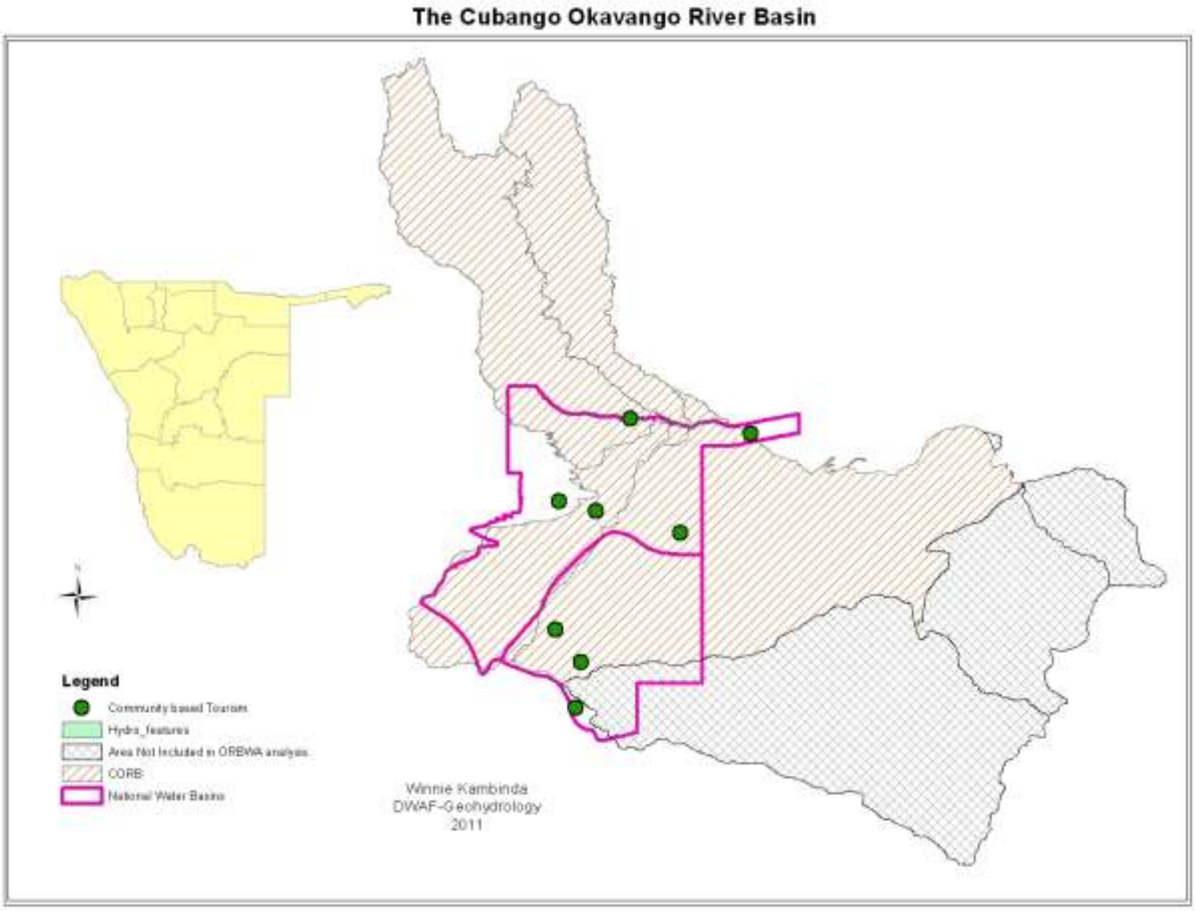

Figure 13: **Location of community-based tourism facilities**

The data derived from the spreadsheets produced by Windhoek Consulting Engineers (WCE) in support of the results in the IWRM Plan based on NTB data for 2007, were considered more reliable and subsequently the adjustments made for the tourism water demand in the CORB-Namibia, were also based thereupon.

Methodology

Water demand by the tourism facilities within the CORB-Namibia will be estimated from the current and projected water demand as calculated in the IWRM Plan for relevant national water basins, i.e. those national basins sharing the CORB-Namibia.

To estimate and project the tourism water use by national water basin, the IWRM Plan applied 11 surface area relationships between national water basins and the respective administrative regions sharing them, one for each of the 11 national water basins. Four of the 11 surface-are relationships are shown in section 3.1: equations (3a), (3b), (3c), and (3d). These are the surface-area relationships for those four national water basins sharing CORB-Namibia. They will be used in section 4.7 to calculate estimated tourism water demand within CORB-Namibia.

In calculating estimated tourism water demand by national water basin on the basis of 2007 NTB statistics, two key assumptions are made by the IWRM Plan:

- Average water demand of 100 litres per available bed per day (without explicitly factoring in the actual bed occupancy rate)

- Average water demand of 15,000 m^3 per tourism establishment per annum (assuming that on average 1 hectare per establishment is irrigated for landscaping irrigation).

These IWRM Plan assumptions and IWRM Plan figures for estimated tourism water demand by national water basin underlie the calculations of estimated tourism water demand for CORB-Namibia in section 4.7. Determination of tourism water demand in CORB-Namibia will be done in two ways:

a) Assuming that the surface area of CORB-Namibia can be approximated by that of the merged Okavango-Omatako and Eiseb-Epukiro national water basins and using equation (2a) as well equations (3a) and (3b); and

b) Taking into account the smaller contributions of the two other national water basins also sharing CORB-Namibia (the Omaruru-Swakop and Cuvelai-Etosha basins) and applying the more accurate equation (2b) as well as equations (3a), (3b), (3c), and (3d).

3.2.8 Ecological water requirements, including water use by wetlands, wildlife and natural forests

Ecological water requirements (sometimes called the ecological reserve) is the amount of water necessary for the health and integrity of natural river ecosystems to be maintained and for these ecosystems to be able to continue to provide a range of resources and processes (referred to as ecosystems goods and services)[17] on a sustained basis.

For instance, the interim policy of the GRN for utilising and allocating water from the Okavango River for irrigation, assumes ecological water requirements to be 25% of the average flow during the lowest-flow month in the preceding 20 years. While this approach to defining ecological water requirements seems to be informed more by the fact of previous use of this percentage elsewhere in the region than by new evidence and/or modelling, it does recognise the importance of factoring in ecological water requirements as an essential user of CORB water resources. However, ecological water requirements will have to be agreed by the three riparian countries as part of the Strategic Action Programme (SAP) which is being developed on the basis of the Transboundary Diagnostic Analysis (TDA) finalised in 2011 (OKACOM, 2011).

[17] The United Nations 2004 Millennium Ecosystem Assessment grouped ecosystem services into four broad categories: *provisioning*, such as the production of food and water; *regulating*, such as the control of climate and disease; *supporting*, such as nutrient cycles and crop pollination; and *cultural*, such as spiritual and recreational benefits.

The Environmental Protection and Sustainable Management of the Okavango (EPSMO) Project used an environmental flow model, along with water flow scenarios, to undertake environmental flow assessments as a basis for its transboundary diagnostic analysis (TDA) (OKACOM, 2011). However, the development of EPSMO's TDA did not involve a thorough assessment of the ecological water requirements of the Namibian part of the Cubango-Okavango River. Such an assessment has not been made to date.

Ecological water requirements are an inherent dimension of ecological or environmental flow models of river, wetlands or coastal zone systems. An environmental flow is defined as the water regime provided within a river, wetland or coastal zone to main ecosystems and their benefits where there are competing water uses and where flows are regulated (IUCN, 2003).

There has been some analysis of the water use of wildlife that can be regarded as a specific component of the natural environment. For instance, the Water Accounts for Namibia (WAN, 2004) include wildlife as a water user in national parks that are classified as self-providers of water. Wildlife water consumption can be estimated on the basis of numbers of wildlife by species and multiplied by average water consumption of individual animals by species. Table 12 below provides data on the average water consumption of wildlife (WAN, 2004).

Table 12: **Water consumption of wildlife**

Species	Average Daily Water Consumption (litres)
Elephant	150-300
Hippo	?
Buffalo	31
Giraffe	40
Eland	23
Roan antelope	10
Sable antelope	9
Hartmann's zebra	12
Burchell's zebra	12
Blue wildebeest	9
Kudu	9
Oryx	9
Hartebeest	5.5
Waterbuck	9
Black-faced impala	2.5
Common impala	2.5
Tsessebe	5
Springbok	1.5
Warthog	3.5
Ostrich	11[18]

Source: WAN, 2004

MET conducts periodic aerial surveys of wildlife in different parts of the country to monitor the state of the country's wildlife resources. In principle, the results of aerial surveys covering the Namibian part of the CORB, in conjunction with the figures for average water consumptions by species in Table 12 above, could be used to estimate wildlife water use in the Namibian part of the CORB. However,

[18] This figure for (wild) ostriches differs markedly from the figure for the average daily water consumption of (farmed) ostrich in Table 12, Section 3.2.2 (4 litres).

wildlife is a mobile resource, and aerial wildlife surveys can only provide an indicative snapshot picture of wildlife resources in a given area.

At the same time, wetlands which in the case of the CORB form the livelihood basis of most of the wild animals listed in Table 12, “consume” a large amount of water through evapotranspiration -- likely much more than the water consumed by the wild animals, although it is not clear if data is available to quantify and corroborate this supposition.

4.1 Irrigated cultivation

4.1.1 Green Scheme projects along the Namibian section of the Cubango-Okavango River

According to (Liebenberg, 2009), a total of 2,197 hectares were under irrigation within Green Scheme projects along the Namibian section of the Cubango-Okavango River, as of 2009 -- 1,641 ha upstream and 556 ha downstream of the Cuito confluence. These irrigation activities abstract a total of some 33 Mm^3/a of river water. River water abstraction for meeting domestic needs of human settlements long the river, amounted to about 4.5 Mm^3/a, nearly all upstream of the Cuito confluence (MAWF, 2005),[19] leaving some 169 Mm^3/a of river water upstream to meet irrigation demand during peak demand periods while virtually not affecting downstream river water availability for irrigation.

Section 3.2.1 explained the policy and methods for the stipulated rate at which water may be abstracted from the river during "minimum" flow conditions (169 Mm^3/a upstream and 425 Mm^3/a downstream) during peak irrigation demand and the stipulated peak rate at which water may be applied for irrigation per unit area (100 m^3/ha/day or 36,500 m^3/ha/a). These two rates together determine the areas that Namibia can irrigate along the Cubango-Okavango River: 4,630 ha upstream and 11640 ha downstream of the Cuito confluence, respectively – for a total of 16,270 ha. Considering the areas already under irrigation (see above), this means that roughly 14,000 ha of additional land can be irrigated, of which 2,900 ha are located upstream and 11,100 ha downstream of the Cuito confluence. These results approximately tally with the figures in (MAWF, 2005) and (Liebenberg, 2009).

In order to irrigate the total calculated land areas of 16,270 ha, Namibia will use an overall allocation of some 245 Mm^3/a. That amounts to about 2.5% of the long-term average flow of the Okavango River (10,000 Mm^3/a).

Figure 14 shows the location of existing Green Scheme irrigation schemes along the Cubango-Okavango River, with an indication of the location of tribal areas and constituencies. Table **13** provides a breakdown of existing and planned Green Scheme irrigation schemes along the River, indicating respective areas already under irrigation or envisaged for irrigation, river water abstraction rates, and the remaining available flow balance. The indicated "planned future" irrigation schemes of 2,904 ha (upstream) and 13,462 ha (downstream) of the Cuito confluence are projected to come on stream within the coming 7-10 years, i.e. by 2020 or so, with a total of about 1,500 ha (out of the planned Future irrigation schemes) expected to come under irrigation by the end of 2012, most of it upstream of the confluence of the Cuito.[20]

Table **13** summarises current as well projected future areas irrigated and volumes of irrigation water abstracted for different categories of irrigation areas/activity in the Okavango-Omatako basin, as a proxy for the Namibian part of the CORB, on the basis of aggregate figures derived from the

[19] (MAWF, 2005) estimates current domestic water uses at 4.48 Mm^3/a (4.28 M m^3/a upstream and 0.2 Mm^3/a downstream of the Cuito confluence) and projects domestic water uses to grow at 4.5% per annum to 13.25 Mm^3/a in 2030.
[20] Piet Liebenberg, MAWF, personal communication, 27 June 2011

irrigation master sub-list in Annex A1. It is clear that the Green Scheme projects along the Cubango-Okavango River already dominate irrigation activity in the national water basin, constituting some 85% of the areas irrigated in the basin and volumes of water abstracted (as of 2008). This share is projected to increase further, to some 97% by 2030. This clearly suggests that the Green Scheme projects account for the lion's share of irrigation water demand in the Namibian part of the CORB, both currently and even more so in future.

Table 14 indicates that currently (year 2008) 32 Mm^3/a (about 85%) of the total of 38 Mm^3/a of water abstracted for irrigation activity in CORB-Namibia is surface water from the Cubango-Okavango river that is applied to green scheme projects along the river, while 6 Mm^3/a of water withdrawals for irrigation activity come from groundwater sources, mostly in the Karst area.

It has been shown in Figure 4 above that the boundaries of the Okavango-Omatako basin deviate from those of the CORB in three parts of the basin**.** From the perspective of irrigation water abstraction, the only basin part where the deviation between the basin boundaries really matters is the GTO Karst area. Section 4.1.2 below discusses the correction that would have to be made to the irrigation inventory and to the total estimated amount of irrigation groundwater abstracted for irrigation, for that part of the Okavango-Omatako basin which lies within in the Karst area (1.69 Mm^3/a, according to Table **14**) in order to arrive at an improved Karst irrigation inventory and level of Karst irrigation groundwater use for the Namibian part of the CORB.

In that section, it is found that depending on the option chosen for how to calculate the estimated amount of Karst groundwater abstracted for irrigation that should be apportioned to CORB-Namibia, between 0.35 Mm^3/a (+- 0.1 Mm^3/a) and 12.1 Mm^3/a (+- 1.3 Mm^3/a) of Karst irrigation groundwater should be apportioned to CORB-Namibia. This implies a correction in the range from – 1.3 Mm^3/a (+- 0.1 Mm^3/a) to +10.4 Mm^3/a (+- 1.3 Mm^3/a) to be made to the figure of 1.69 Mm^3/a of Karst irrigation groundwater shown in Table **14**. In other words, the "correct" amount of Karst irrigation groundwater to be apportioned to CORB-Namibia could be more or less than the figure shown in Table **14**. It all depends on the method used to determine what proportion of overall Karst irrigation groundwater abstraction should be assigned to CORB-Namibia.

A comparison of Table **13** below reveals a slight inconsistency in the figures from the two respective sources ((Liebenberg, 2009) and (IWRMPJVN, 2010b)) for the Green Scheme project areas that are currently irrigated (as of 2008) along the Cubango-Okavango River. In order to shed light on this inconsistency, the irrigation area figures for the existing Green Scheme projects derived from the two respective sources are juxtaposed in Table **15** below. Inconsistencies with regard to the following irrigation schemes are apparent: Vungu Vungu, Mashare, Shitemo, Bagani gardens, and Divundu Prisons (see shaded fields in the Table **15** below). These inconsistencies may arise, at least in part, from differing assumptions about the proportions of the land areas earmarked by particular schemes for irrigation that are actually irrigated.

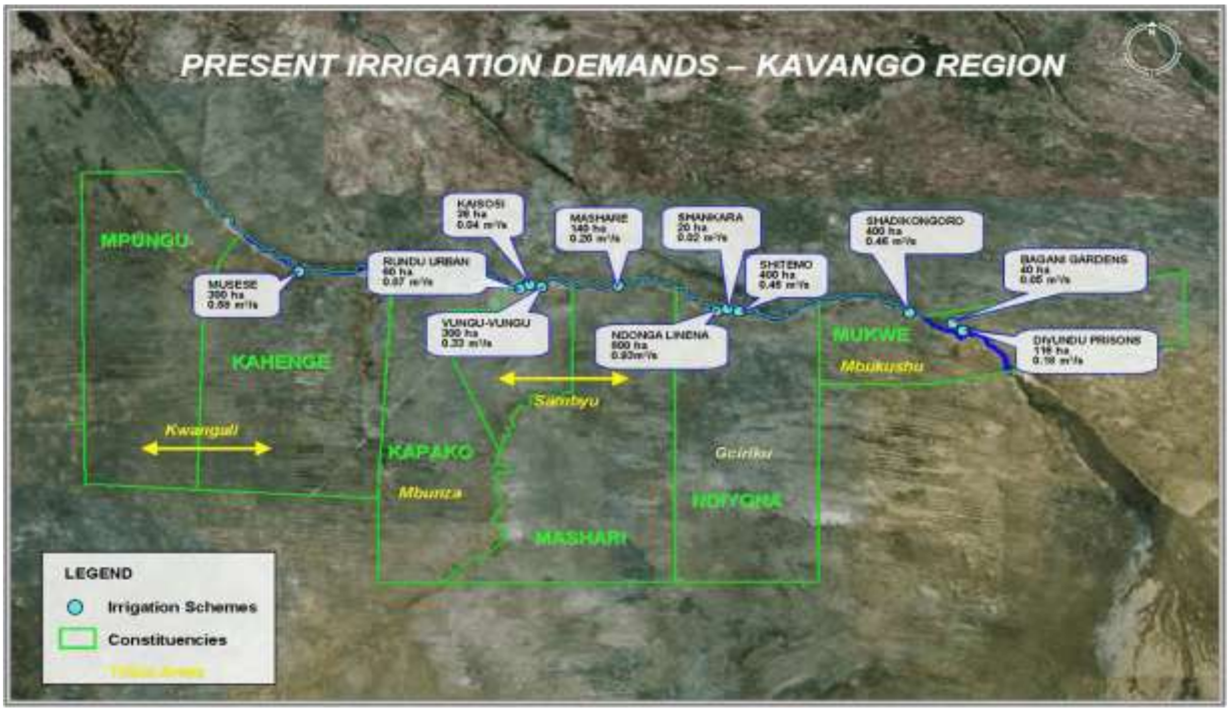

Figure 14: **Green Scheme irrigation schemes along the Cubango-Okavango River**

Source: Liebenberg, 2009

Table 13: **Scheme irrigation development along the Cubango-Okavango River**

Tribal Authority	Irrigation Scheme	Existing Area under Irrigation (ha)	Planned Future Irrigation (ha)	Total Area Eventually Irrigated (ha)	Peak abstraction rate (m^3/s)	Balance of available peak abstraction flow (m^3/s)
UPSTREAM FROM CUITO CONFLUENCE maximum abstraction rate						**5.50**
Kwangali	Musese & Maguni	300	200	500	0.58	4.92
	Simanya	0	200	200	0.23	4.69
	Sihete	0	200	200	0.23	4.46
	Other	0	200	200	0.23	4.23
	Sub-total	**300**	**800**	**1,100**	**1.27**	
Mbunza	Sikondo	0	800	800	0.93	3.30
	Other	0	300	300	0.35	2.95
	Sub-total	**0**	**1,100**	**1,100**	**1.28**	
Sambuyu	Rundu	60	0	60	0.07	2.88
	Kaisosi	36	0	36	0.04	2.84
	Vungu-Vungu	285	0	285	0.33	2.51
	Mashare Irrigation Training Centre	60	0	60	0.07	2.44
	Mashare CFU	80	30	110	0.13	2.31
	Mashare	0	574	574	0.66	1.65
	Sub-total	**521**	**604**	**1,125**	**1.30**	
Gciriko	Ndonga Linena	400	400	800	0.93	0.72
	Shankara	20	0	20	0.02	0.70
	Shitemo	400	0	400	0.46	0.24
	Sub-total	**820**	**400**	**1,220**	**1.41**	
	TOTAL	**1,641**	**2,904**	**4,545**	**5.26**	

