Chapter 5. Groundwater

Groundwater is rainwater that has seeped into the ground where it is stored in water-bearing layers known as aquifers. This water is very important in areas where other water suitable for human consumption is not aavailable, for example from surface water that has been treated. Everyone and their livestock in these places then relies on groundwater pumped from deep below the surface. This is the case in most places south of Etosha and in eastern Oshikoto and western Omusati.

Elsewhere, groundwater is used to supplement supplies obtained from other sources, notably water pumped from the Kunene River into a vast network of pipelines across much of the northern half of the Basin (see page oo). Other surface water in this area is available from *iishana* and pans after good rains have fallen, and from small freshwater ponds known as *ondobe*. This surface water is often contaminated by livestock, however, and not well-suited for human use. Cleaner water is also widely available in small quantities from shallow hand-dug wells called *omifima*.

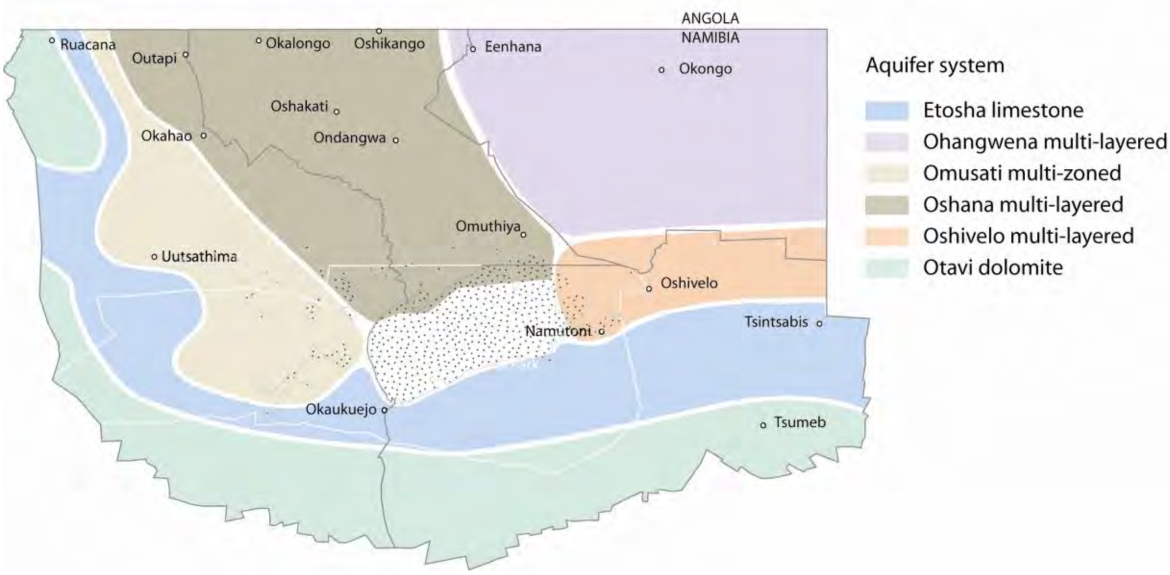
Given the high value of groundwater, a great many boreholes have been drilled to find and pump groundwater to the surface. Of about 6,000 boreholes drilled in the Basin, many proved dry or to produce too little to be used economically. However, data from these and other, more productive boreholes, has been useful in providing information on such aspects as how groundwater is distributed and flows in the Basin, and its depth and quality. This chapter provides a synthesis of this information and our current understanding of groundwater resources.[i]

The focus in this chapter is on deep groundwater, but it is useful to remember that access to shallow groundwater in *ondobe* pools and *omifima* wells was fundamental in enabling people to live in the Basin for hundreds of years before piped and pumped water became available. Without that water, people would simply have been unable to settle here permanently. The water often becomes brackish towards the end of the drty season and it is extremely vulnerable to poluution because it is shallow.

It is also notewothy that water in *ondobe* and *omifima* is actually trapped in a very shallow and discontinuous aquifer; strictly speaking it is therefore also groundwater. Layers of impermeable ferrocrete rock close to the surface trap rainwater in this lens by preventing it from percolating further. In most areas, the shallow water can only be used by digging wells which are often just a few metres deep. These are the *omifima* wells (top) while wells that go down 10 or 20 metres are called *eendungu* (centre). Most *eendungu* are north of Etosha in southern Oshana and Omusati where the wells provide water for dozens of cattle posts. The water in these deeper wells is often rather saline. Fresh water in *ondobe* pools (bottom) has been trapped in the same shallow aquifer but the water collects in small depressions which are often surrounded by jackal berry trees.[ii]

Figure 5.1. Type of aquifers. In broad terms, aquifers are divided into those that are confined and those that are unconfined. The former describe bodies of water that have an impermeable layer of clay or rock both above and below them. They are thus confined, and ususally fully filled with water which is under pressure. Unconfined aquifers are underlain by impervious layers, but the soil layers above are permeable and thus allow water to seep down into the aquifers.