Tribal Authority	Irrigation Scheme	Existing Area under Irrigation (ha)	Planned Future Irrigation (ha)	Total Area Eventually Irrigated (ha)	Peak abstraction rate (m^3/s)	Balance of available peak abstraction flow (m^3/s)
	UPSTREAM					
DOWNSTREAM FROM CUITO CONFLUENCE maximum abstraction rate						**21.50**
Gciriko	Other	0	3,500	3,500	4.05	17.45
	Sub-total	**0**	**3,500**	**3,500**	**4.05**	
Mbukushu	Shadikongoro	400	0	400	0.46	16.99
	Bagani Gardens	40	0	40	0.05	16.94
	Divundu Prisons	116	40	156	0.18	16.76
	Katondo	0	4,000	4,000	4.63	12.13
		0	3,018	3,018	3.49	8.64
	Sub-total	**556**	**7,058**	**7,614**	**8.81**	
	TOTAL DOWNSTREAM	**556**	**10,558**	**11,114**	**12.86**	
GRAND TOTAL (UPSTREAM + DOWNSTREAM)		**2,197**	**13,462**	**15,659**		

Source: Liebenberg, 2009

Table 14: **Status of irrigation farms and schemes in the Okavango-Omatako national water basin[21], as of June 2009, aggregated on the basis of the figures presented in Annex A1[22]**

Category of Irrigation Activity	**Maximum Area to be Irrigated (ha)**	**Area under Irrigation in 2008/9 (ha)**	**Water Use in 2008 (M m^3/a)**	**Expected Irrigation Area by 2015 (ha)**	**Expected Water Use by 2015 (Mm^3/a)**	**Expected Irrigation Area by 2020 (ha)**	**Expected Water Use by 2020 (Mm^3/a)**	**Expected Irrigation Area by 2030 (ha)**	**Expected Water Use by 2030 (Mm^3/a)**
Okavango River (Green Scheme)	31,010	2,133	32.0	4,286	64.3	7,616	114.2	11,666	175.0
Omatako River	5,000	0	0	0	0	0	0	0	0
GTO Karst area within Okavango.-Omatako basin	156	141	1.69[23]	141	1.69	141	1.69	141	1.69
Grootfontein municipal sewage	75	75	0.9	75	0.9	75	0.9	75	0.9
(Inactive) mines[24]	425	128	1.54	208	1.54	208	1.54	208	1.54
Other irrigation farms/ schemes	159.5	155.5	1.87	155.5	1.87	155.5	1.87	155.5	1.87
Total	**36,826**	**2,633**	**38.0**	**4,866**	**70.3**	**8,196**	**120.2**	**12,246**	**181.0**

Source: IWRMPJVN, 2010b

Notes: Appendix 2 (see Annex A1) – but unlike the IWRM Plan, assuming a water allocation (application rate) of 15,000 m^3ha/a only for the Okavango River Green Scheme projects using surface (river) water and 12,000 m^3/ha/a (rather than 15,000 m^3/ha/a) for all other categories of groundwater-using irrigation activity in the Okavango-Omatako national water basin.

[21] As argued elsewhere in this report (section 3.2.1), the Okavango-Omatako basin is a reasonably good proxy for the Namibian part of the CORB, as far as the inventory of irrigation activities and aggregate irrigation water use are concerned.

[22] Karst irrigation farms/schemes apportioned to the Ugab-Huab national water basin by the IWRM Plan, but listed under the Okavango-Omatako national water basin (IWRMPJVN, 2010b), Appendix 2 -- see Annex A1 for the "Okavango-Omatako" list of irrigation farms/schemes), have been omitted from the present Table.

[23] This quantity of groundwater used for irrigation in the Karst area provides only a rough indication of the amount of Karst irrigation groundwater that should be apportioned to CORB-Namibia (see section 4.1.2).

[24] This comprises the (currently inactive) Berg Aukas and Kombat mines. The maximum areas to be irrigated from groundwater accumulating in the mine shafts of the two mines are indicated in Annex A1 as 175 ha (Berg Aukas) and 250 ha (Kombat). Areas under irrigation are indicated as 8 ha (Berg Aukas) and 120 ha (Kombat), and areas expected to be irrigated in 2015, 2020 and 2030 are indicated as 8 ha (Berg Aukas) and 200 ha (Kombat).

Table 15: **Green Scheme project areas currently under irrigation since 2008 along the Cubango-Okavango River**

Irrigation scheme	**Areas under Irrigation, as of 2008 (ha)**				
	Source 1	**Source 2**			
Upstream from Cuito confluence	**2008**	**2008**	**2015**	**2020**	**2030**
Musese & Maguni	300	300	400	600	800
Rundu (Sarasungu)	60	60	60	60	60
Kaisosi	36	36	36	36	36
Vungu Vungu	285	300	300	300	300
Mashare (incl. irrigation training centre and CFU)	140	160	200	250	300
Ndonga Linena	400	400	800	800	800
Shankara	20	20	30	30	30
Shitemo	400	300	400	400	400
Downstream from Cuito confluence					
Shadikongoro	400	400	400	500	500
Bagani Gardens	40	20	40	40	40
Divundu Prisons	116	137	170	200	200
Total	**2,197**	**2,133**	**2,836**	**3,216**	**3,466**

Source 1: Liebenberg, 2009; Source 2: IWRMPJVN, 2010b (data inputs from the Geohydrology Division, DWA, MAWF)

Notes: Only existing schemes are listed; new schemes projected to come on-stream in 2015, 2020, and 2030 not included (which explains the relatively small totals in areas under irrigation for the years 2015, 2020, and 2030, compared to Table 14).

4.1.2 Grootfontein-Tsumeb-Otavi (GTO) Karst irrigation area

The GTO Karst area consists of eight (8) irrigation sub-regions (sub-catchments) and is shared by three national water basins – the Okavango-Omatako, Ugab-Huab, and Cuvelai-Etosha basins as well as crossed by the CORB, as Figure **8** and Figure **9** above in section 3.2.1 show. This sub-section presents the results for irrigated areas and volumes of irrigation water abstracted from the Karst that might be apportioned to the Namibian part of the CORB, for each of the two approaches and seven options outlined in section 3.2.1 for how to apportion Karst irrigation activity and data to the CORB:

- *Approach A: Apportioning Karst irrigation activity to the CORB on the basis of the shape/size of Karst irrigation sub-regions and on the basis of data available by Karst irrigation sub-region:*
  - *Option i: the whole Karst area (i.e. all eight Karst irrigation sub-regions – A, B1, B2, C, D, E, F, and G) are apportioned to the CORB;*
  - *Option ii: only the southern parts of the Karst area (i.e. irrigation sub-regions D, E, F, and G) are apportioned to the CORB;*
  - *Option iii: those of the Karst irrigation sub-regions falling within or crossed by the CORB boundary (i.e. essentially the sub-regions D and E) are (fully) apportioned to the CORB;*
  - *Option iv: only those parts of the Karst irrigation sub-regions strictly falling within the CORB (i.e. appropriate surface-area based proportions of the sub-regions C, D, and E) are apportioned to the CORB.*
- *Approach B: Apportioning Karst irrigation activity to the CORB on the basis of the shape/size of the national water basins sharing the Karst area and on the basis of data available by national water basin Karst segment (building on the IWRM Plan)*
  - *Option v: the whole Karst area (the Karst segments of all three national water basins sharing the Karst area) are apportioned to the CORB*
  - *Option vi: only the Karst segment of the Okavango-Omatako national water basin is apportioned to the CORB*

- *<u>Option vii</u>: only those parts of the Karst segments of the national water basins sharing the Karst area strictly falling within the CORB are apportioned to the CORB*

Approach A, option (i) (apportioning the whole Karst area to the CORB)

All irrigation water abstraction in the Karst is apportioned to the Namibian part of the CORB. The number of permit holders in the Karst area who report back on water actually used has been increasing over the years, and so has the proportion of complete returns (see Table **16** below). Nevertheless, data on actual water abstraction in irrigated cultivation remains incomplete and cannot be used to determine overall water abstraction for irrigation in the Karst area. Therefore, irrigation water abstraction can only be estimated on the basis of irrigation permit allocation data in the Karst.

Table 16: **Evolving permit status in the GTO Karst area**

Irrigation Sub-region	**Number of Permit Holders**				**Number of Returns (Completed Returns) Received**			
	2003	**2005**	**2007**	**2010**	**2003**	**2005**	**2007**	**2010**
A			7	7			3 (1)	3 (3)
B1			7	B			5 (2)	7 (7)
B2			52	58			37 (18)	46 (32)
C			4	5			3 (0)	3 (1)
Sub-total			**70**	**78**			**48 (21)**	**59 (43)**
D			3	4			3 (1)	3 (2)
E+F			6	7			2 (0)	5 (4)
G			19	19			12 (7)	14 (5)
Sub-total			**28**	**30**			**17 (8)**	**22 (11)**
Total	**78**	**78**	**98**	**108**	**24 (4)**	**44 (12)**	**65 (29)**	**81 (54)**

Source: DWA, 2008 (2003, 2005 and 2007 data); Beukes, 2011 (2010 data)

Table **17** below, provides a time series of irrigation permit allocations as well as groundwater appropriations for irrigation (i.e. irrigation allocation limits) by Karst irrigation sub-region. Overall irrigation permit allocations for the whole Karst area have been in the range of 11.0 to 12.6 Mm^3/a, with groundwater appropriations for irrigation ranging between 11.3 to 11.8 Mm^3/a.

Under this option, approximately **11.8 Mm^3/a (+- 0.8 Mm^3/a)** of groundwater abstracted for irrigation in the overall Karst area (estimated on the basis of overall permit allocations) should be apportioned to the Namibian part of the CORB.

The actual overall irrigation water use in the Karst is likely to be lower than overall irrigation permit allocations, judging from figures for reported water use for irrigation by those 50% of permit holders who submitted complete returns for 2010. The aggregate irrigation water abstraction reported by these permit holders amounted to about 80% of their aggregate permit allocations (Beukes, 2011).

Table 17: **Irrigation permit allocations and groundwater appropriations for irrigation**

Irrigation Sub-region	Surface Area		Irrigation Permit Allocations (Mm^3/a)			Groundwater Appropriations for Irrigation (Mm^3/a)		
	(km^2)	% of total	**2004**	**2008**	**2010**	**2004**	**2006**	**2008**
A	5,690	35.6	0.62	0.638	0.700	0.500	0.500	0.500
B1	2,050	12.8	2.09	1.290	1.550	2.400	2.400	2.400
B2	1,520	9.5	6.19	6.300	7.138	5.200	5.200	6.200
C	1,720	10.8	0.40	0.195	0.305	0.500	0.500	0.500
Sub-total (Northern)	**10,980**	**68.6**	**9.29**	**8.423**	**9.693**	**8.600**	**8.600**	**9.600**
D	900	5.6	0.18	0.230	0.350	0.200	0.500	0.200
E	940	5.9	0.30	0.420	0.560	0.500	0.500	0.500
F	790	4.9	0.00	0.000	0.000	0.500	0.500	0.000
G	2,390	14.9	1.54	1.825	2.010	1.500	1.500	1.500
Sub-total (Southern)	**5,020**	**31.4**	**2.02**	**2.475**	**2.920**	**2.700**	**3.000**	**2.200**
Total	**16,000**	**100.0**	**11.31**	**10.898**	**12.613**	**11.300**	**11.600**	**11.800**

Source: DWA, 2004 (permit allocations and groundwater appropriations for irrigation); DWA, 2006 (groundwater appropriations for irrigation); DWA, 2008 (permit allocations and groundwater appropriations for irrigation); Beukes, 2011 (2010 permit allocations)

Approach A, option (ii) (apportioning the Southern Karst/Grootfontein and Otavi Aquifers) to the CORB

Only the irrigation water abstraction within the southern Karst region (i.e. Karst sub-regions D, E, F, and G) is apportioned to the Namibian part of the CORB. According to Table **17** above, overall water allocations for the southern Karst region (as a proxy for actual irrigation water use in that region, for lack of data on actual water use) are in the range of 2.0 to 3.0 Mm^3/a (18% - 23% of overall irrigation water allocations in the Karst area), with overall groundwater appropriations for irrigation in that region ranging between 2.2 and 3.0 Mm^3/a.

This means that approximately **2.5 Mm^3/a (+- 0.5 Mm^3/a)** of the groundwater abstracted for irrigation in the overall Karst area (estimated on the basis of overall permit allocations) should be apportioned to the Namibian part of the CORB.

Approach A, option (iii) (apportioning to the CORB those Karst sub-regions that are within or crossed by the CORB boundary)

Figure 8 shows that while none of the Karst sub-regions fully fall within CORB-Namibia, the CORB boundary crosses three of the eight Karst sub-regions, namely sub-regions C, D, and E. The proportion of sub-region C that falls within the CORB is very small (about 5%). Therefore, for all practical purposes only sub-regions D and E should be included here. According to Table **17**, the overall amount of groundwater abstracted for irrigation in these two sub-regions (taking permit allocations as a proxy) varies between 0.48 Mm^3/a (2004) and 0.91 Mm^3/a (2010).

Under this option, approximately **0.7 Mm^3/a (+- 0.3 Mm^3/a)** of the groundwater abstracted for irrigation in the overall Karst area (estimated on the basis of overall permit allocations) should be apportioned to the Namibian part of the CORB.

Approach A, option (iv) (apportioning to the CORB only those parts of the Karst sub-regions strictly falling within the CORB boundary

For this option, equation (6), presented in section 3.2.1 and reproduced below for convenience, can be used to calculate the estimated amount of Karst groundwater abstracted for irrigation that should be apportioned to CORB-Namibia.

(6) KR portion of CORB-Namibia = 5% of KSR C + 80% of KSR D + 30% of KSR E =
1% of Northern KSRs + 20% of Southern KSRs =
7% of overall Karst region

This results in an amount of Karst groundwater abstracted for irrigation of ranging between 0.25 Mm^3/a (2004) and 0.46 Mm^3/a (2010). In other words, approximately **0.35 Mm^3/a (+- 0.1 Mm^3/a)** should be apportioned to CORB-Namibia.

Approach B, option (v) (apportioning the whole Karst area, i.e. the Karst segments of all three national water basins sharing the Karst area)

The IWRM Plan (IWRMPJVN, 2010b) provides detailed breakdown ("master list") of irrigation farms and schemes nation-wide, organised by national water basin, indicating, among others, irrigable areas, areas currently under irrigation (as of 2008), projections for areas expected to be irrigated in future (2015, 2020, and 2030), the corresponding volumes of irrigation water abstracted currently and in future, as well as water allocations (as per licence), for each irrigation farm or scheme. For those irrigation farms or schemes that are located in the GTO Karst area, the Karst irrigation sub-region is indicated as well. The irrigation "master sub-lists" for the three national water basins that share Karst area are reproduced in Annex A1.

Drawing on this irrigation data base, Table **19** below, provides an overview of irrigation activity and water abstraction in the Karst area, showing the number of irrigation farms, maximum areas to be irrigated, volumes of water allocated by licence, areas irrigated in 2008/9, and estimated volumes of water abstracted, by Karst irrigation sub-region and national water basin.

Table **19** indicates that as of June 2009, overall water allocations to 97 irrigation permit holders for a maximum of 1,276 ha of land (to be) irrigated within the Karst area, distributed over the three national water basins, amounted to about 10.8 Mm^3/a. The corresponding actual water abstraction (water applied to 1,119 ha of irrigated area in 2008/9) was estimated at 13.4 Mm^3/a.

Based on these figures, approximately **12.1 Mm^3/a (+- 1.3 Mm^3/a)** of Karst groundwater used for irrigation should be apportioned to the Namibian segment of the CORB.

Approach B, option (vi) (apportioning the Karst segment of only the Okavango-Omatako national water basin to the CORB)

Table **19** shows for the Okavango-Omatako basin segment of the Karst area as of June 2009 that 12 irrigation permit holders had been collectively allocated 750 Mm^3/a irrigate up to 156 ha of land (7% of the overall irrigation water allocations in the Karst segments of the three national water basins). The corresponding actual water abstraction (water applied to 141 ha of irrigated area in 2008/9) was estimated at 1.69 Mm^3/a (13% of the estimated water abstractions for irrigation in the Karst segments of the three national water basins).

These figures suggest that approximately **1.2 Mm^3/a (+- 0.5 Mm^3/a)** of Karst groundwater used for irrigation should be apportioned to the Namibian segment of the CORB.

Approach B, option (vii) (apportioning to the CORB *only those parts of the Karst segments of the national water basins sharing the Karst area that strictly fall within the CORB)*

This calculation can only be completed when Figure 8 in section 3.2.1 has been revised to include the boundaries of the other two national water basins (Ugab-Huab and Cuvelai-Etosha). The calculation entails the following steps:

- Identify the Karst segments of the three national water basins from Figure 8
- Estimate the proportions of the surface areas of the Karst segments of the three national water basins, which fall within the CORB – and apply these surface area percentages to the Karst segments of the national water basins in order to calculate Karst irrigation water use for these segments to be apportioned to the CORB
- Add up the irrigation water use determined from the previous bullet and apportion it to the CORB

Estimated amounts of Karst irrigation groundwater that should be assigned to the Namibian part of the CORB are summarised in Table **18**.

Table 18: **Overview of estimated amounts of Karst irrigation groundwater that should be apportioned to CORB-Namibia**

Approach	**Approach A (using data available by Karst sub-catchment)**				**Approach B (using data available by national water basin)**		
Option	**i**	**ii**	**iii**	**iv**	**v**	**vi**	**vii**
Amount of Karst irrigation water to be assigned to CORB-Namibia (Mm^3/a)	11.8 (+- 0.8)	2.5 (+- 0.5)	0.7 (+- 0.3)	0.35 (+- 0.1)	12.1 (+- 1.3)	1.2 (+- 0.5)	Pending (awaits revision of Figure 8)

Depending on which approach and which option is taken, as little as 0.25 Mm^3/a or as much as 13.4 Mm^3/a of abstracted irrigation groundwater in the Karst area could be apportioned to CORB-Namibia. The wide variation in possible Karst irrigation water allocations to the CORB reflects the different assumptions underlying the different approaches and options.

Table 19: **GTO Karst areas under irrigation, volumes of water allocated and abstracted by Karst irrigation sub-region and national water basin as of June 2009**

National Water Basin	Karst Irrigation Sub-Region								
	A	**B1**	**B2**	**C**	**D**	**E**	**F**	**G**	**Total GTO Karst area**
Okavango-Omatako basin									
Number of irrigation permit holders	1	0	0	0	2	6	0	3	**12**
Maximum area to be irrigated (ha)	5	0	0	0	22	79	0	50	**156**
Water allocation ($10^{-3}Mm^3/a$)	50	0	0	0	80	420	0	200	**750**
Area irrigated in 2008/9 (ha)	5	0	0	0	17	74	0	45	**141**
Estimated water abstraction ($10^{-3}Mm^3/a$)	60	0	0	0	204	888	0	540	**1,692**
Ugab-Huab basin									
Number of irrigation permit holders	0	0	0	0	2	0	0	15	**17**
Maximum area to be irrigated (ha)	0	0	0	0	15	0	0	209	**224**
Water allocation ($10^{-3}Mm^3/a$)	0	0	0	0	150	0	0	1,410	**1,560**
Area irrigated in 2008/9 (ha)	0	0	0	0	5	0	0	164.5	**169.5**
Estimated water abstraction ($10^{-3}Mm^3/a$)	0	0	0	0	60	0	0	1,974	**2,034**
Cuvelai-Etosha basin									
Number of irrigation permit holders	6	6	50	4	0	0	0	2	**68**
Maximum area to be irrigated (ha)	50.8	169	624.8	29.5	0	0	0	21.5	**895.6**
Water allocation ($10^{-3}Mm^3/a$)	508	1,190	6,248	295	0	0	0	215	**8,456**
Area irrigated in 2008/9 (ha)	23	60	659.8	45	0	0	0	21	**808.8**
Estimated water abstraction ($10^{-3}Mm^3/a$)	276	720	7,918	540	0	0	0	252	**9,706**
Total (for the above water basins)									
Number of irrigation permit holders	**7**	**6**	**50**	**4**	**4**	**6**	**0**	**20**	**97**
Maximum area to be irrigated (ha)	**55.8**	**169**	**624.8**	**29.5**	**37**	**79**	**0**	**280.5**	**1,276**
Water allocation ($10^{-3}Mm^3/a$)	**558**	**1,190**	**6,248**	**295**	**230**	**420**	**0**	**1,825**	**10,766**
Area irrigated in 2008/9 (ha)	**28**	**60**	**659.8**	**45**	**22**	**74**	**0**	**230.5**	**1,119**
Estimated water abstraction ($10^{-3}Mm^3/a$)	**336**	**720**	**7918**	**540**	**264**	**888**	**0**	**2,766**	**13,432**

Source: IWRMPJVN, 2010b, Appendix 2 (Annex A1)

Notes:

a) "Irrigation farms" are private properties most of which have a Farm ID, a property number, and a permit number.

b) "Estimated water abstraction has been calculated by multiplying areas irrigated in 2008/9 by 12,000 m^3/ha/a.

c) For a map of the GTO Karst irrigation sub-regions, see Figure 7, section 3.2.1.

4.2 Livestock production

Livestock numbers in Namibia have decreased dramatically since the 1950's, due to overgrazing and widespread bush encroachment (which has reduced the carrying capacity of the land) and due to the gradual phasing out of (explicit and implicit) government subsidies for commercial livestock farmers (which contributed to overgrazing and bush encroachment). Another important factor contributing to the decline in livestock numbers has been the rapid expansion of wildlife-based nature tourism since the time freehold farms were granted use rights over animal wildlife (in the mid 1970's), followed by the granting of such rights to communal-area conservancies in the mid 1990's. Sizable numbers of freehold stock farms have been converted to game farms, and this trend has continued. Given the current more limited livestock carrying capacity in Namibia and the economic attractiveness of turning stock farms into game & guest farms for tourism, it is considered unlikely that in future there will be any significant expansion in livestock numbers.

Table 20 below, summarises livestock numbers by veterinary district, on the basis of the results of the latest completed livestock census (conducted in 2006). Cattle, goats and sheep predominate (in terms of numbers) in most districts and overall. Annex A2 provides a time series of data on livestock numbers by veterinary district, drawing on the results of the annual livestock censuses for the period 2000-2006.

Table 20: **Livestock numbers by veterinary district for the year, 2006**

State Vet District	Total Cattle	Total Goats	Total Sheep	Total Horses	Total Donkeys	Total Poultry	Total Pigs	Total Dogs	Total Camels	Total Ostriches
East Caprivi	156,379	92,000	762	19	28	38,000	524	30,000	0	0
Oshana	107,959	69,459	5,083	217	10,606	88,235	6,279	8,031	0	0
Omusati (Outapi)	246,674	240,853	15,993	1,016	37,504	164,629	17,605	19,272	0	0
Ohangwena (Eenhana	183,488	151,052	83	575	18,150	111,383	7,957	11,808	0	0
Oshikoto	218,882	176,696	2,502	1,761	37,948	113,502	1,761	18,758	0	7
Rundu	125,927	44,135	1,472	524	1,555	55,116	1,778	7,122	0	0
Opuwo	217,879	201,557	43,751	2,314	8,384	8,994	0	4,230	0	0
Otavi	70,535	29,225	20,072	664	795	8,764	606	1,346	5	272
Grootfontein	117,727	25,623	31,576	976	1,257	16,133	485	2,264	3	85
Okahandja	132,219	30,648	21,246	2,474	1,573	92,440	559	2,283	0	238
Outjo	91,714	161,700	54,807	2,987	6,558	16,121	304	5,998	0	16
Otjiwarongo	124,569	66,818	37,713	3,076	3,801	15,561	95	5,381	0	25
Otjinene	70,787	11,245	7,643	365	684	432	10	0	0	0
Gobabis	264,059	143,997	270,443	11,516	9,248	32,548	392	8,839	56	57
Omaruru	59,746	161,244	75,887	1,979	8,023	17,358	89	4,509	0	8
Walvis Bay	429	3,191	352	92	235	1,252	837	1,224	6	0
Windhoek	114,978	35,522	119,343	3,823	2,060	106,203	1,020	2,099	0	20
Mariental	43,536	182,123	956,745	5,884	5,941	20,426	10,771	4,508	0	9,741
Keetmanshoop	36,473	234,315	994,779	5,947	5,598	16,458	900	5,374	3	395

State Vet District	Total Cattle	Total Goats	Total Sheep	Total Horses	Total Donkeys	Total Poultry	Total Pigs	Total Dogs	Total Camels	Total Ostriches
GRAND TOTAL	**2,383,960**	**2,061,403**	**2,660,252**	**46,209**	**159,948**	**923,555**	**51,972**	**143,046**	**73**	**10,864**

Section 3.2.2 mentions the unavailability of a shape file for the veterinary districts (Figure **10**) and areas. Since it is therefore not possible to produce a map superimposing the livestock districts or areas on to the Namibian part of the CORB in order to estimate the (proportions of) livestock districts or areas that fall within the CORB, livestock numbers in the Namibian part of the CORB are estimated by drawing on the livestock numbers for the national water basins (in particular the Okavango-Omatako, Eiseb-Epukiro, Omaruru-Swakop, and Cuvelai-Etosha basins), as determined by the IWRM Plan (IWRMPJVN, 2010b), and by using equation (2b) in section 3.2.2 to calculate livestock numbers in the Namibian part of the CORB from livestock numbers in the four national water basins. Table **21** below, presents the resulting livestock numbers, and Table 22 below presents the corresponding livestock water demand figures per basin, using the livestock-specific unit daily water needs shown in Table 9 above, (section 3.2.2).

Clearly cattle dominates water demand among livestock in CORB-Namibia, followed by goats and sheep whose water demand is an order of magnitude lower, followed by other types of livestock whose water demand is another order of magnitude (or more) lower.

Table 21: **Livestock numbers by national water basin and in the CORB - Namibia, 2006**

Type of Livestock	Livestock Numbers by Basin				
	Okavango-Omatako Basin	Eiseb-Epukiro Basin	Omaruru-Swakop Basin	Cuvelai – Etosha Basin	Cubango-Okavango Basin (Namibian Part)
Cattle	350,877	218,843	156,595	815,132	537,566
Goats	119,973	83,007	149,488	686,158	225,114
Sheep	61,245	136,139	87,273	45,865	176,353
Horses	3,924	6,034	3,851	4,535	8,967
Donkeys	5,455	5,346	7,546	105,956	15,343
Poultry	101,924	25,062	88,405	485,935	144,243
Pigs	2,532	280	1,391	33,992	4,285
Camels	4	25	6	3	24
Ostriches	207	54	167	155	232

Source: IWRMPJVN, 2010b (for the stock numbers in the three national water basins)
Note: The livestock numbers in the CORB - Namibia (last column) are calculated from those of the four national water basins (three columns to the left) according to formula (2b) presented in section 3.2.2.[25]

[25] Formula (2b) calculates the surface area of the Namibian part of the CORB from the proportions of the surface areas of the national water basins sharing it:
CORB-Namibia = 85% of Okavango-Omatako basin + 80% of Eiseb-Epukiro basin + 15% of Omaruru-Swakop basin + 5% of Cuvelai-Etosha basin.

Table 22: **Livestock water demand by national water basin in the CORB - Namibia, including water loss and wastage, 2006**

Type of Livestock	Livestock Water Demand by Basin (Mm^3/a)				
	Okavango-Omatako Basin	Eiseb-Epukiro Basin	Omaruru-Swakop Basin	Cuvelai-Etosha Basin	Cubango-Okavango Basin (Namibian Part)
Cattle	8.630	5.380	3.850	20.052	13.223
Goats	0.657	0.455	0.819	3.760	1.234
Sheep	0.336	0.746	0.478	0.251	0.967
Donkeys	0.045	0.044	0.062	0.870	0.126
Horses	0.054	0.083	0.053	0.062	0.123
Poultry	0.056	0.014	0.048	0.266	0.079
Pigs	0.014	0.002	0.008	0.186	0.023
Camels	<0.001	0.001	<0.001	<0.001	0.001
Ostriches	<0.001	<0.001	<0.001	<0.001	0.001
Total	**9.79**	**6.73**	**5.32**	**25.4**	**14.50**

Note: The water demand figures for the national water basins are calculated from the livestock numbers in Table **22**: Livestock water demand by national water basin in the CORB - Namibia, including water loss and wastage, 2006 above by multiplying them with the livestock-specific unit daily water needs (including an assumed 50% water wastage), as presented in Table 9 (section 3.2.2). Livestock water demand in the Namibian part of the CORB is then calculated from those of the national water basins according to formula (2b) in section 3.1 (see footnote to Table **21**).

For reasons pointed out above, the IWRM Plan projects livestock water demand to remain fairly constant in the longer run (over the time horizon of Namibia's Vision 2030) and assumes no increases in stock numbers for the purpose of estimating future livestock water demand by national water basin (IWRMPJVN, 2010b).

Within the Namibian part of the CORB, there are areas, particularly in the Kavango Region/Okavango-Omatako national water basin, closer to the Cubango-Okavango River, where grazing resources are currently underutilised and could accommodate increases in livestock numbers, provided that the necessary water infrastructure is put in place.[26] But livestock densities in most parts of the Namibian part of the CORB, especially the Omaheke Region/Eiseb-Epukiro national water basin, seem to correspond fairly closely to the carrying capacity of the land, with little room for increases in livestock numbers.

It makes sense, therefore, to adopt the IWRM Plan's assumption of no future increases in livestock numbers, also for the purpose of estimating future livestock numbers and livestock water demand in the Namibian part of the CORB. On the basis of this assumption, the results presented in Table **22**: Livestock water demand by national water basin in the CORB - Namibia, including water loss and wastage, 2006 above, for livestock water demand in the year 2006 also represent projected future livestock water demand. However, livestock water demand has the potential to diminish in future to the extent that water demand management measures are implemented toward reducing water leaks and wastage on farms.

Groundwater versus surface water withdrawals to meet livestock demand within CORB-Namibia

[26] Dr Alec Bishi, Veterinary Epidemiology, Import/Export & Training Division, Directorate of Veterinary Services, Department of Agriculture, MAWF, personal communication, 27 June 2011.

Namibia's IWRM Plan estimates livestock water demand that is met from groundwater sources, by national water basin (IWRMJVN, 2010b, Chapter 10). Based on this information, Table 23 summarises livestock groundwater demand within CORB-Namibia, using equation (2b) for apportioning livestock groundwater demand from the four relevant national water basins to CORB-Namibia. Total livestock groundwater demand within CORB-Namibia amounts to about 11.5 Mm^3/a for the year 2006. This is approximately 80% of the total livestock water demand within CORB-Namibia (14.50 Mm^3/a – see Table 22). The remaining 20% (3 Mm^3/a) represents surface water demand.

Table 23: **Livestock groundwater demand by national water basin including water loss and wastage, 2006**

Livestock Groundwater Demand by Basin (Mm^3/a)				
Okavango-Omatako Basin	**Eiseb-Epukiro Basin**	**Omaruru-Swakop Basin**	**Cuvelai-Etosha Basin**	**Cubango-Okavango Basin (Namibian Part)**
5.85	6.72	5.28	7.56	11.52

Source: IWRMJVN, 2010b

Notes:

a) Livestock groundwater demand for CORB-Namibia is calculated from those of the four national water basins using equation (2b), Section 3.1

b) Figures shown include water wastage and losses of 50%.

4.3 Freshwater aquaculture

A review of the literature on aquaculture in Namibia revealed that there are currently no figures on water abstraction for the freshwater aquaculture sector available. It was stated in the WAN (2006), that economically, freshwater aquaculture is still quite small compared to marine fishing, but it is highly water intensive, like crop irrigation. Freshwater aquaculture has been identified as a sector with high-growth potential so monitoring water abstraction volumes should be a priority. Most of the implemented schemes require a daily input of 10 to 15% fresh water input relative to the storage in the pond. The overflow is normally used for small-scale irrigation schemes provided that the effluent is suitable for irrigation. Reuse of water within requires expensive filtration systems and is only applied in small-scale operations. For a few sectors in Namibia such as communal agriculture, fishing (inland aquaculture) and fish processing, water productivity is reported to have declined significantly (WAN, 2006), however, few if any data are available for the sector-specific economic contribution of freshwater aquaculture to national income.

4.4 Urban settlements (local authority areas)

In line with Table 11, section 3.2.4, only those local authorities strictly falling within CORB-Namibia are considered in calculating estimated water demand by urban settlements. This means that of the two municipalities abstracting their own water supply from groundwater resources in the Karst area (Tsumeb and Grootfontein – see IWRMJVN, 2010b)), only Grootfontein is taken into account.

Error! Reference source not found. provides a population density map of Namibia, with the boundaries of the national water basins indicated. It is apparent that population density within the Namibian part of the CORB (essentially the merged Okavango-Omatako and Eiseb-Epukiro basins) varies greatly. Up to 50 people per km^2 are found along the Cubango-Okavango River, in the Karst area, near the Omatako dam, and in other pockets. By contrast, there are few if any people in some of the central and eastern parts of the CORB that reach into the Kalahari sands region. The principal urban centres within the Namibian part of the CORB are shown in Error! Reference source not found. and Error! Reference source not found. below, by population size and type of local authority, respectively.