There are six main aquifer systems in the Basin that are characterised by differences in geology, chemistry, patterns of flow, types of confinement and depths. Most of the systems contain different aquifers or layers of water that are separated by impermeable layers and thus overlay one another. From the table of information for each aquifer system it is clear that there is considerable variation within one system. Some of this variation is due to presence of separate aquifers at different depths in the same area. Thus, one borehole may pass through quite different layers of water in a multi-level system. The chemical qualities of the layers are often quite different, some being brackish and others fresh, for example. Other variation from place to place is due to water being held in cavities of different capacities, or in different rock formations at different depths.

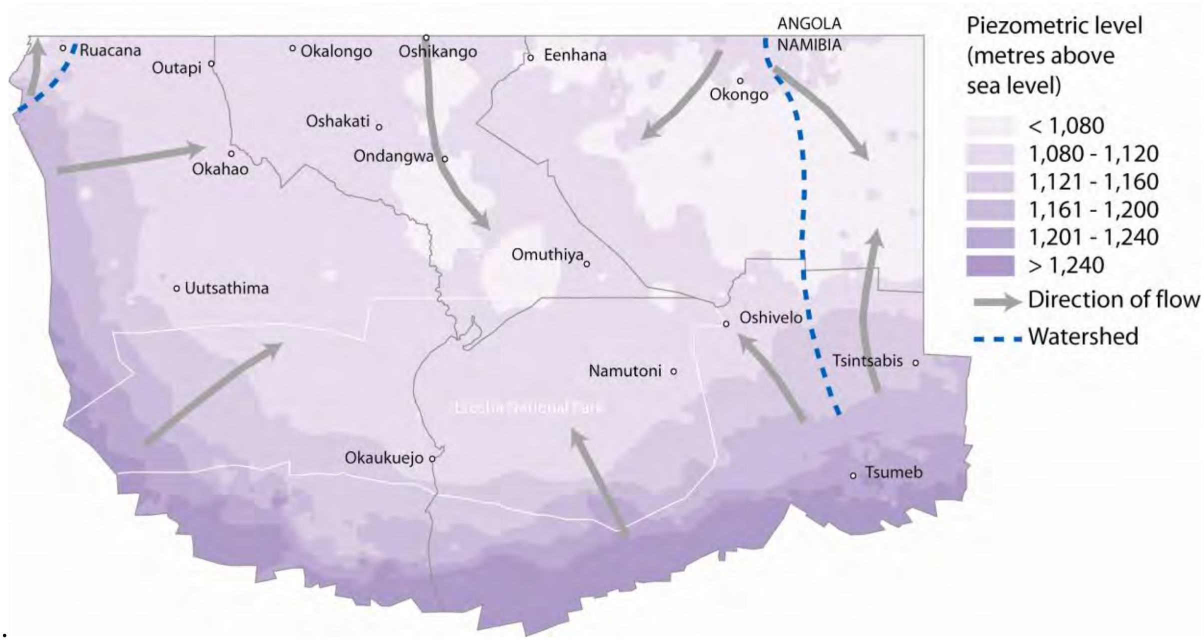


Aquifer system	Main rock type	Depth in metres below the surface	Quality of water	Yield in cubic metres per hour
Ohangwena Multi-layered Aquifer	Sand, sandstone	60-300	Fresh to brackish	1-50
Oshivelo Multi-layered Aquifer	Conglomerate, sand, sandstone, dolocrete, calcrete	30-150	Fresh to brackish	5-100
Etosha Limestone Aquifer	Dolocrete, calcrete, sand	10-100	Fresh, locally high nitrate concentrations	3-100
Oshana Multi-layered Aquifer	Sand, calcrete/limestone	10-80	Saline to hyper saline	1-30
Omusati Multi-zoned Aquifer	Sand, clay and calcrete, dolocrete	10-50	Brackish, freshwater in places	1-30
Otavi Dolomite Aquifer	Dolomite	20-250	Fresh	More than 50

Adjust Ohangwena aquifer boundary

Figure 5.2 The flow of groundwater. An important part of understanding an aquifer system is to know how water flows into and perhaps out of an aquifer. It is hard, for instance, to envisage if, or how aquifer water will be replenished if potential sources of recharge water are not known. Similarly, predictions on where groundwater may be found are improved by knowing directions of flow.