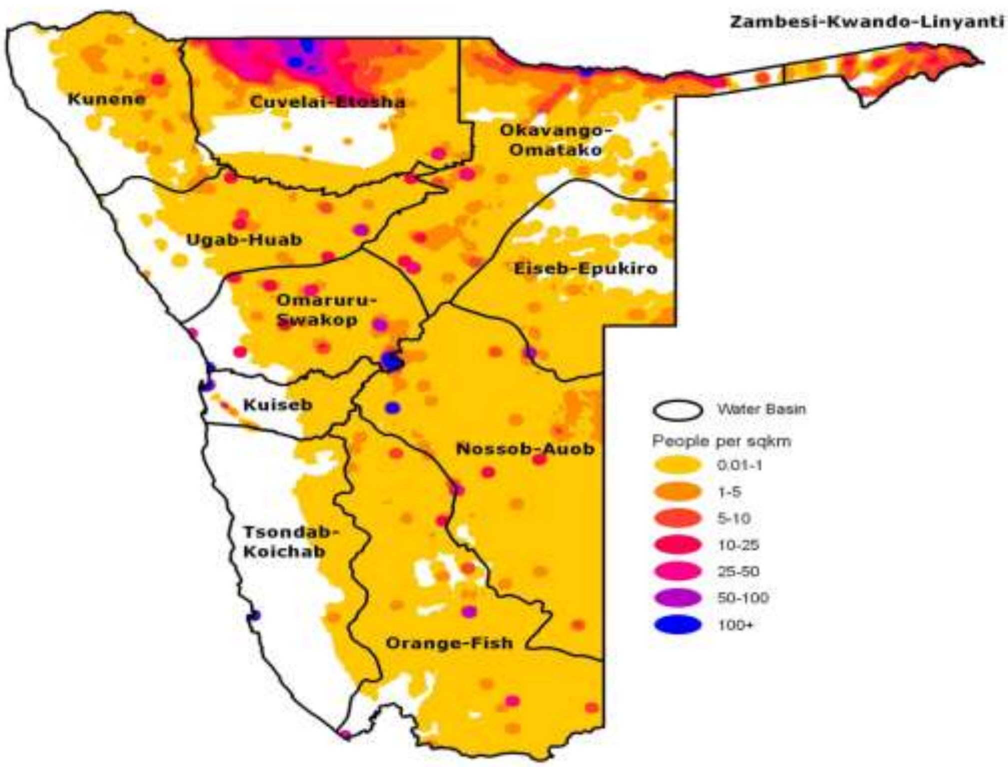

Figure 15: **Population density map of Namibia per water basin**

(Source: IWRMPJVN, 2010b)

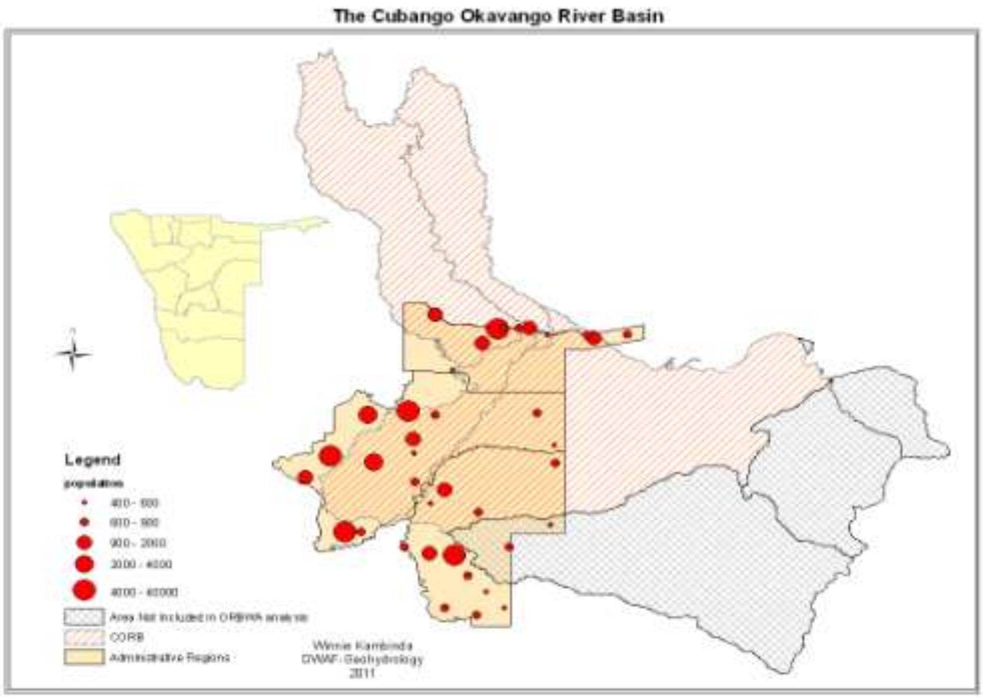

Figure 16: Urban centres by population size in the CORB - Namibia

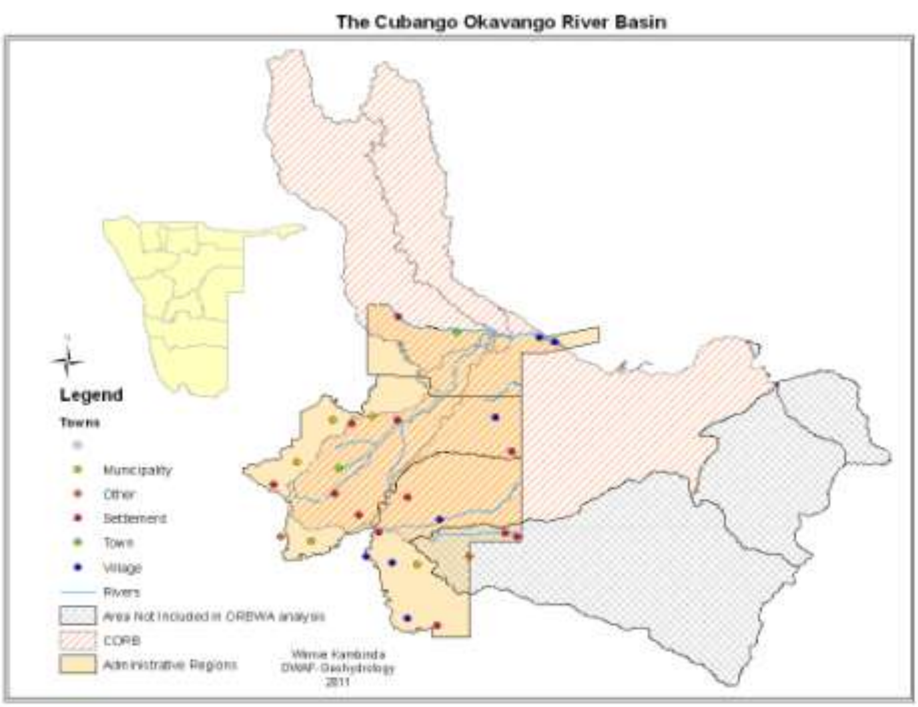

Figure 17: Urban centres by type of local authority in the CORB - Namibia

Table 24 below, provides a detailed overview of urban areas, their populations and their current (year-2008) levels of water demand in the Namibian part of the CORB by national water basin and administrative region and broken down by (type of) local authority, on the basis of the approach, methods and data sources outlined in section 3.2.4. Some 100,000 people live in the urban settlements of CORB-Namibia, whose water demand amounts to about 6 Mm^3/a, as of 2008, nearly 90% of urban water demand in the merged two national water basins (Okavango-Omatako and Eiseb-Epukiro). Three quarters of these urban basin people reside in the two principal urban centres: the town of Rundu on the perennial Cubango-Okavango River and the municipality of Grootfontein in the Karst groundwater area.

Table 25 below, presents projections of urban water demand in CORB-Namibia and the two national water basins, up to the year 2030, again based on methods and information sources explained in section 3.2.4. Urban water demand in the Namibian part of the CORB is projected to increase from about 6 Mm^3/a in 2008 to approximately 14 Mm^3/a in 2030. The proportion of water demand in CORB-Namibia that comes from the two major population centres (Rundu and Grootfontein) in the CORB segment is projected to increase from 75% in 2008 to 80% in 2030.

Table 24: **Current urban population and their water demand in the CORB – Namibia**

Name of Urban LA	Type of Urban LA	Urban Population 2008	Urban Population 2008	Urban Water Demand 2008 (m^3/a)	Urban Water Demand 2008 (m^3/a)
		National Water Basin	Namibian Part of the CORB	National Water Basin	Namibian Part of the CORB
Okavango-Omatako Basin					
Kavango Region					
Rundu	Town	55,646	55,646	2,449,880	2,449,880 (S)
Kapako	Settlement	482	482	71,527	71,527 (S)
Kayengona	Settlement	1,088	1,088	108,040	108,040 (G)
Mabushe	Settlement	1,700	1,700	62,036	62,036 (S)
Mukwe	Settlement	866	866	136,469	136,469 (S)
Muroro-Mashari	Settlement	842	842	94,535	94,535 (S)
Ndiyona	Settlement	702	702	29,565	29,565 (S)
Nkamagoro	Settlement	1,734	1,734	63,286	63,286 (S)
Nkurenkuru (Kahenge)	Settlement	2,146	2,146	78,338	78,338 (G)
Divundu	Settlement	1,426	1,426	52,033	52,033 (S)
Mururani-Gate	Settlement	511	511	26,080	26,080 (G)
Omega	Settlement	1,104	1,104	50,370	50,370 (G)
Otjozondjupa Region					
Grootfontein	Municipality	18,245	18,245	2,066,912	2,066,912 (G)
Okakarara	Town	4,220	4,220	207,882	207,882 (G)
Okamatapati	Settlement	536	536	120,705	120,705 (G)
Okatjoruu	Settlement	754	754	27,514	27,514 (G)
Okondjatu	Settlement	995	995	36,334	36,334 (G)
Coblenz	Settlement	1,479	1,479	47,661	47,661 (G)
Tsumkwe	Settlement	1,007	1,007	72,270	72,270 (G)

Name of Urban LA	Type of Urban LA	Urban Population 2008	Urban Population 2008	Urban Water Demand 2008 (m^3/a)	Urban Water Demand 2008 (m^3/a)
		National Water Basin	Namibian Part of the CORB	National Water Basin	Namibian Part of the CORB
Sub-total		**95,483**	**95,483**	**5,801,437**	**5,801,437**
Eiseb-Epukiro Basin					
Omaheke Region					
Gobabis	Municipality	19,223	(outside CORB)	742,847	(outside CORB)
Eiseb	Settlement	676	676	24,669	24,669 (G)
Epukiro Post 3	Settlement	766	766	37,089	37,089 (G)
Otjinene	Settlement	1,832	1,832	96,067	96,067 (G)
Summerdown	Settlement	500	500	18,264	18,264 (G)
Buitepos	Settlement	880	(outside CORB)	18,522	(outside CORB)
Talismanus	Settlement	515	(outside CORB)	31,701	(outside CORB)
Otjozondjupa Region					
Gam	Settlement	438	438	15,994	15,994 (G)
Sub-total		**24,830**	**4,212**	**985,153**	**192,083**
TOTAL		**120,313**	**99,695**	**6,786,590**	**5,993,520**

Source: IWRMPJVN, 2010b

Table 25: **Projected growth in urban water demand for the CORB - Namibia**

Water Basin/ CORB-Namibia	Urban LA	Type of Local LA	Water Demand				
			2008	2015	2020	2025	2030
Okavango – Omatako Basin (O-O)	Grootfontein Rundu Okakarara 16 Settlements	Municipality Town Town Settlements	2,066,912 2,449,880 207,882 1,076,763	2,662,704 3,302,471 267,804 1,311,066	3,399,957 4,061,806 341,954 1,500,045	4,278,258 4,943,659 430,291 1,698,836	5,275,256 5,930,097 530,565 1,896,638
Sub-total (O-O)			**5,801,437**	**7,544,046**	**9,303,762**	**11,351,044**	**13,632,556**
Eiseb-Epukiro Basin (E-E)	Gobabis 7 settlements	Municipality Settlements	742,847 242,306	1,036,822 284,152	1,434,558 324,053	1,956,428 365,893	2,615,268 406,939
Sub-total (E-E)			**985,153**	**1,320,973**	**1,758,611**	**2,322,321**	**3,022,207**
TOTAL (O-O + E-E)			**6,786,590**	**8,865,019**	**11,062,373**	**13,673,365**	**16,654,763**
CORB-Namibia	Grootfontein Rundu Okakarara 16 settlements (O-O) 5 settlements (E-E)	Municipality Town Town Settlements	2,066,912 2,449,880 207,882 1,076,763 192,083	2,662,704 3,302,471 267,804 1,311,066 227,437	3,399,957 4,061,806 341,954 1,500,045 260,684	4,278,258 4,943,659 430,291 1,698,836 295,833	5,275,256 5,930,097 530,565 1,896,638 330,688
TOTAL (CORB)			**5,993,520**	**7,771,483**	**9,564,446**	**11,646,877**	**13,963,244**

Source: IWRMPJVN, 2010b

Groundwater versus surface water withdrawals to meet urban water demand within CORB-Namibia

The right-hand column of Table 24 indicates the source of water (surface water (S) or groundwater (G)) from which the different urban local authority (LA) areas are supplied (either by NamWater or through own supply). All LAs in CORB-Namibia that are located in the Eiseb-Epukiro basin or within that part of the Okavango-Omatako basin which belongs to Otjozondjupa Region plus a few LAs located within that part of the Okavango-Omatako basin which belongs to the Kavango Region are supplied with groundwater. The groundwater volumes abstracted to meet the demand of these LAs add up to 3.03 Mm^3/a (out of total water withdrawals of 5.99 Mm^3/a), with the self-supplying Municipality of Grootfontein accounting for 2.07 Mm^3/a (nearly 70% of the total). This means that currently (year 2008) about half of the urban water demand is met from groundwater sources, while the other half of the demand is met from the Cubango-Okavango river (surface water), with the Town of Rundu accounting for 2.45 Mm^3/a (more than 80% of the total).

4.5 Rural households (outside local authority areas)

Section 3.2.5 explains the methods and data sources that are used a) to determine current and projected future rural populations of national water basins and their domestic water demand, drawing mainly on the IWRM Plan (IWRMPJVN, 2010b), and b) to transpose population and water use figures from the national water basins to the Namibian part of the CORB. In this section, the results of the application of these methods and data sources are presented.

Table 26 below, shows current (year-2008) rural populations and domestic water demand levels for the four relevant national water basins and the Namibian part of the CORB. Table 27 below, provides projections of the rural basin populations (both national water basins and CORB-Namibia) and their respective domestic water demand levels. The 2008 rural population in CORB-Namibia is estimated to be about 244,000 people, i.e. approximately 2.5 times as large as the 2008 urban population (some 100,000 people – see **Error! Reference source not found.** above in section 4.4). Rural domestic water demand is estimated to be in the range of 2.2 – 2.5 Mm^3/a over the coming two decades (up to 2030), considerably lower than water demand in urban settlements which is projected to increase from 6 Mm^3/a to 14 Mm^3/a over the period (see Table 24 above).[27]

[27] If average rural domestic water demand were taken as 50 litres/capita/day, as assumed in (Beuster, 2010) for the EPSMP TDA (OKACOM, 2011), instead of the 25 litres/ capita/day assumed in the IWRM Plan (IWRMJVN, 2010b) and in the present report, then the CORB-Namibia rural domestic water demand figures in Table 26 and Table 27 would double, but still remain significantly below the 2008 figures in Table 24 for water demand in urban settlements

Table 26: **Current rural population and rural domestic water demand in the CORB - Namibia, 2008**

National Water Basin/ Namibian Part of the CORB	Rural Population (in 2008)	Rural Water Demand (in 2008) (Mm^3/a)
Okavango-Omatako basin	211,584	1.931
Eiseb-Epukiro basin	32,538	0.297
Omaruru-Swakop basin	29,845	0.272
Cuvelai-Etosha basin	679,264	6.198
Namibian Part of the CORB	**244,316**	**2.230**

Source: (IWRMPJVN, 2010b)

Notes: a) Formula (2b): "CORB = 85% of Okavango-Omatako basin + 80% of Eiseb-Epukiro basin + 15% of Omaruru-Swakop basin + 5% of Cuvelai-Etosha basin" is used to calculate rural population and rural water demand figures from those of the national water basins
b) The rural water demand figures are based on an assumed average daily water need of 25 litres per rural dweller

Table 27: **Projected rural population and rural domestic water demand in the CORB - Namibia**

National Water Basin/ CORB-Namibia	Rural Population 2008	Rural Water Demand (M/a)				
		2008	2015	2020	2025	2030
Okavango-Omatako basin	211,584	1.931	1.992	2.038	2.084	2.131
Eiseb-Epukiro basin	32,538	0.297	0.306	0.313	0.320	0.328
Omaruru-Swakop basin	29,845	0.272	0.281	0.287	0.294	0.301
Cuvelai-Etosha basin	679,264	6.198	6.396	6.541	6.690	6.842
Namibian Part of the CORB	**244,316**	**2.230**	**2.300**	**2.353**	**2.406**	**2.461**

Source: (IWRMPJVN, 2010b)

Notes: a) Formula (2b): "CORB = 85% of Okavango-Omatako basin + 80% of Eiseb-Epukiro basin + 15% of Omaruru-Swakop basin + 5% of Cuvelai-Etosha basin" is used to calculate rural population and rural water use figures from those of the national water basins
b) The rural water demand figures are based on an assumed average daily water need of 25 litres per rural dweller
c) Projected rural water demand figures have been calculated on the assumption of an annual rural population growth rate of 0.45%.

Groundwater versus surface water withdrawals to meet demand from rural households within CORB-Namibia

Namibia's IWRM Plan calculates estimated rural groundwater demand by national water basin (IWRMJVN, 2010b, Chapter 10). Drawing on these figures, Table 28 presents volumes of groundwater withdrawals to meet the demand of rural households for each of the four relevant national water basins as well as for CORB-Namibia, using equation (2b) in section 3.1. The IWRM Plan figures for rural groundwater demand in the four national water basins are evidently not consistent with those for overall rural water demand in Table 26, as groundwater demand exceeds overall water demand. In the absence of more reliable information, the preliminary conclusion is drawn that virtually all water abstracted in CORB-Namibia to meet demand from rural households comes from groundwater sources.

Table 28: **Groundwater demand from rural households by national water basin in the CORB – Namibia, 2008**

Livestock Groundwater Demand by Basin (Mm^3/a)				
Okavango-Omatako Basin	Eiseb-Epukiro Basin	Omaruru-Swakop Basin	Cuvelai-Etosha Basin	Cubango-Okavango Basin (Namibian Part)
2.002	0.348	0.117	6.508	2.32

Source: IWRMJVN, 2010b

Note: Groundwater demand from rural households within CORB-Namibia is calculated from those of the four national water basins using equation (2b), Section 3.1

4.6 Mines and industrial establishments

Table 29 below shows the estimated water demand of the active Otjozondu mine and the currently inactive Kombat and Berg Aukas mines inside the boundary CORB-Namibia are also listed. Table 30 below, shows the projected water demand by the mining sector in the CORB-Namibia to increase from currently (2008) 5,000 m^3/a to approximately 8,000 m^3/a by 2030. This excludes the currently inactive Kombat and Berg Aukas mines.

As a result of rising international mineral prices, it is anticipated that Kombat and Berg Aukas will be reactivated in the near future. As and when that happens, it is possible or likely that (at least part of) the groundwater pumped from the mine shafts would be used (again) in support of mining operations. While the two mines have been inactive, pumped shaft water has been used for crop irrigation in the vicinity of the mines (an estimated 2.4 million m^3/a to irrigate some 160 ha, as of 2008 – see Table 14) and by NamWater as a source of bulk water to the Central Area of Namibia (CAN) via the Eastern National Water Carrier (ENWC) and to customers along the ENWC canal (currently some 0.5 million m^3/a, down from up to 1 million m^3/a around the year 2000) (IWRMPJVN, 2010b). In the event that mine shaft water were to be used (again) for mining operations, local irrigators and NamWater currently using this water would have to look for alternative sources of (ground)water in the Karst area (or elsewhere inside or outside of CORB-Namibia) or scale down operations.

Once the Kombat and/or Berg Aukas mines are re-commissioned and commence operation, and with up-to-date information becoming available on where these mines' will source their process water from, the water demand projection for the mining sector in the CORB-Namibia presented in Table 28 will have to be revised.

Table 29: **Estimated water demand by the mining sector in the CORB - Namibia, 2008**

Mine	Source	Water Demand (m^3/a)	Active	Inactive
Otjozondu	Groundwater	5 000	X	
Kombat	Groundwater	0		X
Berg Aukas	Groundwater	0		X
Total			**5 000**	**0**

Source: IWRMPJVN, 2010b

Table 30: **Projection of total freshwater demand by the mining sector (m^3/a) in the CORB - Namibia**

Basin	2008	2015	2020	2025	2030	Growth
Otjozondu	5 000	5 743	6 341	7 001	7 730	2%

Source: IWRMPJVN, 2010b

Suggestions related to the mining sector

1. It is suggested that the relevant line ministries adopt a more detailed sectoral work plan with the mining sector aimed at compiling and/or validating data for water abstraction, losses, and return flows, from mining companies. This would require greater efforts in the compilation, systematization, desegregation and validation of water data and information.

2. According to the IWRM Plan it is not possible to estimate potential water use savings achievable through water demand management, for the mining sector without a detailed assessment at each mine. To prevent the excessive use of water through water inefficient processes (such as heap leaching) it is recommended that:

- Strict license conditions should be applied to prevent water and environmental pollution from mining activities;

- Recover the true cost of water supply without subsidies from other sectors; and

- Promulgate the necessary regulation to control mines with respect to water use efficiency and prevention of water pollution.

4.7 Tourism facilities and other service establishments

Examining water demand for the period 1999 – 2008 reveals a disproportionately rapid increase in water demand by the tourism, rural domestic, and livestock sectors. Table 29 below shows a segment of Table **4** above **(**see Section 2) of the tourism sector growth in water demand in relation to the total economic sector water demand for the period 1999-2008. The projections in Table 32 were based on an annual growth rate of 5% for the period 2008-2015, 3% for the period of 2015-2020 and 2% for the period of 2020-2030.

Table 31: **National tourism sector growth in water demand 1999-2008 (Mm^3/a)**

Sector	Water End Use 1999	% of Total 1999	Water End Use 2008	% of Total 2008
Tourism	2.3	0.8	19.6	5
Total	**296.9**	**100**	**334.1**	**100**

Table 31 is snapshot of the results in Table 32 and Table 33 below, to highlight the following:

- If the CORB-Namibia is approximated by the merged Okavango-Omatako and Eiseb-Epukiro basins, then the tourism water demand would amount to about 4.0 Mm^3/a by 2030. This would be a close to accurate picture if the boundary of CORB-Namibia were to be adjusted to coincide with the boundaries of the two national water basins.

- Should adjustments be made to take into account all four national water basins sharing CORB-Namibia (in the absence of adjustments to the CORB-Namibia boundary), then tourism water demand would be approximately 5.0 Mm^3/a by 2030. With national water basin boundaries and CORB-Namibia boundaries defined as they are, this is the more correct figure.

Table 32: **Estimated total projected water demand by the CORB Namibia by 2030 (m^3/a)**

Basin	CORB-Namibia 2 (a)	CORB-Namibia 2 (b)
Okavango-Omatako	**3,984,577**	**5,021,504**

Estimation of water demand based on surface relationships 2 (b)

Table 33: **Surface-relationship (2b): Projection of the water demand by tourism per basin (m^3/a)**

B	2008	2015	2020	2025	2030
Omaruru-Swakop (15%)	802,863	1,129,709	1,309,642	1,445,951	1,596,447
Eiseb-Epukiro (80%)	441,091	620,659	719,514	794,402	877,084
Okavango-Omatako (85%)	1,234,629	1,737,247	2,013,945	2,223,558	2,454,988
Cuvelai-Etosha (5%)	53,399	75,138	87,105	96,171	106,181
Total	**2,531,982**	**3,562,763**	**4,130,207**	**4,560,082**	**5,034,699**

Notes: (2a) "CORB = *100% of Okavango-Omatako basin + 100% of Eiseb-Epukiro basin*
(2b) "CORB = 85% of Okavango-Omatako basin + 80% of Eiseb-Epukiro basin + 15% of Omaruru-Swakop basin + 5% of Cuvelai-Etosha basin"
Growth rates: 2008-2015 = 5%, 2015-2020 = 3%, 2020-2030 = 2% (IWRMJVN, 2010b)

Groundwater versus surface water withdrawals to meet tourism water demand within CORB-Namibia

Table 34 below, shows groundwater abstraction volumes to meet water demand in local authority areas in the CORB-Namibia, based on spreadsheets prepared by Windhoek Consulting Engineers (WCE) for the IWRM Plan of Namibia (C. Muir, WCE, personal communication, 09 July 2011). Groundwater withdrawals to meet tourism demand total 2.2 Mm^3/a. With total withdrawals of 2.53 Mm^3/a (Table 33), this implies surface water withdrawals of 0.33 Mm^3/a.

Table 34: **Groundwater withdrawals to meet tourism water demand in the CORB-Namibia, 2008**

Region/ National Water Basin/ CORB-Namibia	Groundwater Abstraction (m^3/a)
Region	
Kavango	449
Otjozondjupa	1,397
Omaheke	596
Erongo	5,676
Khomas	5,141
Oshikoto	2,121
Ohangwena	52
Omusati	
Oshana	396
Kunene	3,585
National Water Basin	
Okavango-Omatako*	1,148
Eiseb-Epukiro**	557
Omaruru-Swakop***	4,199
Culevai-Etosha****	2,928
CORB-Namibia*****	**2,198**

Source: Windhoek Consulting Engineers, spreadsheets prepared for IWRM Plan, Thematic Report 2 (IWRMPJVN, 2010b)

Notes:

* Okavango-Omatako basin = 100% Kavango + 50% Otjozondjupa

** Eiseb-Epukiru basin = 70% Omaheke + 10% Otjozondjupa

*** Omaruru-Swakop basin = 60% Erongo + 20% Otjozondjupa + 10% Khomas

**** Cuvelai-Etosha basin = 100% Oshikoto + 100% Ohangwena + 100% Omusati + 100% Oshana + 10% Kunene

***** Equation (2b), Section 3.1:

CORB-Namibia = 85% Okavango-Omatako basin + 80% Eiseb-Epukiro basin + 15% Omaruru-Swakop basin + 5% Cuvelai-Etosha basin

Research

A closer analysis of the NTB data is recommended to ascertain the reasons for the huge fluctuation in the number of beds AVAILABLE and the number of beds SOLD. The statistics can be viewed at http://www.namibiatourism.com.na/Research-Center/.

For future research on the water demand of the tourism sector, it is recommended to distinguish between the number of employees that are permanently residing on the lodge premises and those who are effectively only present during daily working hours but not living in staff accommodation at the lodges.

This recommendation draws on the conclusions in a study by Schachtschneider (2000), which examined the results of a one-year survey of water demand in twelve tourist camps conducted in 1999 by the Department of Water Affairs. Based on the survey results, the study found that visitors account for only a fraction of the water demand, while most of the water demand comes from staff, to irrigate the gardens or is lost due to leaks. One of the main findings of the 1999 survey was that there is little or no correlation between monthly water demand from tourist facilities and visitor numbers. The visitors' water demand was determined to be in the range of 4 % and 20 %. The conclusions drawn by the study further crudely stated that none of the former water demand were directly related to visitor numbers but were rather based on the level of control over water use exercised by management.

The crude assumption of 15,000m^3/ha/a landscape irrigation per tourism establishment on which the results of this study as presented in section 4.7 should be verified by a field survey to measure the actual water demand for gardening/landscaping in the tourism sector.

Limitations

The costing system of local authorities makes it almost impossible to get water demand figures separately for the tourism sector. Water demand in general, but specifically volumes of groundwater abstraction of certain sectors is unknown, e.g. the tourism industry. In consideration of the growth in the tourism industry, it may potentially have a significant impact on groundwater sustainability and quality, but there is no obligation on the industry to manage and record the way water is used. As a result, the tourism industry is unable to supply accurate information about the distribution of tourists in the urban and rural tourist establishments in Namibia and there are no known measurement systems in place to accurately distinguish between the proportions of supplies coming from municipalities, rural sources and own groundwater sources (self-supply) (IWRMPJVN, 2010b).

4.8 Ecological water requirements, including water use by wildlife and natural forests

Section 3.2.8 presents figures for the daily average water consumption of different game animals by species. To the extent that aerial surveys of animal wildlife cover the Namibian part of the CORB, wildlife water demand could be estimated by multiplying game populations with average water needs per animal, by species.

Comprehensive assessments of ecological water requirements (water consumption of the natural environment, including evapotranspiration) of wetlands) in the Namibian part of the CORB have not been done to date.

5. Water use by water supply source in CORB-Namibia

The natural and institutional water supply sources meeting water demand in the Namibian part of the CORB are discussed in this section. As far as natural water supply sources are concerned, only three categories are considered, as noted in section 3.1:

- surface water abstracted from perennial rivers;
- surface water abstracted from ephemeral river dams; and
- groundwater.

Other categories (such as rainwater, wastewater, recycled water, grey water, soil water, etc.) are either not relevant or not amenable to analysis because of lack of data or gaps in the available data.

Institutions supplying water in CORB-Namibia include:

- NamWater -- abstracting bulk water from all three natural sources listed above and supplying a variety of water users, including local authorities (municipalities, towns, villages, and settlements), irrigation and livestock farmers, mines, as well as a various service institutions (public and private),[28] industrial establishments, and tourism establishments outside local authority areas;
- Directorate of Rural Water Supply (DRWS) – running its own production boreholes from which to supply rural communities; and
- Self-providers
    - Local authorities (LAs) -- abstracting their own water;
    - Irrigation farmers -- operating their own boreholes and supplying their own water;
    - Livestock farmers -- operating their own boreholes and supplying their own water;
    - Mines and industrial establishments (outside LA areas) – abstracting their own water;
    - Tourism establishments (outside LA areas) – abstracting their own water;
    - National parks – abstracting their own water.

5.1 Natural water supply sources

The principal natural water supply sources in the Namibian part of the CORB are:

- Surface water abstracted from the perennial Cubango Okavango River;
- Surface water abstracted from the Omatako dam located in the upper reached of the ephemeral Omatako river, just outside the Okavango-Omatako national water basin; and
- Groundwater from the Karst water control area (WCA) and other areas.

Nationwide, groundwater was the largest natural source of freshwater during 1997/8 – 2001/2, accounting for about 40% of all freshwater abstracted during that period, while perennial and ephemeral river water respectively provided about 30% of the freshwater during that period. Recycled water, while locally important (notably in Windhoek), provided more than 1% of freshwater during the

[28] Such as schools, hospitals, police stations, prisons, churches, and government offices.

period (WAN, 2004). The share of perennial water appears to have been increasing in more recent years, due to the growth of irrigated agriculture along the perennial rivers.

Each of the three principal natural water supply sources is now briefly discussed and to the extent possible quantified for CORB-Namibia.

5.1.1 Surface water abstracted from the perennial Cubango Okavango River

Currently (as of 2008/9), a total of about close to 40 Mm^3/a of perennial river water is abstracted.[29] This water supply primarily meets demand from Green Scheme irrigation activities along the river (totalling close to 35 Mm^3/a – thereof 2/3 upstream from the Cuito confluence and 1/3 downstream) and to a much lesser extent domestic demand from human towns and settlements along the river (about 5 Mm^3/a). River water supply for Green scheme irrigation is projected to increase rapidly in coming years, up to a limit of about 250 Mm^3/a (or 2.5% of long-term average river flow), as stipulated by an interim Namibian government policy governing that abstracting of water from the Cubango Okavango River. The upper abstraction limit is expected to be reached by or before 2030. Domestic urban water demand is projected to increase to about 13 Mm^3/a by 2030 (see section 4.1.1 for more details).

There are new plans (a revival of older plans) to abstract perennial river water for transfer to two water demand centres:

a) to consumers in the Central Area of Namibia (CAN) via a pipeline running from the Cubango-Okavango river to the Karst area, from there via the Eastern Water Carrier (EWC) to the Omatako Dam, and from there to the CAN; and
b) to the North-Central Regions via a separate pipeline running from the Cubango-Okavango river to Oshakati and from there onwards to other demand centres in the North-Central Regions.

Details about the amounts of river water to be abstracted, the period during abstraction will take place, and the locations of the abstraction point(s) – upstream or downstream of the Cuito confluence – are being discussed and not yet available. It is anticipated that abstraction volumes will be much smaller than the volumes expected to be required for Green scheme irrigation and that abstraction will not take place during low-flow periods.[30] If these plans come to fruition and once the necessary water abstraction and transfer infrastructure is in place, the contemplated scheme would substantially increase the quantities of river surface water exported out of the CORB-Namibia (see Section 6 for more details on water exports out of the CORB-Namibia).

[29] The IWRM Plan comes up with a figure 36.7 Mm^3/a for the amount of river water that is "developed" and "utilised", as of 2008 (IWRMJVN, 2010b, Table 9.6)
[30] Piet Liebenberg, personal communication, 18 August 2011.

5.1.2 Surface water abstracted from the Omatako dam

The Omatako dam is used as a "conduit" (interim water storage facility) to transfer water to consumers in the CAN via the EWC from the Grootfontein Karst aquifer (Karst sub-regions E – see Figures 7 and 8 in section 3.1.1) located (mostly) inside the Omuramba-Omatako catchment and falling within the Namibian part of the CORB . Most of that water goes to the national capital Windhoek, after having been pumped from the Omatako dam to the Von Bach dam. Historical data on the volumes pumped between the Omatako and Von Bach dams appear to be available, but it is difficult to determine the sales volumes, i.e. the portion of the pumped volumes that were actually sold.[31]

The Omatako dam has a storage capacity of 43.5 Mm^3 and a mean annual runoff of Mm^3/a (IWRMJVN, 2010b). The Omatako Dam is normally operated in conjunction with two other dams, the Von Bach Dam and the Swakopoort Dam, to supply the Central Area of Namibia (CAN) with water. In this configuration, the Omatako Dam alone has a "safe" (95% assured) yield of 2.0 Mm^3/a, while the three dams together have a "safe" (95% assured) yield of 7.5 Mm^3/a.[32]

5.1.3 Groundwater from the Karst water control area (WCA) and other areas

The principal data sources for quantifying groundwater supply and use are DWA and NamWater. Availability of groundwater abstraction data from local authorities is limited. The Geohydrology Division of DWA do not receive abstraction data on a regular basis from all the mines in Namibia (IWRMJVN, 2010b).

NamWater groundwater bulk supply

NamWater abstracts groundwater from 505 production holes at 97 bulk supply schemes throughout Namibia. Error! Reference source not found. below, shows the geographic distribution of these schemes, overlain on top of a map of the national water basins. Table 35 below, provides numbers of NamWater bulk supply schemes and boreholes as well as average annual groundwater abstraction volumes, by national water basin (IWRMJVN, 2010b).

The Okavango-Omatako basin has 25 supply schemes, 10 of them located along the Cubango Okavango (and abstracting perennial river water) and all of them falling within CORB-Namibia. NamWater abstracted about 1,470,000 Mm^3/a of water (groundwater and perennial surface water) in the basin during 1999-2008. The Eiseb-Epukiro basin has 8 groundwater supply schemes, of which the 4 southernmost supply schemes which are located in the Rietfontein Block area, fall outside the CORB.

[31] Hanjörg Drews, personal communication, 13 July 2011.

[32] Hanjörg Drews, citing from the not-yet-published Master Water Plan for the Central Area of Namibia (CAN), personal communication, 02 December 2011.

NamWater abstracted about 630,000 Mm^3/a of groundwater in the basin during 1999-2008. There are no NamWater supply schemes located in those parts of the Omaruru-Swakop and Cuvelai-Etosha basins which belong to CORB-Namibia

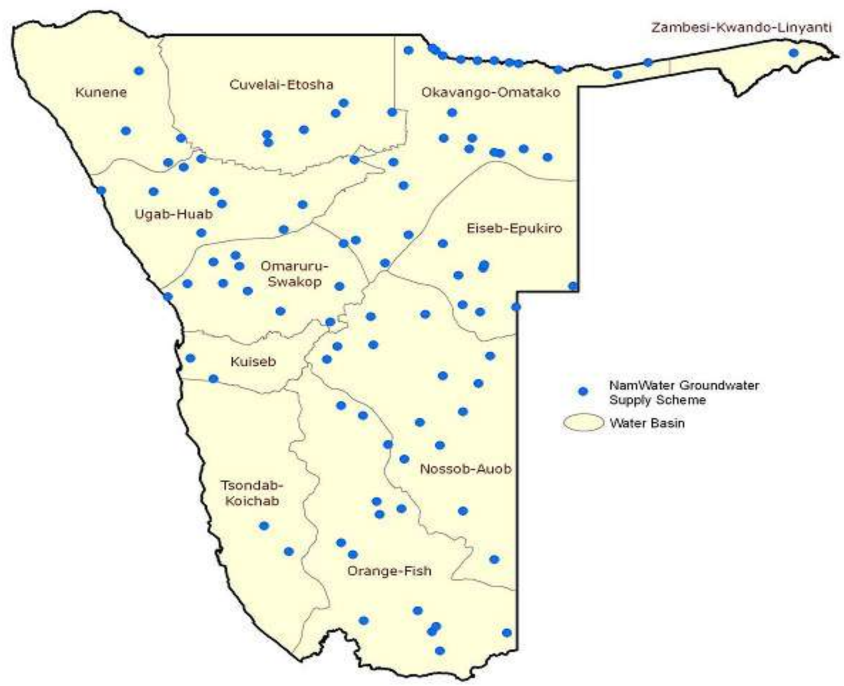

Figure 18: **Distribution of NamWater supply schemes**

Source: (IWRMJVN, 2010a) and IWRMJVN, 2010b)

Table 35: **NamWater bulk water supply schemes and boreholes by national water basin, 1999-2008**

Water Basin	Cuvelai-Etosha	Eiseb-Epukiro	Kuiseb	Kunene	Nossob-Auob	Okavango-Omatako	Omaruru-Swakop	Orange-Fish	Tsondab-Koichab	Ugab-Huab	Zambesi-Kwando-Lintanti
Boreholes	18	66	52	13	46	76	89	54	20	66	5
Supply Schemes	6	8	2	4	14	25	10	15	2	10	1
Average water abstraction (Mm^3/a)	626,214	616,837	5,996,113	604,065	935,128	1,468,264	7,126,943	1,191,162	1,068,107	2,458,844	51,541

Source: (IWRMJVN, 2010b)

Section 5.2 presents detailed data and analysis of groundwater as well as surface water abstracted by NamWater within CORB-Namibia to sell bulk water to customers in the CORB-Namibia and beyond.