This map shows the directions of flow of underground water in the Basin. Like rivers on the earth's surface, water beneath the ground also moves from high elevations to lower altitudes. All groundwater within the Basin flows towards the Etosha Pan (which happens to be the lowest area to which all surface waters also move (see page oo)). Much of the groundwater in the southern and western parts of the Basin is shallow and often comes to the surface through springs along the southern edge of Etosha Pan, where the water evaporates rapidly. Groundwater along the northern border of the Basin is recharged by flows from Angola.



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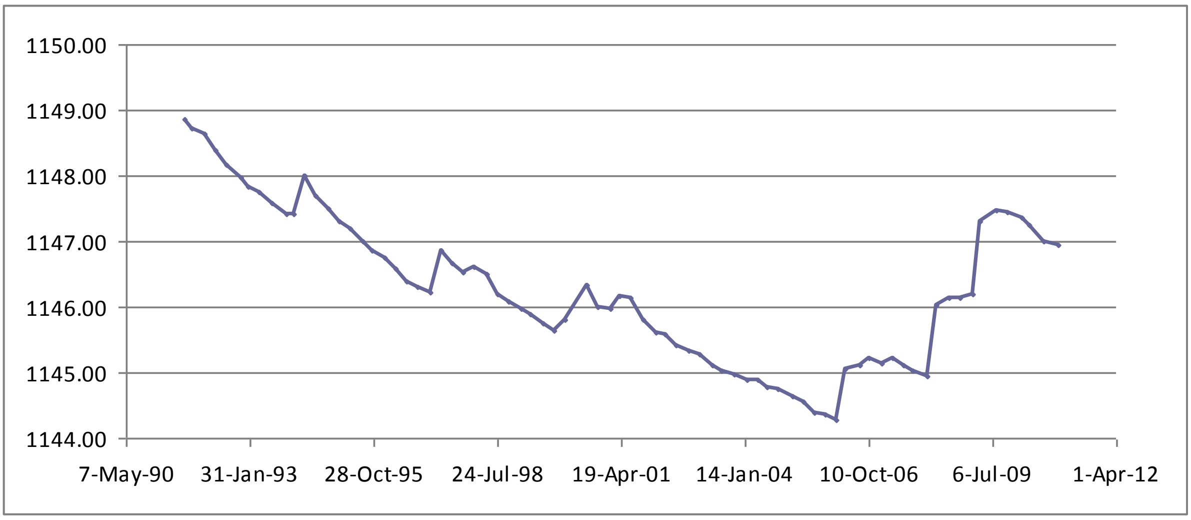
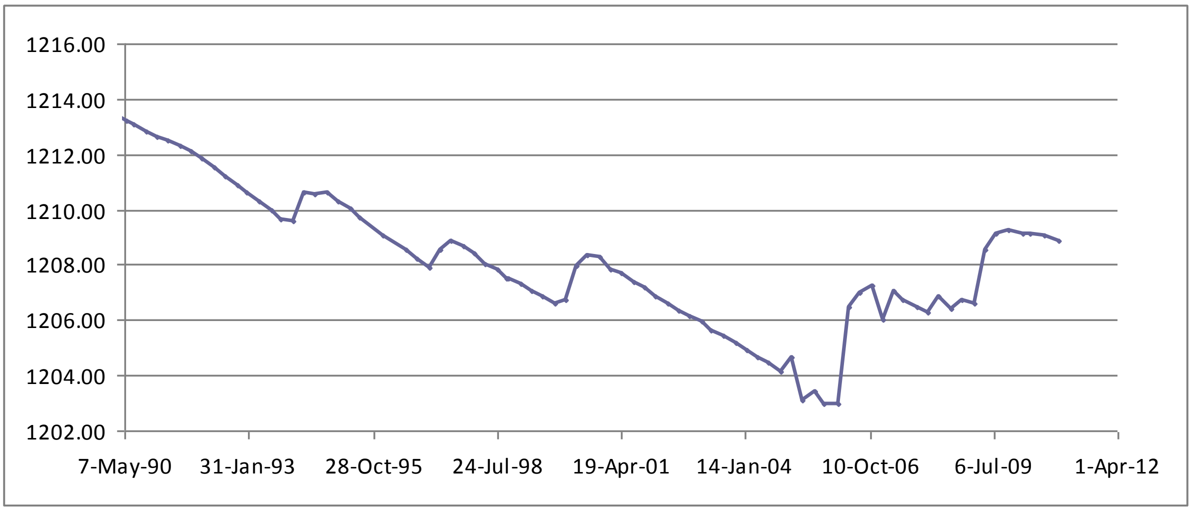
In places where the groundwater is under considerable pressure, the water may rise and flow on to the surface. Such places are called artesian wells, and one of the biggest and most spectacular of these wells is at Gobaub in Etosha National Park. The well is actually above the surrowunding countryside and is central in a natural clearing with a diameter of over half a kilometre. The clearing is a result of trampling by the many animals that visit the water hole and the saline soils that have developed from the groundwater evaporating on the surface.[iii]

Figure 5.3. Rates of depletion and recharge. Groundwater, particularly at very deep levels, has often accumulated slowly over long periods, perhaps tens of thousands of years. The rate at which it is used over short periods is often greater than the rate at which the water is replenished, which means that the groundwater is being mined unsustainably.

These graphs show water levels (in metres above sea level) in two monitoring boreholes some 70 kilometres apart: Concordia 60 kilometres north of Tsumeb and Otjikoto Berg about 20 kilometres west of Tsumeb. Patterns of water depletion and recharge have been almost identical with water levels dropping steadily over the 20 years. Significant recharge of the water at both places occurred in only six of the 20 years: in 1994, 1997, 2000, 2006, 2008 and 2009. Thus, rainfall in 14 years did nothing to restock the aquifer and, in fact, it was only in 2006, 2008 and 2009 that the natural recharges did more than to top up what had been harvested the previous year. At the end of 2010 after the recent years of good rain, water levels at both places remained below those when recording began in 1991.[iv]



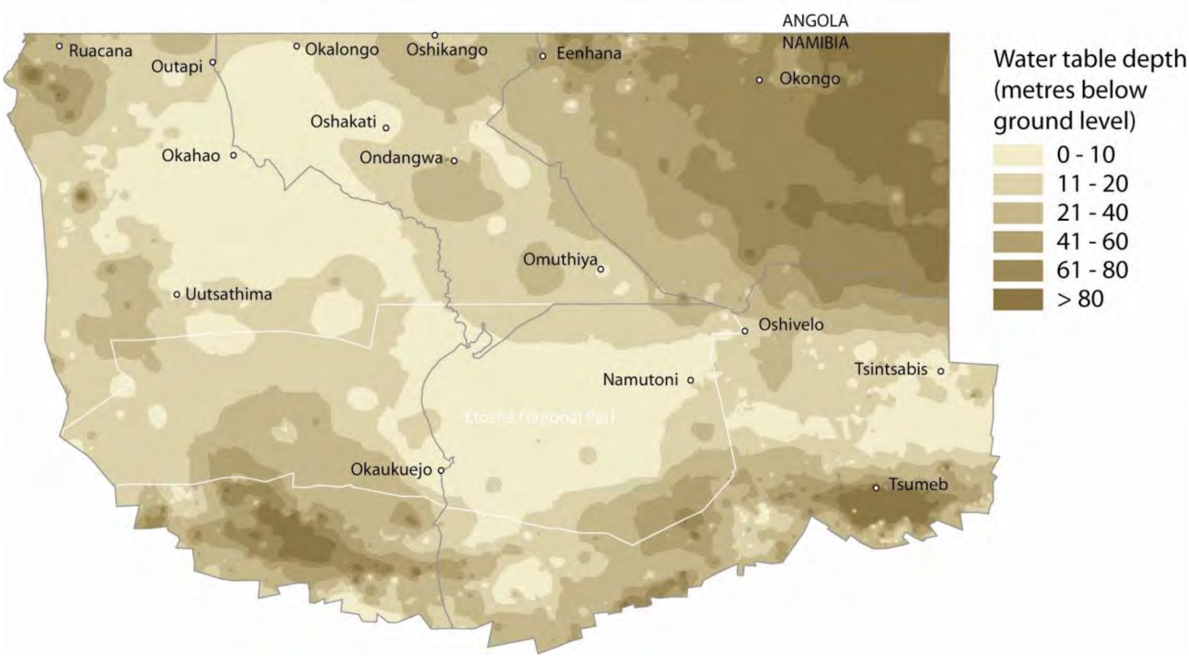
Concordia farm about 60 kilometres north of Tsumeb.