Groundwater self-supply

Local authorities

In Namibia very few local authorities (less than 10) supply their own water, whether groundwater or surface water. Only one of these self-supplying local authorities (Grootfontein Municipality) falls within CORB-Namibia. Grootfontein Municipality is located in the Karst area and abstracts groundwater from the Karst E sub-catchment. Groundwater volumes abstracted by the Municipality are estimated to total about 2 Mm^3/a of groundwater (see Table 23 for year 2008 figures), but this estimate should be treated with caution, as the municipality has not provided the Government (DWA) with reliable and consistent abstraction data. Volumes of Karst groundwater abstracted by Grootfontein Municipality are projected to rise to more than 5 Mm^3/a by the year 2030 (see Table 24).

There is another major self-supplying municipality in the Karst area (Tsumeb) withdrawing even more groundwater than Grootfontein. However, Tsumeb is located outside CORB-Namibia, withdrawing its groundwater from the B2 sub-catchment (Figure 7).

Other self-providers

As with local authorities, data on groundwater abstraction by other self-providers (irrigation farmers, mines, tourism establishments outside LA areas, national parks, etc.) is generally poor, since they do not accurately report on the volumes of groundwater abstracted, as required by the permits they hold. Issues related to poor monitoring and reporting of (ground)water abstraction by self-providers are discussed in Section 3.2.1 (irrigation), Section 3.2.6 (mines), and Section 3.2.7 (tourism establishments).

Groundwater supply to other sectors

The Directorate of Rural Water Supply (DRWS) runs its own groundwater production boreholes from which they supply rural communities. However, DRWS does not keep any records of the quantities of groundwater withdrawn from their boreholes (IWRMJVN, 2010a)

5.2 Bulk water abstraction and supply by NamWater

In this section, we present the results of a quantitative analysis of water abstractions by NamWater within CORB-Namibia, broken down by type of source (groundwater and surface water). The analysis is based on NamWater sales data by water supply scheme.

The analysis is unable to distinguish between different types of end users, since NamWater's customer categories differ greatly from the categories of sectors and end users used by the CORBWA demand study and since NamWater's own customer categories are not always rigorously and consistently applied when sales are recorded.[33] Any attempt to match the NamPower customer categories with the CORBWA end user sector categories, by individual NamWater sales transaction, would certainly be quite time-consuming while not necessarily always being conclusive, and hence will have to be left to the next phase of the CORBWA demand study.

Table 36 shows numbers of NamWater supply schemes located within CORB-Namibia for schemes producing and selling water within CORB-Namibia. The table is broken down by:

a. NamWater Water Supply Area; and
b. category of water source, distinguishing between groundwater and surface water abstraction and between three different sub-categories of groundwater abstraction:
    - Cubango-Okavango (C-O) river schemes abstracting surface water
    - C-O near-river scheme (within 1 km from the river bank) abstracting groundwater
    - Karst-area schemes (CORB-Namibia interior) abstracting groundwater
    - Non-Karst-area schemes (CORB-Namibia interior) abstracting groundwater.

Section 6 will show and discuss a similar table for schemes producing within and selling outside (i.e. CORB-Namibia, i.e. exporting water out of CORB-Namibia.[34]

There are a total of 45 NamWater supply schemes producing and selling bulk water within CORB-Namibia. Of these schemes, eight (8) are surface water schemes on the Cubango-Okavango (C-O), 10 are near-river groundwater schemes, 11 are Karst area groundwater schemes located in the interior of CORB-Namibia , and 16 are other (non-Karst) groundwater schemes located in the interior of CORB-Namibia.

Table 36: **Numbers of NamWater supply schemes producing and selling within CORB-Namibia**

	NamWater's Okavango Water Supply Area	**NamWater's Brandberg Water Supply Area**	**NamWater's Khomas Water Supply Area**	**Total**
Cubango-Okavango (C-O) Surface Water Schemes	8	n/a	n/a	**8**
Near C-O Groundwater Schemes	10	n/a	n/a	**10**
Karst Groundwater Schemes (CORB Interior)	n/a	10	1	**11**
Other Groundwater Schemes (CORB Interior)	7	3	6	**16**
TOTAL	**25**	**13**	**7**	**45**

[33] Hanjörg Drews, NamWater, personal communication, 13 July 2011.

[34] A third category of schemes – those producing water outside and selling it inside, i.e. importing water into CORB-Namibia – was also considered, but it turned out that all schemes selling within CORB-Namibia are located within or on the border of CORB-Namibia. In other words, NamWater does not import any bulk water into CORB-Namibia.

A complete list of the names of all NamWater supply schemes within CORB-Namibia is provided in Appendix A8. The list is grouped into two categories: i) the 45 schemes producing and selling water within CORB-Namibia that are shown in Table 37 in this section, and ii) schemes exporting water out of CORB-Namibia. The second category of schemes is discussed in Section 6.

Based on annual water sales data for the period 1998 – 2011 provided by NamWater for each of the 45 water supply schemes producing and selling water within CORB-Namibia, volumes of water sold annually for surface water schemes and each of the three groundwater schemes within CORB-Namibia have been calculated. The results are presented in Figures 19 and 20. The sales volumes of surface water and groundwater depicted in the two figures can be converted into the corresponding abstraction volumes by adding 5% in (average) water losses in production and delivery of bulk water. [35]

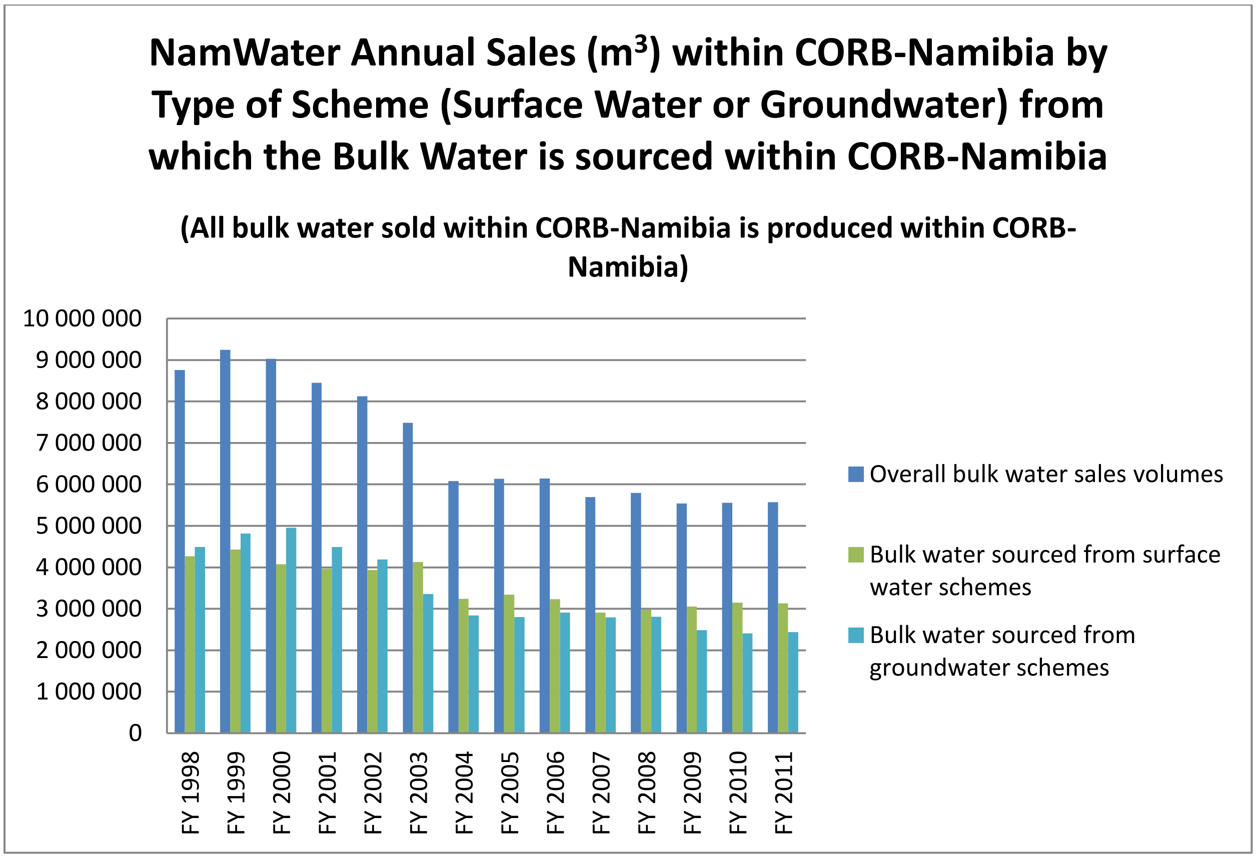

Figure 19: **NamWater annual sales within CORB-Namibia by type of scheme (surface water or groundwater)**

[35] Hanjörg Drews, NamWater, personal communication, 13 July 2011.

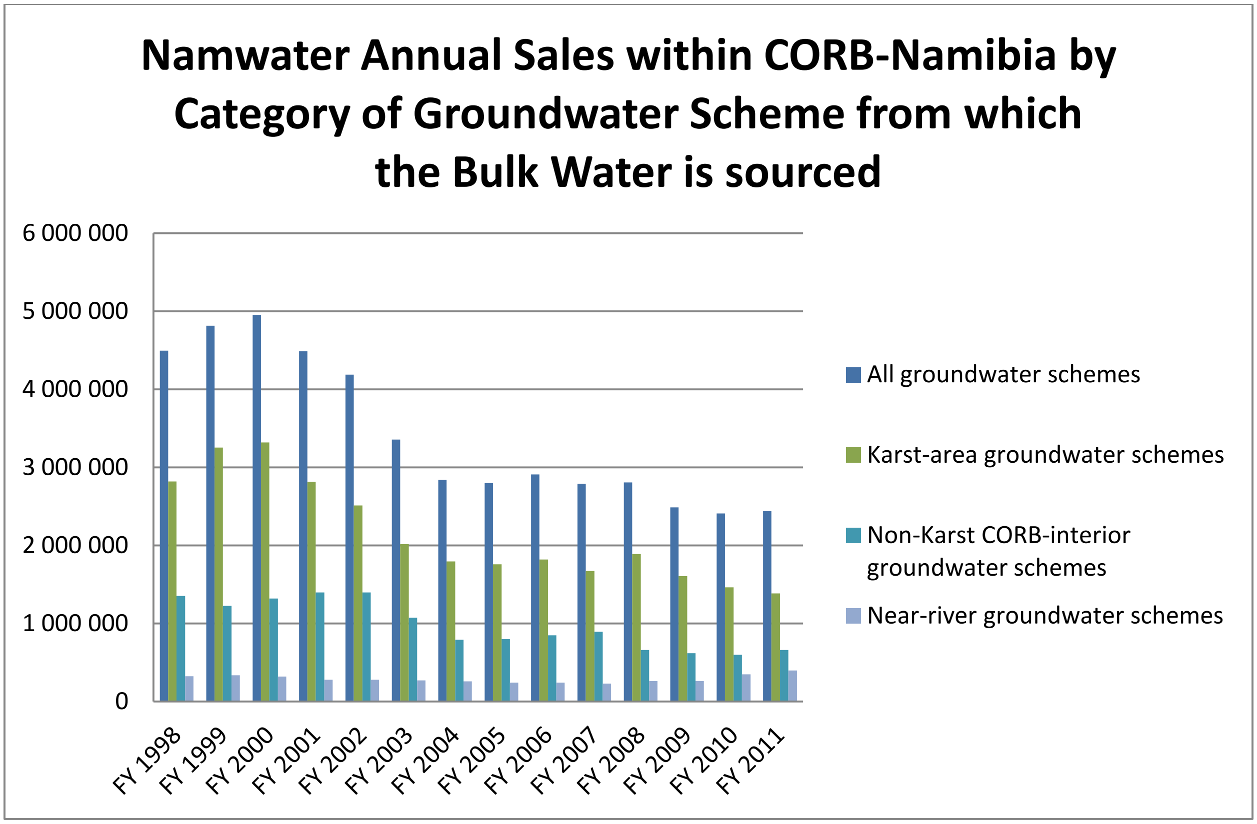

Figure 20: NamWater annual sales within CORB-Namibia by category of groundwater scheme

The two figures show that overall bulk water sales within CORB-Namibia have declined significantly since NamWater started selling bulk water (1998), with most of the drop occurring in the period of 2000-2004. The main reason behind that decline in bulk water sales volumes within CORB-Namibia is likely to be the strong NamWater bulk tariff increases in the early 2000s, as the same trend of declining bulk water sales can be observed in other regions, as the bulk water tariff increases applied country-wide.[36]

At the same time, there has been a shift from groundwater schemes to surface water schemes as sources of bulk water supply within CORB-Namibia since 1998, again with most of that shift occurring in the period of 2000-2004. The drop is more pronounced for bulk water supply from groundwater schemes than for bulk water supply from surface water schemes, with surface water schemes collectively overtaking groundwater schemes as the larger source of bulk water supply. Nevertheless, groundwater bulk sales never exceeded surface water sales by more than 20% before 2003 and surface water bulk sales never exceeded groundwater bulk sales by more than 30% from 2003 onwards.

While reasons for the shift in bulk water supply from groundwater to surface water sources require further analysis, cost advantages in surface water production over groundwater production and groundwater supply constraints may have played a role. The latter (supply constraints) may apply

[36] Hanjörg Drews, personal communication, 02 December 2011.

especially in the Karst-area where sustainable groundwater supply limits seem to have been reached and some degree of substitution of usage of available groundwater supplies away from bulk water supply to other end uses (such as irrigation) may have taken place.

Among the different categories of groundwater bulk supply within CORB-Namibia, Karst-area groundwater supply dominates, followed by non-Karst CORB-interior groundwater supply and near-river groundwater supply (in that order).

It is difficult to draw conclusions from the NamWater sales data for different bulk user categories in CORB-Namibia (such as local authorities, irrigation and livestock farmers, public institutions, private businesses, industrial establishments, and tourism establishments), since NamWater classifies customers in a way that differs from the CORBWA user categories and does not always assign customer categories to sales in a correct and consistent way, as customer categorisation is of limited value to NamWater.[37]

[37] Hanjörg Drews, NamWater, personal communication, 13 July 2011.

6. Water exports out of and imports into CORB-Namibia

The water import-export balance for CORB-Namibia is determined by the following factors:

- The extent to which NamWater imports bulk water for sale within CORB-Namibia;
- The extent to which NamWater exports bulk water for sale outside CORB-Namibia; and
- Possible transfers of Cubango-Okavango surface water via pipeline to water demand centres in the Central Area of Namibia (CAN) and the North-Central Regions – an idea which came up in the 1990s and is currently being revived.

Imports of NamWater bulk water

An analysis of the location of NamWater supply schemes selling within CORB-Namibia has shown that all of these schemes are located within or on the border of CORB-Namibia. In other words, there are no imports of bulk water into CORB-Namibia taking place.

Exports of NamWater bulk water from the Karst area

Table 37 shows that 11 NamWater supply schemes export bulk water from CORB-Namibia to the Central Area of Namibia (CAN).[38] These schemes all abstract groundwater from the Karst area. Two of these schemes (the ones in the Brandberg Water Supply Area – see Table 37 and Appendix A8) sell most of their water to customers along the Eastern National Water Carrier (ENWC), with minimum amounts reaching the Omatako Dam from where this water goes to customers in the CAN. The other nine (9) schemes (the ones in the Khomas Water Supply Area) sell virtually all of the groundwater they abstract in the Karst area to customers in the CAN. Their abstracted groundwater is transferred via the Eastern National water Carrier (ENWC) to the Omatako Dam for temporary storage, from where the water is transferred to customers in the CAN.

Table 37: **Numbers of NamWater water supply schemes producing within and selling outside CORB-Namibia**

	NamWater's Okavango Water Supply Area	**NamWater's Brandberg Water Supply Area**	**NamWater's Khomas Water Supply Area**	**Total**
Cubango-Okavango (C-O) Surface Water Schemes	0	n/a	n/a	**0**
Near C-O Groundwater Schemes	0	n/a	n/a	**0**
Karst Groundwater Schemes (CORB Interior)	n/a	2	9	**11**
Other Groundwater Schemes (CORB Interior)	0	0	0	**0**
TOTAL	**0**	**2**	**9**	**11**

[38] The names of these schemes are found in Appendix A8.