Otjikoto Berg, some 20 kilometres west of Tsumeb

However, there are different domains which behave differently

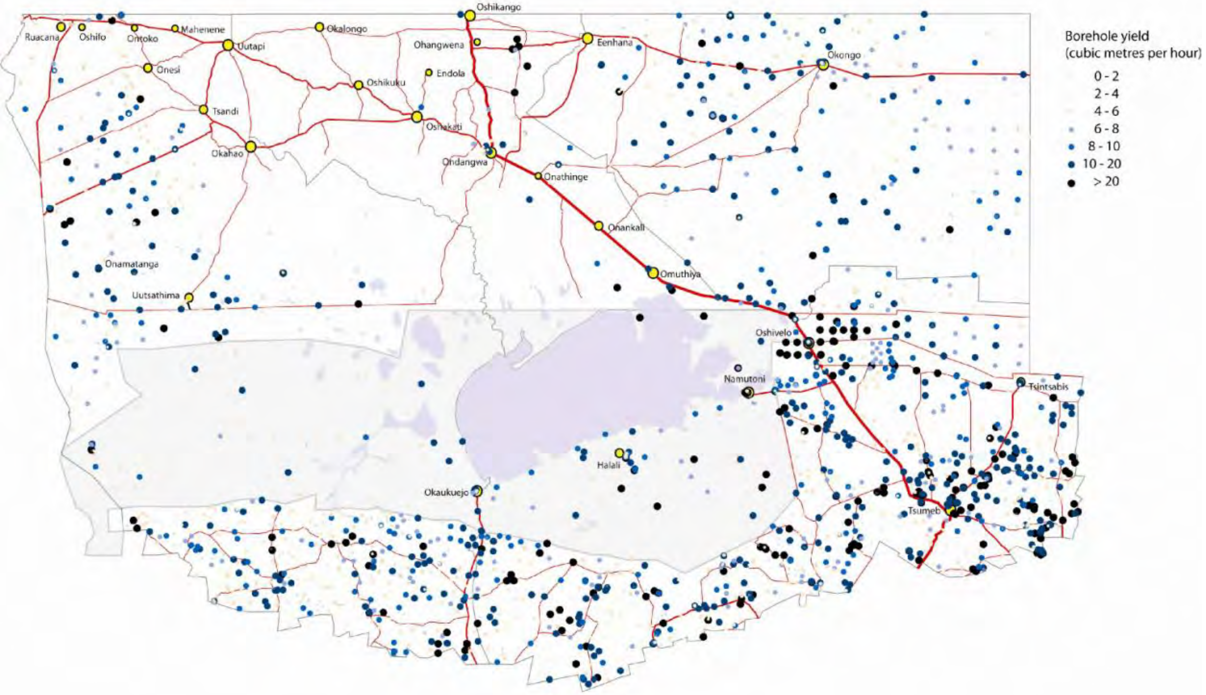
Figure 5.4. Water table depth. Groundwater can be found at less than 40 metres below the surface in most areas of the Basin, especially so in the central and north-western areas. Around the southern rim of the Basin the depth to groundwater increases to 80 metres or more in many areas. The same is true in eastern Ohangwena and Oshikoto. Not shown on this map is a newly discovered aquifer in central Ohangwena which lies at depths of about 300 metres.[v] It appears that this aquifer has the potential to produce freshwater in such high volumes that the water may be used to supplement the delivery of water through the network of pipelines in the central northern areas of the Basin (see page oo).



A variety of pumps are used to bring groundwater to the surface. Windmills are the most conspicuous and work well where the water is not too deep. Diesel engines are also commonly used to drive pumps, and solar energy is now being used increasingly for pumping.[vi]

Figure 5.5 Borehole yields. Nobody knows what will be discovered at the bottom of a borehole when it is being drilled. Often the hole is dry and the drill rig must be moved to try elsewhere. Even when water is found, the yield and chemical quality (see Figure 5.x below) of the water must first be assessed before deciding whether to install a pump or not.

Borehole yields may vary considerably, and even boreholes very close to each other often provide different volumes of water, as many of the symbols in this map show. Modest volumes of between 1 and 5 cubic metres per hour are enough to supply a small village and many boreholes across the Basin produce this much. There are also many places where the majority of boreholes produce much greater quantities, such as around the Oshivelo area, where yields may exceed 100 cubic metres per hour. By contrast, there are also areas where yields are so low that the costs of pumping make them unviable. map will be rotated