The precise amounts of how much water from each of the 11 Karst-area groundwater schemes passes through the Omatako Dam and is then exported to the CAN cannot be determined, according to Hanjörg Drews, NamWater. However, it can be reasonably assumed that:

- Disregarding water evaporation losses for the moment, 100% of the water in the Omatako Dam ends up being exported out of CORB-Namibia (i.e. very little if any of this water is sold between the Dam and the CORB-Namibia boundary);
- The Omatako Dam has operated (i.e. exported water out of CORB-Namibia) at levels that are on average close to its 95% assured yield (with the Dam being used in conjunction with two other major dams, the Von Bach Dam and the Swakopoort Dam, to supply the Central Area of Namibia (CAN) in an optimised "conjunctive use" configuration). This 95% assured yield of the Omatako Dam in this configuration is 2 Mm^3/a, as mentioned in Section 5.2 above.

This means that NamWater bulk water exports from CORB-Namibia amount to approximately 2 Mm^3/a. This compares with currently 2.5 – 3 Mm^3/a of bulk <u>groundwater</u> produced and sold within CORB-Namibia and 5.5 – 6 Mm^3/a of overall bulk water (surface and groundwater) produced and sold within CORB-Namibia. These figures do not explicitly take into account water losses through evaporation and leakage. Such losses could be substantial (perhaps higher than 5%) for water that runs through the open-air canals of the ENWC and spends time in the Omatako Dam.

Exports of C-O river water

Finally, as for the envisaged export of C-O river surface water, there are (revived) plans to build two pipelines to transfer surface water from the C-O river to the CAN via the ENWC and to Oshakati/the North-Central Regions, respectively. The project is called "Kavango Link – Water Transfer Scheme to the CAN and to the Cuvelai". Its scoping phase is to be completed soon, with the scoping report due by the end of March 2012. If and when this project is implemented, exports of COR surface water out of CORB-Namibia (to the CAN and to the Oshakati area) will begin to take place in addition to the already ongoing exports of Karst groundwater out of the CORB-Namibia to the CAN.

It is clear that if river water abstractions for transfer to the CAN were to be initiated, this could have a significant impact on the availability of river water for irrigation purposes and on the integrity of downstream ecosystems, unless conditions are imposed that limit such additional large-scale abstractions and/or prevent them during low-flow conditions. While the quantities of river water that would be transferred to the CAN and to the North-Central Regions are not clear at this point, they are believed to be much smaller than the volumes required for Green Scheme irrigation projects and hence of little concern to water availability for irrigation or downstream environmental uses.[39]

[39] Piet Liebenberg, personal communication, 18 August 2011.

7. Summary, conclusions and recommendations

Water abstraction to meet demand in the CORB – Namibia, by sector

Table 38 summarises the results presented in sections 4.1 through 4.8 for the volumes of water abstracted from surface and groundwater sources in the Namibian part of the CORB for different water use sectors.

Table 38: **Current and projected water withdrawals to meet water demand in the CORB-Namibia**

Water Demand Sector	**Water Withdrawals (Mm^3/a)**				
	2008	**2015**	**2020**	**2025**	**2030**
Irrigated Cultivation	36.55 – 49.7	68.85 – 82.0	118.75 – 131.9	?	179.55 – 192.7
Livestock	14.50	14.50	14.50	14.50	14.50
Urban Settlements	5.99	7.77	9.56	11.65	13.96
Rural Domestic	2.23	2.30	2.35	2.40	2.46
Mining	5.00	6.75	7.45	8.23	9.08
Tourism	2.53	3.56	4.13	4.56	5.03
TOTAL	**66.80 – 79.95**	**103.75 – 116.9**	**156.75 – 169.9**		**224.55 – 237.7**

Notes:

a) "Irrigated cultivation" as per Tables 14 and 18. The range of figures for water demand for given years corresponds to the range of different options for apportioning Karst irrigation activity to CORB-Namibia, as summarised in Table 18..

b) "Livestock" as per Table **22**: Livestock water demand by national water basin in the CORB - Namibia, including water loss and wastage, 2006

c) "Urban settlements" (local authority areas) as per **Error! Reference source not found.** and 24

d) "Rural domestic" as per

and 26
e) “Mining” as per **Error! Reference source not found.**
f) “Tourism” as per **Error! Reference source not found.**

Demand from irrigated agriculture dominates overall water withdrawals within CORB-Namibia. Its share of overall water withdrawals within CORB-Namibia is projected to rise from around 55-60% currently to approximately 80% in 2030. The second most important water demand sector is livestock, followed by urban settlements whose water demand is expected to grow more quickly than that of livestock, such that urban water demand and water withdrawals to meet this demand, are projected to catch up with the livestock sector. Water demand from mining in coming years is very uncertain, as it largely depends on the extent to which existing idle mines will be reactivated (and possible new mines developed), which in turn essentially depends on the extent to which international mineral prices will continue to rise.

Surface water versus groundwater withdrawals to meet current water demand in CORB-Namibia, by sector

Table 41 summarises findings in sections 4.1 through 4.8 on how much of sectoral water demand is met from surface water withdrawals and how much from groundwater withdrawals.

Overall, it is estimated that approximately equal quantities of groundwater and surface water are currently being abstracted to meet total water demand in the CORB-Namibia. However, this overall picture masks strong variations across sectors in the degree of reliance on groundwater versus surface water. For irrigated crop production, abstraction of surface water from the Cubango-Okavango river, substantially exceeds groundwater withdrawals from the Karst area and elsewhere in the CORB-Namibia, and the dominance of surface water for irrigation is expected to steeply rise further in coming years with the expansion of the Green Scheme programme. By contrast, groundwater abstraction tends to dominate water withdrawals to meet demand in other sectors, with the exception of urban water demand which is met by groundwater and surface water to about equal proportions.

Table 39: **Groundwater versus surface water withdrawals in meeting water demand by sector in the CORB-Namibia, 2008**

Water Demand Sector	Groundwater Withdrawals (Mm^3/a)	Surface Water Withdrawals (Mm^3/a)	Total Water Withdrawals (Mm^3/a)
Irrigated Cultivation	4.7 – 17.7	32.0	36.7 – 49.7
Livestock	11.52	2.98	14.50
Urban Settlements	3.03	2.96	5.99
Rural Domestic	~ 2.23	~ 0.00	2.23
Mining	5.00	0.00	5.00
Tourism	2.20	0.33	2.53
TOTAL	**28.68 – 41.68**	**38.27**	**66.95 – 79.95**

Notes:
a) “Irrigated Agriculture” as per Tables 14, 18 and 19
b) “Livestock” as per Tables 20, 22, and 23,
c) “Urban settlements (local authority areas) as per Tables 24 and 25
d) “Rural domestic” as per Tables 25, 26 and 27
e) “Mining” as per tables 29 and 30
f) “Tourism” as per Tables 30, 33, and 34.

Water import – export balance for CORB-Namibia

There are no imports of bulk water taking place into CORB-Namibia. All water sold by NamWater within CORB-Namibia is abstracted by supply schemes located within CORB-Namibia or on the border of CORB-Namibia (as is the case for Karst groundwater abstraction).

A large part of the groundwater abstracted from sub-catchments in the Karst area by NamWater supply schemes has been exported to the Central Area of Namibia (CAN) via the Eastern National Water Carrier (ENWC) and the Omatako Dam. It is estimated that in recent years these Karst groundwater exports have amounted to about 2.0 Mm/a (plus water losses in transit through evaporation).

Plans for a scheme to transfer Cubango-Okavango surface water to Namibia’s main demand centres are being revived. It is envisaged that the water transfer would be done by means of two separate pipelines carrying water to the CAN and to the North-Central Regions, respectively. Volumes of water that might be transferred are expected to be much smaller than projected abstraction for irrigation under the Green Scheme programme.

Data availability and gaps and related recommendations

This report focuses on estimating the volumes of surface water and groundwater abstractions to meet sectoral water demand in the Namibian part of the CORB. Data on surface and groundwater quality are scant in Namibia, and it has not been possible to address water quality issues and aspects for the CORB-Namibia in this report. Hardly any systematic data exist on the proportions of water consumed (evaporated or transpired) and water discharged to the environment as “return flows”, for different end uses and sectors in Namibia, for which reason these aspects could not be addressed in this report. It is recommended that a programme of monitoring and reporting on aspects of water quality, consumption, and quantities and qualities of return flows be initiated for CORB-Namibia, as an integral part of national efforts.

Policy issues and recommendations

Definition of the boundaries of CORB-Namibia and of national water basins sharing CORB-Namibia

The boundaries of two of Namibia’s 11 national water basins -- the Okavango-Omatako basin and the Eiseb-Epukiro basin – roughly coincide with the boundaries of CORB-Namibia, as recently (re-)defined by

OKACOM. However, the deviations in the respective boundaries are significant enough for corrections to be required in the way water abstractions to meet sectoral water demand in the CORB-Namibia are estimated from water abstraction data and information available for the two national water basins (as well as for all other national water basins) from Namibia's IWRM Plan.

Namibia's interim Policy to allocate surface water from the Cubango-Okavango river for Green Scheme irrigation projects

The interim Policy of the Government of Namibia established in 2005 to start allocating Cubango-Okavango river water to Green Scheme irrigation projects along the river is based on principles of reserving 25% of "minimum" flow as "ecological requirements" and sharing the "remaining minimum" flow to equal proportions with the other riparian countries. These principles and restrictions on admissible longer-term irrigation water allocations (15,000 m^3/a/ha) and peak irrigation rates (peak factor of 3) underlie estimates of total irrigable areas on the Namibian side of the river of 16,270 ha (4,630 ha upstream and 11,640 ha downstream of the Cuito confluence) of which 2,200 ha (1,641 ha upstream and 556 ha downstream of the Cuito confluence) are already under irrigation. The interim Policy estimates an allocation of 245 Mm^3/a of river water (2.5% of long-term average flow) to be required to irrigate the 16,270 ha of irrigable land. Whatever the merits and scientific foundations of the principles and assumptions underlying the interim Policy, these have not been agreed by the governments of the other two riparian countries (Angola and Botswana) and need to be revisited as part of a joint strategic action programme (SAP) to be concluded under OKACOM.

How to apportion irrigation activity in the Karst area to CORB-Namibia

At least seven (7) different options exist to apportion irrigation activity and related groundwater abstraction to the Namibian part of the CORB. Depending on which option is chosen, groundwater abstraction volumes to be apportioned to CORB-Namibia differ widely, ranging between 0.25 Mm^3/a and 13.4 Mm^3/a. It is *a priori* not clear which option should be chosen. This needs to be decided by stakeholders. The choice of option may be influenced by the extent to which groundwater withdrawals in the Karst area influence surface water flows in the Cubango-Okavango river and/or groundwater flows in other parts of CORB-Namibia. The water resources/hydrology study being for CORB-Namibia being prepared under the CORBWA initiative is expected to shed light on this latter question.

How to apportion water abstraction for mining in the Karst area to CORB-Namibia

For the mines operating in the Karst area, a similar allocation issue arises and in principle the same options as for irrigation activity could be used to determine the way mining activity and related groundwater abstraction might be apportioned to the CORB-Namibia. In this report, only one of the seven (7) options is pursued: only those mines strictly falling within the CORB-Namibia boundary have been taken into account in estimating groundwater withdrawals for mining in the Karst area that should be apportioned to CORB-Namibia. Other options might be chosen in follow-up phases to the CORBWA initiative, depending on stakeholder preferences and taking into account the results of the CORBWA-Namibia water resources/hydrology study.

Monitoring and reporting water requirements and abstractions for freshwater aquaculture, mining and tourism

Freshwater aquaculture has been identified as a sector with a high-growth potential in Namibia. Freshwater aquaculture is quite water-intensive, usually requiring daily inputs of 10 to 15% fresh water input relative to the storage volume in the pond, although overflow is normally used for small-scale irrigation schemes (provided that the effluent is suitable for irrigation) and water can be reused (but only in small-scale operations and requiring expensive filtration systems. Yet no data exist on water withdrawals, consumption, and return flows in freshwater aquaculture operations in Namibia. Priority should be given to systematic monitoring and reporting to fill current data gaps on water requirements.

In the mining sector in Namibia, data on water inputs and requirements in mining operations is often not available. Mining companies do not report in detail and on a regular basis on their water requirements and abstraction volumes. The Government (DWA) should work with the private mining companies to encourage systematic monitoring and reporting of water abstraction and end use.

The tourism sector generally is characterised by lack of data on how much water tourism establishments purchase from local authorities or NamPower or directly abstract from groundwater or surface water resources for their own operational requirements. A systematic effort should be undertaken to fill these data gaps in Namibia, which would make it possible to estimate water abstractions for tourism in a more accurate way, avoiding the sweeping assumptions that were required to estimate tourism water demand in this report.

Matching NamWater's customer categories with CORBWA's end user and sector definitions

NamWater customer categories differ greatly from the definitions of end users and sectors adopted by CORBWA. For this reason, it has not been possible to determine how much water NamWater sells to different end users and sectors in the CORB-Namibia. An effort should be made in future phases of the CORBWA initiative to find a way of matching NamWater's customer categories with CORBWA's end users and sectors and/or to work with NamWater to adjust their customer categories to facilitate such matching.

Development of local authority systems to record water sales to customers

So far, local authorities, in particular the smaller ones (towns, villages and settlements), do not have systems in place to record water sales to different customers. In the absence of such systems, it is not possible to determine how much of the water purchased or abstracted by a local authority (LA) is sold to different customer categories. This leads to actual or potential double-counting of water demand by tourism establishments, industries and mines that are located within LA areas and purchase their water from the LA. As part of a nationwide effort, LAs in the CORB-Namibia should be encouraged and assisted to develop systems to record and store in data banks data on water sales by customer and to adopt customer categories that allow easy matching with CORBWA's end users and sectors.

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9. Appendices

A1 Irrigated crop sector

See separate file.

A2 Livestock sector

See separate file

A3 Local authorities (urban areas)

See separate file

A4 Methodologies for determining water use in crop irrigation

This Appendix expands on section 3.2.1, as far as methodologies for determining water use in crop irrigation are concerned. It provides more detail on the three principal ways to determine crop irrigation water use:

- through measurement of actual water abstraction, by means of water meters in areas where water charges are levied and/or water permits are required;
- on the basis of information on crops grown and specific crop water requirements; and
- on the basis of the areas irrigated and typical water allocations per unit area.

Measuring irrigation water use by means of water meters in areas where water charges are levied and/or water permits are required

In principle, the most accurate way of determining the quantity of water abstracted by an irrigation scheme is by installing a water meter at the point of water abstraction or intake and measuring the quantity of irrigation water abstracted over time on the basis of periodic readings. In practice, however, very few irrigation schemes/farms have their own installed water meter and measure their water use. One reason for the widespread absence of water meters on irrigation schemes/farms is that few schemes/farmers are charged for the water they abstract – and where they are charged, the charge is not levied on the basis of the water actually abstracted but according to the size of the area (to be) irrigated.[40]

[40] Irrigation water charges, where they are levied, are extremely low, typically N$ 10 per hectare irrigated per year and hence negligible for all practical purposes. While such low water charges do little to encourage efficient use of water for irrigation, it is other factors that may provide incentives for using irrigation water efficiently, notably the cost of electricity for pumping water from the point of abstraction to the point of use (for those schemes unable to rely on gravitation to move water to the point of use).

Another reason for the widespread absence of water meters on irrigation farms/schemes is that to date most of water use for crop irrigation has not been subject to any permits that would regulate and control water abstraction by allocating specified quantities of water for the stated purposes and requiring measurement and report-back of actual water abstraction. Such user permits have been required only in declared "water control areas" (i.e. areas endowed with extensive, high-quality groundwater resources requiring special protection and hence regulation of water use, like the GTO Karst) and for Green Scheme projects along strategic transboundary rivers like the Cubango-Okavango.[41] For this reason, many irrigation farms in the GTO Karst area and some of the (more recent) Green Scheme projects along the Okavango Rivers do have water meters in place.

Notwithstanding the presence of these water meters, these are often not used to measure and report actual water abstraction as required. The problem is that compliance with permit requirements has been poor due to poor monitoring and enforcement, and not surprisingly, therefore, most farmers actually do not meet permit conditions, such as measuring and reporting actual water use, as stipulated. In 2003, only 31% of all licensees reported back and merely 5% handed in complete returns -- with some improvement over time (probably due to somewhat better compliance monitoring), such that in 2006, 58% of the licensees reported back and 15% handed in complete returns (IWRMPJVN, 2010c). In the GTO Karst area, the situation, while not satisfactory, seems to have generally been better than average. A recent compliance check found that the majority of permit holders had reported back, but only half (54 out of 108) of the permit holders had submitted all relevant information (complete returns), as per conditions of the irrigation permit, although this was an improvement over previous years (see Table 16).[42]

In conclusion, where water permits are required these can be used in principle to determine quantities of water abstracted for irrigation. But in practice, poor compliance with permit conditions has limited the extent to which licensees have regularly reported actual water abstraction, for which reason it is necessary to resort to data on allocated amounts of water as a proxy for water actually used. However, the stated quantities of water (to be) allocated may not be a good indicator for the quantity of water actually abstracted. The percentages mentioned for actual water abstraction (relative to permitted water use) in the previous paragraph suggest that using allocated quotas as a proxy for water actually abstracted tends to yield conservatively high water abstraction estimates. Nevertheless, this seems to be the best method available for providing a rough estimate of irrigation water abstraction in areas where irrigation farmers and schemes require permits.

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[41] The New Water Act (Act No.24 of 2004) has extended permit requirements for irrigation water abstraction to all irrigation farmers and schemes, not only those in special locations like the GTO Karst and Green Scheme zones, but implementation of the Act has not yet started.

[42] Aggregate water abstraction reported by all complete returns submitted in 2010 corresponded to 80% of the respective permit allocations, while the percentage of aggregate water allocations that was reported as actual water abstraction in 2010 was only 60% when all returns (complete or incomplete) were considered (Beukes, 2011). Only a minority (23%) of permit holders turning in complete returns used their allocated quotas as specified (i.e. stayed within the 60%-120% range), while the majority (65%) under-utilised and 11% over-utilised their quotas.

Estimating water abstraction on the basis of crops grown and specific crop water requirements

In the absence of meters to accurately measure volumes of irrigation water applied and given generally poor reporting of actual water abstraction where permit conditions require installation of a meter are required and exist, estimates of the actual amounts of water abstracted by an irrigation scheme can be made on the basis of the following crop irrigation related data and information:

- The total area planted and irrigated;
- The type of crops grown using irrigation;
- Specific water requirements for the crops irrigated – which are influenced by climatic factors (most importantly the evaporation rate, given Namibia's dry climate, but also factors like rainfall patterns and the wind regime) and agro-ecological conditions (e.g. soil type) of the area where the irrigation scheme is located;
- The irrigation technology employed; and
- The irrigation management efficiency, in particular the efficiency of irrigation scheduling.