Ruacana
Oshifo
Ontoko
Mahenene
Uutapi
Okalongo
Oshikango
Ohangwena
Endola
Eenhana
Okongo
Onesi
Oshikuku
Tsandi
Oshakati
Okahao
Ondangwa
Onathinge
Onankali
Onamatanga
Uutsathima
Omuthiya
Oshivelo
Namutoni
Tsintsabis
Halali
Okaukuejo
Tsumeb
Borehole yield
(cubic metres per hour)
0 - 2
2 - 4
4 - 6
6 - 8
8 - 10
10 - 20
> 20

Groundwater is hard to understand since most of us never get to see the water, let alone to imagine how it is stored, how it flows and how the water is replenished. Lake Otjikoto and Lake Guinas, however, are two places where groundwater is visible because the roofs that covered the caverns holding the water have collapsed. Both lakes have communities of animals that are found nowhere else, and have become popular tourist attractions.[vii]

Figure 5.6. The quality of groundwater. Finding groundwater is one challenge, another is to find water suitable for human or even livestock use. and many boreholes have been drilled and then abandoned because they do not supply usable water. Water quality is the result of a combination of factors, including the geology and chemistry of the rock and soil substrates through which the water has flowed. Water quality can also be negatively influenced by chemical pollution from farming activities and mining.

This map provides a measure of the overall chemical quality of water in different parts of the Basin. The measure is of the total (amount of) dissolved solids (TDS), of which salt makes up much more than any other chemical impurities. The TDS values provide good indications of how groundwater may be used; the lowest values reflect the most potable and pure water, while higher values are associated with increasing salinity. Water with TDS values above 2,600 milligrams per litre is not fit for human use, while water with TDS values above 5,000 is detrimental to livestock.

TDS values generally increase from the south and west towards the centre of the Basin as a result of increasing concentrations of chloride, sodium, fluoride and sulphate, as the maps below show. Consequently, good quality groundwater is only present in the eastern and far western areas of the Basin and up to, and along the southern rim of Etosha Pan.

This map provides measures of the quality of water found in boreholes at depths beyond those reached in hand-dug wells. The very high TDS values in the central parts of the Basin reflect the poor quality of deep water that no one uses, and it is therefore incorrect to assume that the many people living there drink poor quality water. Instead, people here use piped water or water in shallow *omifima* wells.

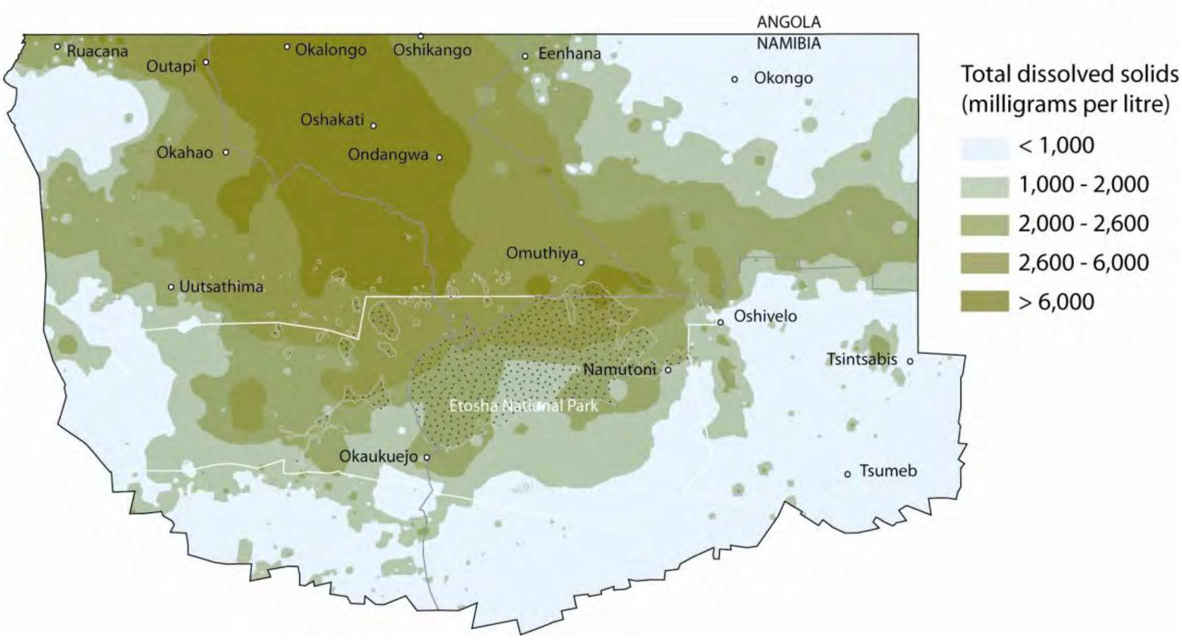


Figure 5.7. The concentration of fluorides. Fluoride levels above 3 milligrams per litre may cause the abnormal development of the skeleton in children, and can also cause the mottling and wearing away of teeth of both humans and livestock. Very high fluoride levels are found in a belt running south-eastwards from Outapi towards Omuthiya and Oshivelo. Fortunately, most people in this area do not use deep groundwater, but high fluoride levels in eastern Oshikoto and western Omusati are of concern to people who drink borehole water in those areas.