As an input into the Water Accounts for Namibia, the Division of Agricultural Engineering of MAWF calculated specific crop water requirements for two categories of regions with significantly different evaporation rates and for different irrigation technologies, using the CROPWAT programme (Windows) to calculate crop water use with optimised irrigation scheduling and with a modified Penman-Monteith formula for the different types of crops to take into account differences in evaporation rates by region (WAN, 2006), as cited in IWRMPJVN, 2010c)). Table 7 presents the results of these calculations for the North and Northeast regions of Namibia (which include the Namibian section of CORB), where (net) evaporation rates are between 2,500 and 2,900 mm/a. With the exception of lucerne (alfalfa), specific crop water requirements are below the widely used irrigation water allocation quota of 15,000 m^3/ha/a – and for some crops (maize, potato, sorghum and vegetables) as little as half (or less) of the allocation quota. Commonly accepted irrigation efficiencies (defined as the proportion of the applied water that is consumed by the crops) are indicated for the different irrigation technologies (flood irrigation, centre-pivot irrigation, sprinkler irrigation, and drip & micro irrigation, respectively) and reflected in the differences in the figures for crop water requirements across irrigation systems.

Table 40: **Specific crop water requirements for the northern and north-eastern Regions of Namibia**

Crop	**Net Water Requirement (mm/season)**	**Irrigation System Water Requirement** (m^3/ha/a)			
		Flood (Efficiency: 65%)	**Sprinkler** (Efficiency: 75%)	**Centre Pivot** (Efficiency: 85%)	**Drip & Micro** (Efficiency: 95%)
Lucerne	1,630	25,100	21,730	19,180	17,160
Cotton	887	13,100	11,830	10,440	9,340
Citrus	836	12,880	11,150	9,840	8,820
Wheat	659	10,100	8,790	7,750	6,940
Vegetable	507	7,810	6,760	5,970	5,340
Maize	506	7,790	6,750	5,950	5,330
Sorghum	492	7,580	6,560	5,790	5,180
Potato	448	6,900	5,970	5,270	4,720

Source: IWRMPJVN, 2010c

Crops grown by Green Scheme projects along the Namibian section of the Okavango River are reported to include staples (mainly maize and wheat), fruit trees, vegetables, and aromatic oil plants (Liebenberg, 2009). Irrigation farmers in the GTO Karst WCA grow staples (in particular maize and to a lesser extent potatoes and wheat) as well as vegetables like carrot. Irrigation permits specify crops to be grown, on the basis of farmer's applications, but the extent to which the crops actually grown correspond to those intended to be grown is not clear at all. It is suspected that significant numbers of irrigation farmers indicate in their applications high-value crops requiring larger amounts of irrigation water, in order to enhance their chances of obtaining an irrigation permit and in order to secure the largest possible water allocation, while ending up growing staples like maize once the permit has been received.[43] As with actual irrigation water abstraction, the main reason for permit holders' lack of compliance with permit conditions, as far as the crops grown are concerned, is poor compliance monitoring and enforcement on the part of the government (MAWF, including the Green Scheme Agency), which, in turn, is can be ascribed to understaffing, lack of institutional capacity and other factors. In the absence of hard, reliable data on crops actually grown, it is not possible to estimate irrigation water abstraction using crop-specific irrigation water requirements.

Estimating water abstraction on the basis of the areas irrigated and a typical water allocations per unit area

In the absence of accurate irrigation water metering/reporting and given the lack accurate data on crops grown, it is necessary to resort to a simpler method for estimating irrigation water use: determining the areas (to be) irrigated (in hectares) and applying typical average irrigation water allocations per hectare of irrigated area. This results in the following formula for estimating irrigation water abstraction:

(4) Quantity of water abstracted in crop irrigation per year = irrigated area (ha) x typical water allocation

This relatively crude method follows the approach adopted by the recent IWRM Plan to determine irrigation water abstraction for each of the national water basins.

We will now first discuss typical irrigation water allocations per hectare and thereafter determine irrigated land areas in the Namibian CORB, with a focus on the principal irrigation areas: the Green Scheme projects along the Namibian section of the Cubango-Okavango River and the Grootfontein-Tsumeb-Otavi (GTO) Karst area.

Typical average irrigation water allocations range from 15,000 m^3/ha/a (as per the Green Scheme criteria - (Liebenberg, 2009) to 10,000 m^3/ha/a (as stipulated by the new water allocation guidelines for

[43] H. Beukes, Geohydrology Division, Department of Water and Forestry, MAWF, personal communication, 10 August 2001.

irrigation farmers in the GTO Karst area - DWA, 2004[44]). The IWRM Plan uses a "typical" irrigation water allocation of 15,000 m^3/ha/a for both surface water and groundwater irrigation in the Okavango-Omatako national water basin as well as for surface water irrigation in other national water basins, and a "typical" lower allocation of 12,000 m^3/ha/a for groundwater irrigation use in all other national water basins. For CORBWA-Namibia, we propose a somewhat different combination of typical irrigation water allocation factors, distinguishing between surface water and groundwater irrigation, rather than between basin: 15,000 m^3/ha/a for all surface river water irrigation (such as in the Green Scheme irrigation projects) and 12,000 m^3/ha/a for all groundwater irrigation (e.g. throughout the GTO Karst area).

[44] Until recently, policy guidelines allowed water allocations to irrigation farmers in the Karst up to a maximum of 12,000 m^3/ha/a (DWA, 1992)

A5 Estimating irrigation water use on the basis of crop water requirements

In the absence of meters to accurately measure volumes of irrigation water applied and given generally poor reporting of actual water abstraction where permit conditions require installation of a meter are required and exist, estimates of the actual amounts of water abstracted by an irrigation scheme can be made on the basis of the following crop irrigation related data and information:

- The total area planted and irrigated;
- The type of crops grown using irrigation;
- Specific water requirements for the crops irrigated – which are influenced by climatic factors (most importantly the evaporation rate, given Namibia's dry climate, but also factors like rainfall patterns and the wind regime) and agro-ecological conditions (e.g. soil type) of the area where the irrigation scheme is located;
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Crops grown by Green Scheme projects along the Namibian section of the Okavango River are reported to include staples (mainly maize and wheat), fruit trees, vegetables, and aromatic oil plants (Liebenberg, 2009). Irrigation farmers in the GTO Karst WCA grow staples (in particular maize and to a lesser extent potatoes and wheat) as well as vegetables like carrot. Irrigation permits specify crops to be grown, on the basis of farmer's applications, but the extent to which the crops actually grown correspond to those intended to be grown is not clear at all. It is suspected that significant numbers of irrigation farmers indicate in their applications high-value crops requiring larger amounts of irrigation water, in order to enhance their chances of obtaining an irrigation permit and in order to secure the largest possible water allocation, while ending up growing staples like maize once the permit has been received.[45] As with actual irrigation water abstraction, the main reason for permit holders' lack of compliance with permit

[45] H. Beukes, Geohydrology Division, Department of Water and Forestry, MAWF, personal communication, 10 August 2001.

conditions, as far as the crops grown are concerned, is poor compliance monitoring and enforcement on the part of the government (MAWF, including the Green Scheme Agency), which, in turn, can be ascribed to understaffing, lack of institutional capacity and other factors. In the absence of hard, reliable data on crops actually grown, it is not possible to estimate irrigation water abstraction using crop-specific irrigation water requirements.

A6 Interim policy of GRN for abstracting irrigation water from the CORB

The GRN interim policy on abstracting river water for irrigation purposes accepts the expected 1 in 20 low flow conditions in the river, more precisely the average flow for the lowest-flow month during the 20 preceding years, as a point of departure for an analysis of the availability of water for irrigation in Namibia, whereby the situations upstream and downstream of the confluence of the Cuito are analysed separately. The policy rests on the following adopted principles:

a) A sufficiently large fraction of the “minimum” flow (i.e. the average flow for that lowest-flow month) must be reserved for “environmental purposes”, i.e. to sustain local and downstream river ecosystems – this is taken as 25% of the “minimum” flow;

b) The “remaining minimum” flow must be divided equally between the respective riparian countries upstream and downstream of the Cuito confluence.

For the upstream section of the river, application of these principles implies that Namibia is allowed to use up to half of the “remaining minimum” flow, with the other half assumed to be used by Angola. For the downstream section, the principles mean that Namibia is allowed to abstract up to one third of the “remaining minimum” flow, with the other two thirds assumed to be abstracted by Angola and Botswana. This corresponds to an upper limit of 5.5 m^3/s (or 173.5 Mm^3/a) and 27 m^3/s (or 851 Mm^3/a) for the maximum rate at which Namibia may abstract water upstream and downstream of the Cuito confluence, respectively. Taking into account that river water abstracted upstream is no longer available downstream reduces the upper limit for water abstraction downstream of the Cuito confluence to 21.5 m^3/s (or 678 Mm^3/a) (Liebenberg, 2009). However, for determining the areas than can be irrigated downstream of the Cuito confluence, the policy conservatively assumes that only half of Namibia’s share of the “minimum” flow share downstream of the Cuito confluence (i.e. 13.5 m^3/s or 425 Mm^3/a) is used for downstream irrigation (see below).

The policy further stipulates that the average volumes of water that can be applied for irrigation over longer periods be limited to 15,000 m^3/ha/a, with a maximum peak factor of 3. This means that no more than 3 times the limit for average irrigation water use (i.e. 45,000 m^3/ha/a or 123 m^3/ha/day) be used during shorter peak demand periods. In order to be on the safe side and more realistic about the peak water flows that would likely be applied for irrigation, the maximum allowable peak water application rate for irrigation purposes was set at a somewhat lower level: 100 m^3/ha/day (or 36,500 m^3/ha/a) (Liebenberg, 2009).

Based on the above limits for river water abstraction rates from the river and for irrigation water application rates, as per GRN interim policy, section 4.1.1 presents the resulting land areas that can be irrigated along the Cubango-Okavango River, upstream and downstream of the Cuito confluence. Section 4.1.1 also presents data for the land areas already under irrigation along the Cubango-Okavango River (upstream and downstream of the Cuito confluence) from which the additional irrigable land areas, i.e. the land areas that can still be irrigated (upstream and downstream of the Cuito confluence) in addition to those already under irrigation, can be determined (see Table 14 for results).

A7 Options for apportioning irrigation activity in the Karst area to the Namibian part of the CORB

Apportioning water abstraction within the Karst area on the basis of the sub-divisions of the Karst area into sub-catchment/ irrigation sub-region (Figure 7 and 8 in section 3.2.1)

One approach of apportioning Karst area water abstraction to the CORB is on the basis of Karst sub-catchment/irrigation sub-region. There are at least four options for how to do this:

i. Include the whole Karst area, on the grounds that the Karst aquifer is an integral non-divisible groundwater system, linked to the Omatako surface catchment, which should not be arbitrarily truncated;
ii. Include the Southern sub-catchments of the Karst area (i.e. irrigation sub-regions D, E, F, and G) and exclude the Northern sub-catchments of the Karst area (i.e. irrigation sub-regions A, B1, B2, and C), on the grounds that the southern sub-catchments of the Karst area are geographically closer and hydro-geologically more closely linked to the Omatako River surface catchment than the Northern sub-catchments of the Karst area;
iii. Include only those irrigation sub-regions (sub-catchments) that fall within the CORB or are crossed by the CORB boundary – essentially the sub-regions D and E -- on the grounds that each of these sub-catchments is an integral non-divisible groundwater system linked to the Omatako River surface catchment (whereas the other Karst sub-catchments have less of a link to the Omatako River catchment); or
iv. Include only those parts of the Karst (and only those portions of its sub-catchments) that strictly fall within the CORB boundary, i.e. portions of sub-catchments C, D and E, as per equation (6) above – thus excluding any part of the Karst area that is outside the CORB boundary.

Option (i) implies that all irrigation activities within the Karst area should be apportioned to the CORB. This makes it possible to use any available aggregate irrigation data for the Karst and/or any disaggregate irrigation data by Karst irrigation sub-region that can be aggregated. Option (ii) implies that all irrigation activities in the Southern irrigation sub-regions D, E, F and G should be apportioned to the CORB. This allows using any irrigation data that is available specifically for this grouping of irrigation sub-regions, while disregarding any irrigation data available for the Northern sub-grouping of irrigation sub-regions. Finally, option (iii) implies that only those irrigation sub-regions in the Karst area falling wholly or partly within the CORB should be apportioned to the CORB, while option iv) means that only those irrigation activities within these Karst sub-regions that strictly take place within the CORB boundary should be apportioned to the CORB.

Option (iv) for including the Karst area in the CORB requires a method for determining which (what proportion of) irrigation activities to include (or exclude) in those Karst irrigation sub-regions through which the COBR boundary cuts. One method would be to determine, for each irrigation farm, whether it lies inside or outside of the CORB or on the CORB boundary, using GIS tools, and then to apportion irrigation activities to the CORB on a farm-by-farm basis. However, knowledge about the precise locations of irrigation farms in the Karst seems to be incomplete: only about 70% of the 110 irrigation farms in the Karst, as listed during a recent report-back compliance check, had their geographic coordinates indicated (Beukes, 2011).

Another simpler, less information-intensive and less time-consuming method would be for all those irrigation sub-regions straddling the CORB boundary (i.e. sub-regions C, D, and E) to apportion irrigation activities in these sub-regions to the CORB on the basis of their surface-area proportions falling within the CORB, as per equation (6), assuming that the level of irrigation activity (irrigation farms) are uniformly distributed in these sub-regions. An advantage of this method is that it does not require farm-specific irrigation data, but is workable also with aggregate sub-region-specific irrigation data.

Apportioning water abstraction within the Karst area to the CORB on the basis of information available for the national water basins sharing the Karst area (Figure 9, section 3.2.1)

The other approach to determining how irrigation activities in the Karst should be apportioned to the CORB builds on the work done for the national IWRM Plan. In preparation of Thematic Report 2 of the IWRM Plan, an effort was made to determine the Karst irrigation sub-region and national water basin to which each irrigation farm in the Karst area belongs, on the basis of its geographic location. Collectively, the Karst irrigation farms were found to distribute over three national water basins: the Okavango-Omatako, Ugab-Huab, and Cuvelai-Etosha national water basins. Karst irrigation farms, with indications of their respective irrigation sub-regions and national water basins, along with irrigation initiatives in other parts of the country were assembled into a detailed “master list” of irrigation schemes and farms throughout the country, constituting the “state of the art” of irrigation in the country as of June 2009. This irrigation “master list” is presented in Appendix 2 to Theme Report 2 (IWRMPJVN, 2010b). The irrigation “master list” is organised by national water basin and indicates current as well as projected future areas irrigated and estimated volumes of irrigation water abstracted by irrigation initiative).[46] The irrigation sub-lists for the three national water basins containing Karst irrigation farms are reproduced in Annex A1.

The sub-lists of irrigation farms for the three national water basins in Annex A1 can be used to calculate aggregate irrigated areas and aggregate volumes of irrigation water abstracted from those parts of the three national water basins that fall within the Karst area. This is done in section 4.1.2 (see Table **19**: GTO Karst areas under irrigation, volumes of water allocated and abstracted by Karst irrigation sub-region and national water basin as of June 2009 below). Several options exist for how to include the Karst area in the Namibian part of the CORB, based on the distribution of Karst irrigation farms among

[46] This “master list” has the following data fields: “name of landowner”; “name of property”; “farm_ID”; “no. of property”; “permit no.”; “water control area”; “GTO Karst irrigation sub-region” (for those irrigation schemes/farms located in the GTO Karst area); “national water basin”; “source of water” (within the national water basin); “maximum area to be irrigated (ha)”; “area under irrigation in 2008/09 (ha)”; “water usage in 2008 (m^3/a)”; “area expected to be irrigated in 2015 (ha)”; “expected water usage in 2015 (m^3/a)”; “area expected to be irrigated in 2020 (ha)”; “expected water usage in 2020 (m^3/a)”; “area expected to be irrigated in 2030 (ha)”; “expected water usage in 2030 m^3/a”).

the three national water basins. These options, and the respective methods of apportioning irrigation activity data from the national water basins to the CORB, are:

I. Include the whole Karst area – this requires adding up the areas irrigated and volumes of irrigation water abstracted for all three national water basins;
II. Include only that part of the Karst area which falls within the Okavango-Omatako basin, on the grounds that, as pointed out in section 3.1, the merged Okavango-Omatako and Eiseb-Epukiro national water basins can be taken as a reasonable first approximation of the Namibian part of the CORB, which for irrigation leaves the Okavango-Omatako basin only, since there is very little, if any, irrigation activity in the Eiseb-Epukiro basin (in fact, there are no entries for the Eiseb-Epukiro basin in the irrigation "master list")[47] – this entails apportioning to the CORB the Karst irrigation data for the Okavango-Omatako basin only; or
III. Include only those parts of the Karst (and only those portions of the three national water basins) which strictly fall within the CORB boundary – this requires estimating the respective proportions for each of the national water basin areas (within the Karst area) that fall within the CORB and applying those percentages to the aggregate areas irrigated and aggregate volumes of irrigation water abstracted for Karst irrigation farms in each of the three national water basins, respectively.

It is not clear, *a priori*, which of the two approaches and seven options (four for the first approach and three for the second approach) for how to allocate Karst irrigation water abstraction to the Namibian part of the CORB should be selected for the purpose of CORBWA-Namibia. This needs to be decided by the relevant stakeholders, on the basis of data availability and other criteria. For this reason, both approaches and all seven options are used in section 4.1.2 to calculate estimated irrigated areas and volumes of irrigation water abstracted within the Karst area, which should be apportioned to the Namibian part of the CORB.

[47] This does not seem quite consistent with Figure 7 and Figure 8 which show at least one irrigation area near Otjinene town in the Eiseb-Epukiro basin.

A8 List of NamWater supply schemes producing inside, and selling inside or outside, CORB-Namibia

See separate file