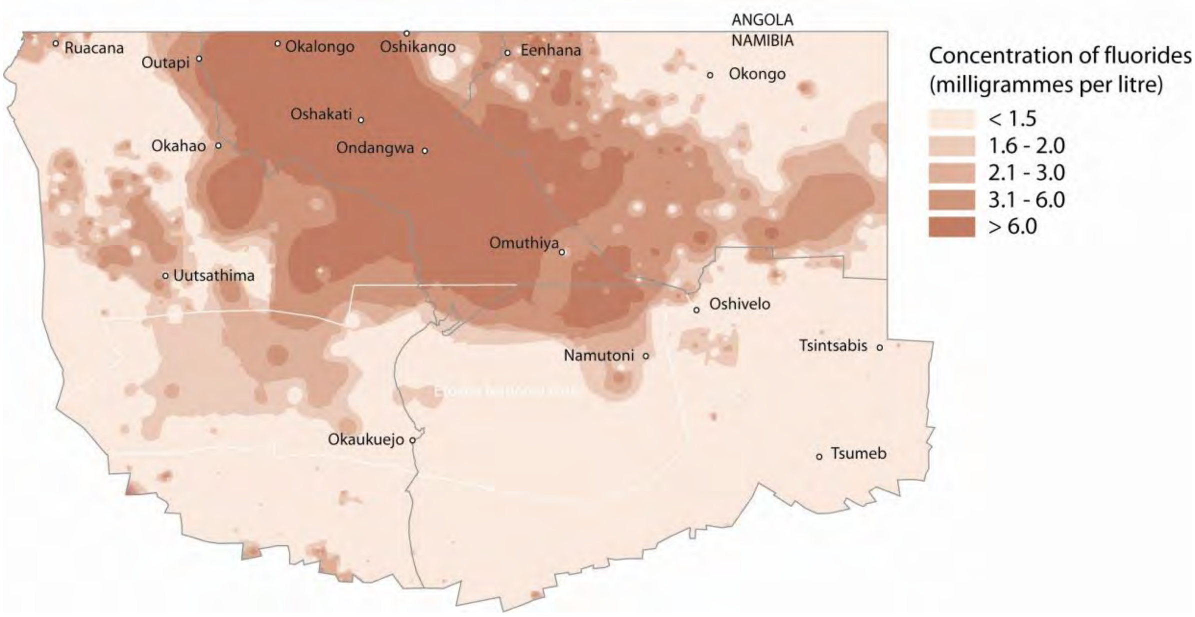


Figure 5.8. The concentration of nitrates. High levels of nitrates can cause birth defects and even death in infants. Levels above 10 milligrams per litre are considered harmful as they

affect the availability of oxygen in tissues. Levels far higher than 10 milligrams are found in large parts of Omusati and in localised places in a belt across the south of the Basin. Cattle dung may contribute to unsafe levels of nitrates, and care thus needs to be taken to ensure that water sources used by livestock are not polluted.

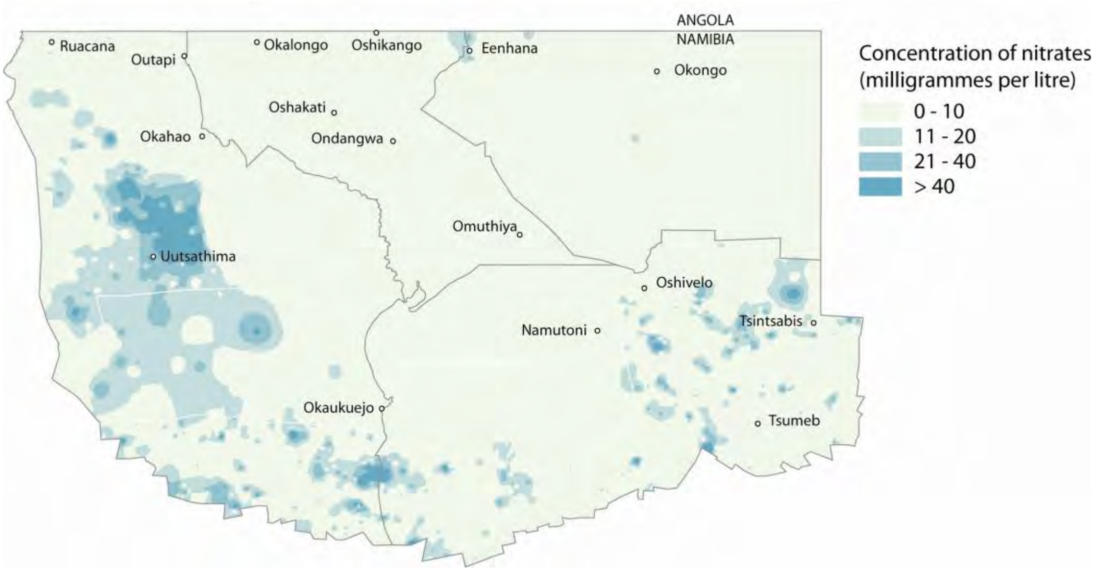
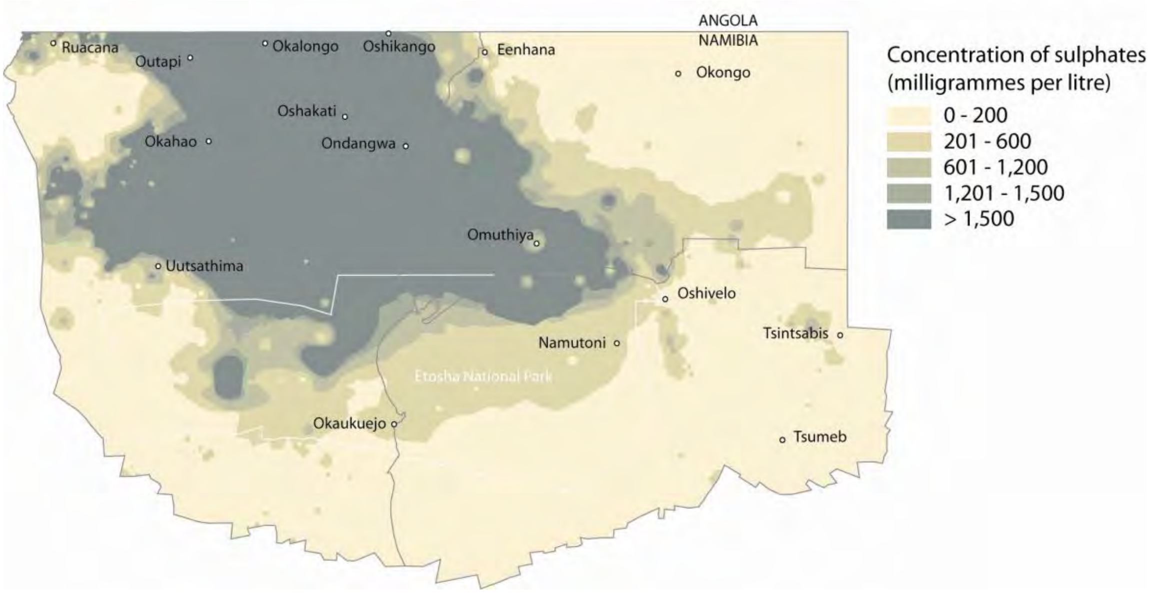


Figure 5.9. The concentration of sulphates. Sulphate concentrations above 1,200 milligrams per litre can act as a laxative. Much of the Basin north of Etosha Pan has levels higher than this, but the high concentrations in the central parts of the Basin are of little concern to people who have access to piped water. However, the many people who depend on deep groundwater in southern and western Omusati perhaps have more runs for nature than other people.



There is concern that chemicals used at the copper smelter at Tsumeb contaminate local groundwater, and sites near the smelter indeed have elevated levels of sulphates and trace elements that include arsenic, lead and cadmium. However, more research is required to establish the significance of these levels and to install systems to prevent further pollution.

[i] Most of the information provided here, as well as a comprehensive database, was provided under commission by Arnold Bittner, operating as BIWAC Water Consulting CC.

[ii] All photos RAISON

[iii] Aerial photograph taken in 2007, courtesy of European Union Rural Poverty Reduction Programme (RPRP) in Namibia.

[iv] These data were provided by the Geohydrology Division of the Ministry of Agriculture, Water & Forestry.

[v] As reported by the BGR project in the Geohydrology Division of the Ministry of Agriculture, Water & Forestry.

[vi] Photo Helge Denker

[vii] Photo Helge Denker